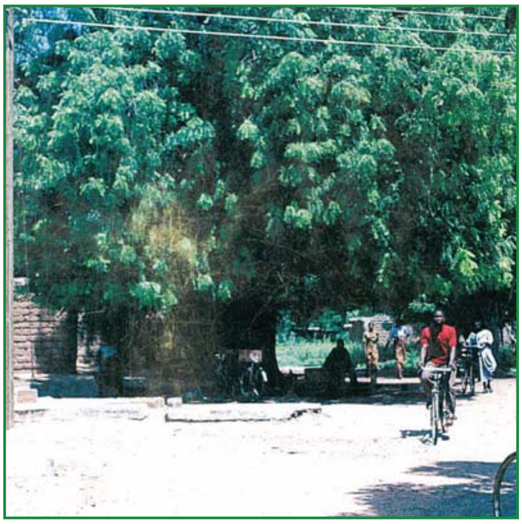
Improvement of Neem and its Potential Benefits to Poor Farmers



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SUMMARY

This report presents findings from project R7348 'Improvement of neem (Azadirachta indica) and its potential benefits to poor farmers in developing countries'. This 9 month project, funded through the Forestry Research Programme of the UK Department for International Development, was developed in response to a need to assess the benefits a genetic improvement programme aimed at increasing the azadirachtin content of neem trees would bring to the poor. The project was broadened to look at the current benefits poor farmers and communities derive from the neem tree and the constraints to these benefits being fully optimised. The specific aim of the project was 'to develop a prioritised assessment of research and development requirements for the improved use of neem by poor farmers as a means of targeting and optimising the focus of donor and research funds for work on neem and its products'.

Information was obtained through fieldwork in Ghana and India, a postal survey of one-hundred and forty-six organisations working with farmers using neem, an extensive review of published and unpublished literature and consultation during a global electronic workshop.

Research showed that the main use of neem was for medicinal purposes, with only a low proportion of farmers using neem in crop protection. Constraints to the use of neem for crop protection were identified and categorised as resource-based, information-based and technology-based. The electronic workshop further highlighted the need to categorise constraints in order that they could be tackled in a co-ordinated way.

The project has highlighted that the neem tree is not currently actively managed by farmers in that farmers do not practise any silvicultural techniques in order to optimise productivity. Neem planting programmes, initiated by NGOs and government organisations in many countries, do not always have access to good genetic material and in many cases these planting programmes are jeopardised through a lack of information on the correct germination and planting procedures. Being a multi-purpose tree, communities tend to utilise neem for a variety of purposes e.g. fuelwood, medicine and crop protection. Often these uses are conflicting in terms of appropriate tree management. However, little research has been done to examine optimum management regimes for the production of different resources. A need for greater understanding and research into silvicultural techniques to optimise various products from the tree was identified.

The current genetic improvement programme, co-ordinated by the International Neem Network, Food and Agriculture Organisation, has established provenance trials in a number of countries. To date, growth characteristics have been assessed. The trials will shortly begin to assess azadirachtin content in the seeds. Although much headway has been made in developing a universal method for analysing azadirachtin content, a lack of funding means that this method is yet to be fully developed. Many involved in the trials agree that the lack of a standard method of measuring azadirachtin is a major constraint to optimising the results from the neem genetic improvement programme.

The demand for commercially produced neem products, for example pesticides, cosmetics and medicines, is likely to increase. At present the market for seed production and sale is unstructured and poorly developed. As a result remuneration received by collectors for seeds is low. Commercial manufacturers have demonstrated that they are willing to pay more for higher quality seed and there exists substantial opportunities for the benefits of neem commercialisation to have increased impacts on the poor.

Both vertical and horizontal information exchange on neem related issues was found to be weak. A lack of national and international communication between researchers has led to research being duplicated. Poor communication between researchers and extension organisations has sometimes hampered development interventions. Poor flow of information between farmers and researchers, mediated by extension organisations, means that research has not always been directed at farmers' needs. South-south exchanges linking organisations promoting neem to farmers could help to increase the effectiveness of development interventions.

A number of research and development interventions likely to have positive impacts on the poor have been identified. These interventions span a number of disciplines. A genetic improvement programme aimed at producing trees with higher azadirachtin content is unlikely to be of use to the poor at present. This is because the tree is currently under-utilised and also those using the tree products for crop protection are sometimes employing practices that reduce the efficacy of azadirachtin i.e. applying home-made neem products in bright sunlight and not storing seeds appropriately. Prioritised research and development interventions have been identified together with possible implementers and funders.

1 Background

Neem (*Azadirachta indica* A. Juss. *Meliaceae*) is thought to have originated in Assam and Myanmar where it is common throughout the central dry zone and the Siwalik hills (NRC, 1992). However, the exact origin is uncertain and some authors suggest it is native to the dry forest of south and south-east Asia, including Pakistan, Sri Lanka, Thailand, Malaysia and Indonesia (Ahmed & Grainge, 1985). In the 19^{th} century, neem was introduced by Indian immigrants to the Caribbean (i.e. Trinidad and Tobago, Jamaica and Barbados), to South America and the South Pacific (NRC, 1992). The cultivation of neem spread to Africa in the 1920's when it was introduced to Ghana, Nigeria and the Sudan, and the species is now well established in more than 30 countries.

Neem can grow in tropical and subtropical regions with semi-arid to humid climates. Neem will typically experience a mean annual rainfall of 450-1200 mm, mean temperatures of 25-35ºC and grow at altitudes up to 800 metres above sea level. The species is drought-tolerant, and thrives in many of the drier areas of the world. There is, therefore, considerable interest in neem as a means to prevent the spread of deserts and ameliorate desert environments, e.g. in Saudi Arabia (Ahmed *et al*, 1989), sub-Saharan Africa (NRC, 1992) and western India (Gupta, 1994).

Neem has been used as a pesticide throughout southern Asia for over 2000 years (NRC, 1992). Neem products are cheap, easy to prepare, non-hazardous and low-cost alternatives to agro-chemicals. Neem extracts have been compared with commercial pesticides on various crop pests where they have been found to be efficacious, and equally or more cost effective (Shukla *et al*, 1996; Ghewande *et al*, 1993). There is evidence to suggest, however, that neem is not being exploited to its full potential by farmers, both in sub-Saharan Africa and south and south-east Asia (Ahmed, 1988; Moser, 1996). There appears to be a number of reasons for this, including a lack of knowledge surrounding neem's role in crop protection.

Studies in Niger and Burkina Faso suggest that neem seed processing is cost effective if labour is not limiting, subsidies for commercial pesticides are removed and other neem products are also utilised (Marz, 1992; Ostermann, 1993). Hegde (1993) suggested that in India, little attention had been paid to the economics of neem use or to increasing the popularity of its cultivation. The price of neem seed has been increasing (Jattan *et al*, 1995) and it has been suggested that factory owners in India are prepared to pay still higher prices for neem seed, but do not do so because of the poor quality of the seed collected (Jattan *et al*, 1995). Hegde (1993) proposed that farmers could benefit from access to improved material, improved seed harvesting, processing and storage technology, improved extraction methods for on-farm use, and the development of local markets.

Since the early 1980's, research on neem and its products has been increasing. Many organisations in India, e.g. the Arid Forest Research Institute (AFRI), Jodhpur, the Forest Research Institute (FRI), Dehra Dun, and the Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore, have had extensive research programmes on neem, as have many research organisations in developed countries, e.g. the University of Keele, UK, with their EU-funded AZTEC project. The growing world-wide interest in the neem's medicinal and insecticidal properties and the fact that the neem cultivated in many countries was thought to be of poor genetic quality (Read & French, 1993), stimulated the establishment of the International Neem Network (INN) in 1994. The Network is co-ordinated by the FAO and has the objective to improve neem and its utilisation for rural people (Thomsen & Souvannavong, 1994).

The International Centre for Insect Physiology and Ecology (ICIPE) has been running a Neem Awareness Project in eastern and southern Africa since 1994. GTZ have been involved in both research and developmental activities with neem, and several of their country programmes have been designed to promote the use of neem for crop protection, e.g. in Nicaragua, the Dominican Republic, Madagascar and Thailand. GTZ also promotes the use of neem through IPM projects such as those in Ghana under the supervision of Dr Mathias Braun. In spite of the existence of several large co-ordinated programmes aimed at promoting and increasing the use of neem in crop protection, there are many smaller projects that have been initiated in-country by local NGOs. These projects often have limited access to information and other resources.

The demand for commercial neem products is increasing both for local markets and export markets. Neem pesticides are registered in the USA and, as the search for more environmentally benign pesticides continues, the demand from both the USA and Europe is likely to increase. Currently, the major producer of neem products is India. In general, neem seeds are gathered through an informal process and reach the manufacturer through unstructured markets. The income received by seed collectors may not reflect adequately the labour required to collect and produce good quality seed. A number of GTZ projects have helped to establish in-country manufacturing plants producing products such as neem oil.

2 Materials And Methods

Both literature-based research and fieldwork, as detailed below, were carried out. Following data collection an external review through an electronic workshop allowed the project findings to be critically appraised.

2.1 Postal survey

A postal questionnaire, consisting of mainly closed questions with applicants being asked to select from a number of possible answers, was sent to approximately 400 organisations during April 1999. These organisations consisted mainly of NGOs, but included government and university research institutes and government ministries of agriculture and forestry. The organisations contacted were thought likely to have some involvement with farmers using neem. Selecting organisations in this way was not thought to bias the data but to allow the maximum amount of information on the way in which neem is used to be obtained. The results were found to be comparable to results obtained from a previous global study carried out by Moser (1996) on behalf of GTZ. One-hundred and forty-six responses were received within the five month deadline and the results analysed by using chi-squared analysis to compare responses from countries where neem exists in its natural range (native) with countries where neem has been introduced (non-native).

2.2 Fieldwork in Ghana and India

A semi-structured questionnaire consisting of both open and closed questions was developed for use in both India and Ghana. Individuals were interviewed in an informal manner at their homes or in the fields. Where appropriate, interviews were conducted through an interpreter. Field sites were selected to ensure interviews were conducted among a range of agro-ecological zones and in areas with different degrees of urbanisation. Stratified sampling ensured that respondents represented a range of socio-economic characteristics. The survey was implemented by the BAIF Research and Development Foundation in India and by the Ghana Organic Agriculture Network (GOAN) in Ghana. In both countries, fieldwork took place between June and September 1999. Results were analysed using a chi-squared analysis. Comparisons were made between different agro-ecological zones and zones of differing degrees of urbanisation.

2.3 Electronic workshop

The workshop involving over 200 participants from around the world ran during November 1999. Participants included representatives from commercial companies, research institutes and NGOs. The aim of the workshop was to allow project findings to be critically appraised and project recommendations discussed. Five topics were covered: Global neem use, Neem use in Ghana and India, Neem silviculture, Neem genetic improvement and Neem commercialisation. Topics were distributed at three-day intervals and participants given three days to respond to the discussion points raised in each topic. These responses were collated and distributed for further discussion. A summary of workshop findings was sent to participants at the close of the workshop.

3 Results

3.1 Neem use for crop protection and its constraints

3.1.1 Background

Neem has been used for centuries and is currently used by many people throughout the world for a variety of purposes. One of the most exciting and potentially valuable uses of neem is in crop protection. Research on, and development of, interventions promoting the use of neem for crop protection are in progress throughout the world. At the same time, manufacturers are developing commercial neem pesticides for use by farmers in both developed and developing countries. Both home-made and commercial neem-pesticides are of potentially great value to poor farmers. There exist, however, a number of constraints that currently prevent this potential from being achieved.

3.1.2 Neem use in crop protection

Sixty-three percent of organisations contacted in the postal survey reported that neem was used for the protection of crops. However, only 10% of organisations identified the use of neem in crop protection as common (Childs *et al*, 1999). The most common way in which neem is used is as an unprocessed raw material e.g. the use of neem leaves in protecting stored crops. Sixty-six percent of organisations, reporting that farmers used neem for crop protection, reported that at least some farmers used a home-made neem product, although only 33% of organisations categorised this as common.

Thirty-eight percent of organisations reported that some farmers in their area purchased commercial neem products, this figure being comparable with that of 35% obtained by Moser (1996). The purchase of locally made and commercially manufactured pesticides was significantly greater in native ranges, reflecting the longer tradition of use of neem in native ranges, greater market opportunities and, in addition, greater commercial and manufacturing knowledge.

It was interesting to note that there seemed to be a thriving trade in the sale and purchase of locally produced neem pesticides (60% in native ranges). It is also interesting to note that 25% of organisations from non-native ranges reported that farmers in their area were able to purchase locally produced as opposed to industrially manufactured neem pesticides (14%). In spite of the fact that the market for neem based pesticides is very well developed in India, 74% of organisations in native ranges reported that farmers in their area made their own pesticides. This conflicts with results from fieldwork in India, which suggested that farmers tend to use commercial neem pesticides, with only 26% of farmers using home-made neem pesticides.

Seventy-nine percent and 73% of organisations reported that farmers who made their own neem-pesticides obtained material from their own trees and from trees on communal land, respectively. Fourteen percent of organisations reported that farmers bought their materials, reflecting some trade in neem raw materials. Access to trees on communal land should be taken into account when promotion of local neem income generating activities is considered, as there may be a danger of reducing the resource base or causing conflicting demands within a community.

The reasons for which farmers chose to use neem for crop protection differed between native and non-native ranges. In native ranges, traditional reasons were more important than in non-native ranges, i.e. neem had been used by previous generations, whereas the importance of extension organisations was greater in non-native ranges. Seventy percent of organisations reported that farmers in their area chose to use neem for pest and disease control because it was cheap. This demonstrates the importance of neem for resource poor farmers and perhaps illustrates that, in spite of the high labour requirements, poor farmers may consider the use of neem for pest and disease control an economic choice.

Organisations were asked from where farmers obtained their information on the use of neem for pest and disease control and were able to list as many sources as they liked. No significant differences were obtained between native and non-native ranges for sources of information, except where the source was cited as traditional, this being significantly higher in native ranges, 93%, than in non-native ranges, 59%. Eighty-one percent of all organisations reported that farmers gained knowledge about the use of neem in crop protection, at least in part, from extension services (government and NGOs). There was a significant difference between the number of organisations reporting extension services as a major source of information, the number being higher in non-native ranges than in native ranges.

3.1.3 Constraints to the use of neem pesticides produced on-farm

There is a range of constraints to the use of home-produced neem pesticides in developing countries. For the purpose of this review, these have been categorised as resource-, information- and technology-based constraints. Of these three, resource-based constraints are likely to show the most variation between and within countries.

Resource-based constraints

Lack of raw materials: Moser (1996) reported that lack of neem trees was cited as a barrier to the widespread acceptance of neem as a pesticide. Childs *et al* (1999) reported that access to trees and material were regarded as constraints by approximately 50% of organisations contacted during a postal survey. This figure was significantly higher where responses came from regions where neem has been introduced. Gomez *et al* (1993) cited accessibility to trees as a factor determining the use of neem by farmers in Nicaragua. The seasonality of neem fruit production has also been cited as a constraint to the use of neem as a pesticide (Childs *et al*, 1999).

Home-made neem solutions used for crop protection require large amounts of water if they are to be used over a reasonable area. As a result a lack of water or access to water may in some instances constrain the extent to which neem is used. Radcliffe *et al* (1992) reported that there was a lack of both seed and available water to produce enough aqueous NSKS to use in crop protection on areas planted with grain crops. However, there was an adequate supply of both of these raw materials for use on the smaller areas of land planted with vegetable crops.

Labour: One of the main constraints for using neem insecticides produced on-farm is that their preparation is time consuming and requires more labour than the use of chemical insecticides (Hoddy, 1991; Ahmed, 1995; P.S. Sohdi, pers. comm.[1]). Farmers in Gujarat, India, found NSKS to be effective, but the preparation was thought to be time-consuming and created more work for women who collect the water needed on-farm and in the home (P.S. Sohdi, pers. comm.). Moser (1996) reported that just over 65% of organisations contacted during a postal survey, regarded labour requirements as a constraint to the use of home-produced neem pesticides. Childs *et al* (1999) report that just over 50% of organisations contacted during a postal survey felt that labour was a constraint to the use of neem in crop protection. In a study on the potential of neem as a crop protectant in Niger, Radcliffe *et al* (1992), asked villagers who would do what in the process of making an aqueous neem seed kernel extract. They concluded that women play an important role in the labour demanding activities of grinding seeds, carrying water and transporting the solution. Ostermann (1993) also concluded from her study that seed gathering was an activity predominantly confined to women and children. Several researchers in India also felt that seed harvesting was an activity confined to children, women and old people (Chamberlain, 1999). Where neem-based pesticides are produced on-farm, there is an additional constraint in that neem trees generally fruit at the busiest time in the farm calendar, i.e. the onset of the rains.

Equipment: Saxena and Kidiavi (1997) reported that most households in Kenya, like many other African countries, own traditional pestles and mortars which can be used for pounding neem seed. Zehrer (1984) reported that the use of neem oil for post-harvest crop protection was suitable for Togo owing to the quantity of neem trees available and the fact that no addition equipment was required. However, Radcliffe *et al* (1992) perceived that the inadequate supply of such implements was a potential constraint in Niger. The tainting of implements with neem extracts, which is perceived to affect the taste of food prepared with the same equipment, has also been cited as a constraint to the preparation and use of NSKS (S. Belmain, pers. comm.[2]).

Information-based constraints

Moser (1996) concluded that lack of information was the primary constraint to the use of neem pesticides produced on-farm. Manu *et al* (1999) and Naik *et al* (1999) both report that farmers perceive the main factor that would increase the use of neem in crop protection to be more information. Leupolz (1991), working on a GTZ-funded neem project in Nicaragua, concluded that a higher level of knowledge and understanding is required for innovative plant protection measures than is required for chemical insecticides. Neem differs from synthetic pesticides in its mode of action and, therefore, where this technology is introduced to farmers familiar with chemical pesticides, it is important to explain that they will not see a rapid reduction in insect numbers or the cessation of crop predation. Rather, insects will continue to feed, albeit with reduced voracity, and after a while a reduction in pest numbers will be observed (Schmutterer, 1990). Childs *et al* (1999) report that 57% of organisations contacted during a postal survey felt that the fact that neem was slow to have effect was a constraint to the increased use of pesticides derived from it. The number of organisations categorising this as a major/ medium constraint was significantly higher in areas where neem has been introduced than in areas where neem is native (89% and 69% respectively), perhaps reflecting a higher degree of understanding about neem pesticides in the native range.

Technology-based constraints

A number of constraints surround the harvesting and processing of neem seed and may affect the efficacy of neem pesticides produced on-farm, thereby reducing their acceptability to farmers. Table 1 lists some of the technical constraints to the use of neem. A brief explanation is provided and where applicable, a solution suggested to avoid or minimise the constraint.

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2 S. Belmain, NRI, Chatham, Kent, UK.

Table 1: Technical constraints to the use of neem pesticides produced on-farm and their possible solutions.

Technical constraint	Problem	Solution	Reference
Seed collection	Risk of contamination with aflatoxin if seeds picked from the ground	Pick seeds from the tree, or sweep regularly under the tree	Nagaveni *et al* (1987) Chaturevedi (1993) Gunasena & Marambe (1998)
Loss of, or damage to, seed material	Risk of reduction in efficacy Loss of material during storage	Efficient and quick drying. Dry in sun, if humid conditions, or shade if low humidity Appropriate storage vessels. Store at reduced moisture content	Hellpap & Dreyer (1995)
Quality of material	Variable quality of seeds in terms of amount of oil and azadirachtin	Picking seeds when greenish yellow in colour ensures higher quantities of azadirachtin	Rengasamy & Parmar (1994) Johnson *et al* (1996)
Photostability of active ingredients	Azadirachtin and other related compounds degrade in UV light	Keep neem preparations away from sunlight Where possible, apply formulations at dusk when sun is weak	NRC (1992) Raguraman & Jayaraj (1994) Mohapatra *et al* (1995) Jarvis *et al* (1997)
Phytotoxicity	High concentrations of both oil and azadirachtin may cause phytotoxicity	Don't make pesticides too strong	
Effects on non-target organisms	Affects aquatic invertebrates. May have variable effects on different organisms and with different neem formulations	Effects should be balanced against the effects and environmental persistence of synthetic pesticides	Scott & Kaushik (1998) Kreutzweiser (1997)

3.1.4 Commercial neem products

Commercial neem products are considerably more sophisticated than the crude NSKS. A variety of solvents can be used to extract limonoids (the active compounds in the neem tree) from neem seed, e.g. hexane, pentane, methanol and ether, either on their own or in a mixture of more than one solvent (Feuerhake, 1984). One of the most effective is methanol, limonoids being highly soluble in alcohol. Once azadirachtin, the major limonoid present, has been extracted and purified, it is added to inert compounds to produce a product with a known, stable, azadirachtin concentration. In many countries, a standard of active ingredient is required for the registration of commercial pesticides and their subsequent use on a commercial scale (Zubkoff, 1999). Neem formulations also contain a number of additives to increase shelf-life, ease of handling and scaling up of the manufacturing process. Sunscreens, such as para-aminobenzoic acid (PABA), are added to reduce the photo-oxidation of azadirachtin by UV light.

Constraints to the use of commercial neem formulations

Jeloise Company Limited (JCL), Ghana, began importing neem formulations from India in 1998 in response to demand from a farmers' co-operative, Kuapa Kokoo (Childs, 1999). They now import preparations suitable for vegetable growers and have promoted these formulations through workshops organised by the Ghana Organic Agriculture Network. JCL found, however, difficulties in meeting the demand for neem pesticides. When an order is sent to India, there may be a lag of over six months before the order is received and processed. The reason for this appears to be that the suppliers manufacture in response to demand and do not have stock sitting on shelves owing to the short viability of the formulations (M. Ansare-Ansah, pers. comm.[3]). Economic studies in Thailand, Kenya and Dominican Republic have also confirmed that manufacturers are producing on demand to avoid problems caused by a short shelf-life (P. Foerster, pers. comm.[4]). Other major constraints to the use of commercial neem pesticides include a variety of policy and legislation issues:

Registration of commercial pesticides: Commercial neem-based pesticides were first registered for use in 1992 (Gruber & Karganila, 1992) and are now registered in at least 14 countries world-wide, either without restrictions or with limited use on certain crops (Moser, 1996). Problems with registering neem products for pesticide use have been greater in industrialised countries where the registration procedure is more complex and demanding. Despite this, however, formulated pesticides are registered for use in the USA and in certain countries within the EU. The registration requirements for different products can often be unclear, and this is highlighted by the regulations surrounding the use of biopesticides for organic agriculture (Hellpap, 1999).

Patents on neem products: In India, neem products such as toothpastes, soaps, shampoos and cosmetics have been manufactured using extracts of neem for many years. In recent years, modern packaging techniques and technology have been used to manufacture pesticides and medicinal products based on neem, and over 30 patents have been granted for different processes and products in India, the USA and Japan. Immaraju (1998), like many other neem researchers, feels that neem is uniquely positioned to become a key insecticide in the global bio-pesticide market.

Private sector efforts in patenting neem tree-related processes and products began to raise controversy in the mid-1990's (Balasubramanian, 1995; Hoyle & Rifkin, 1995; Kocken & van Roozendaal, 1997). The focus of the debate was a 1992 US patent on a process for extracting and stabilising azadirachtin granted to the US company W.R. Grace. A coalition of non-governmental organisations opposed this patent on political and legal grounds. The coalition's underlying arguments were: (1) biological resources are common heritage and should not be patented; (2) the patent would restrict the availability of living material to local people, whose ancestors have spent centuries developing the material; and (3) the patent may block economic growth in developing countries. The legal challenged failed, however, on the grounds that there was no prior knowledge of the process within US borders, and the use of traditional extractions of neem would not be prohibited. This patent might have been rejected if USA patent law recognised certain forms of prior inventive activity (Kadidal, 1998). The USA only recognises prior 'knowledge, use or invention' as blocking a claim to a patent when those activities take place within US borders, or are evidenced by publications accessible in the USA or, more commonly, by foreign patents. However, in May 2000, the European Patent Office did reject a patent on the fungicidal effects of neem oil submitted by W.R. Grace on the grounds of there being prior knowledge of this use.

Insect resistance: there is some concern that the use of azadirachtin in commercial formulations, without the presence of other liminoids, may result in insect resistance developing after a period of prolonged use.

The advantages and disadvantages of the use of neem in crop protection are summarised in Table 2.

3 M. Ansare-Ansah, Jeloise Company Ltd., P.O. Box 8568, Kumasi, Ghana.

4 Dr Peter Foerster, Pesticide Service Project, GTZ, Germany.

Table 2: The advantages and disadvantages of a range of neem products for crop pest control in the field.

Product	Advantages	Disadvantages
Commercial formulations	Minimum labour requirements	Poor distribution
	Can be formulated for stability under UV	Restricted availability
		Poor quality
		Standardisation necessary
		Registration necessary
		May be expensive
		Risk of resistance developing when formulations based on a single compound
Aqueous neem leaf extracts	Leaves available all year round	Less effective than neem seed extracts (does not contain azadirachtin)
	Relatively low labour requirement for preparation	Active ingredients degrade quickly
	Simple to prepare	
	Cheap	
Aqueous neem seed extracts	Seed can be stored ready for use	Active ingredients degrade quickly
	Simple to prepare	Quality may be variable
	Cheap	Seed not available all year round
Neem oil		Active ingredients degrade quickly
	Seed and oil can be stored ready for use	High labour requirement for preparation
	Cheap	Seed not available all year round
		Phytotoxicity
Neem seed cake	Effective both as manure and for nematode control	High labour requirement for preparation
		Seed not available all year round
	By-product of neem oil extraction, therefore can be produced or bought cheaply	

3.1.5 Case studies

The use of neem for crop protection in Ghana

Background

There are millions of neem trees growing in Ghana, especially in the coastal and interior savannahs (Schmutterer, 1998). Many of these trees are used for the production of firewood and charcoal, but other potential uses remain under-exploited. In recent years there has been interest in neem in Ghana for crop protection, both in the field and storage. GTZ, through the Goethe Institute in Accra, has held two conferences, the first in 1998 ('The potential of the neem tree in Ghana') and the second in 1999 ('Commercialisation of neem in Ghana'). These conferences have succeeded in promoting awareness of neem to a number of institutions within Ghana and have also helped to network the activities of these institutions. As a result of the conference in 1998, three working groups were set up within Ghana: 'Neem as a pesticide,' 'Neem as a cosmetic' and 'Neem for afforestation'.

Key results

The results of farmer surveys suggested that, the most common use of neem in Ghana is for medicinal purposes with 60-80% of farmers in all agro-ecological zones reporting that they used neem for this purpose. In general, the use of neem for other purposes was not common, but the use of neem was greater in both the coastal and interior savannah, where there are more neem trees, than in the forest zone.

Nineteen percent of farmers indicated that they used neem for crop protection, with 9% of farmers indicating that they used neem to protect their stored crops and 12% of farmers indicating that they used neem to protect their crops in the field. These figures were higher than was expected, but closer examination of the data revealed that the use of neem for crop protection was strongly linked to areas where there had been recent interventions promoting neem.

Farmers using neem for crop protection (users) were able to cite a number of ways in which they used neem, the majority making aqueous formulations with leaves or seeds. The majority indicated that these materials were collected from trees on communal lands. Eight percent of users indicated that they used commercial formulations, which are imported by the Jeloise Compamy Limited, Kumasi, and distributed via their own network of retailers and Ministry of Agriculture shops. Most farmers using neem for crop protection had gained their information from extension programmes and organisations. When users were asked what they felt the perceived benefits of using neem for crop protection were, the majority indicated that it was cheap.

Users were asked to indicate what they felt, if any, were the constraints to using neem for crop protection. No one constraint was cited by a majority of farmers. This may be because use is relatively new and farmers have not had time to become fully aware of constraints. The most frequently cited constraint (18%) was that neem preparations were time consuming to prepare. All 200 farmers interviewed were asked whether they thought there was the potential for neem to be used more widely in crop protection. All felt that there was and that the factor that would increase use the most was education/information.

The use of neem for income generation purposes is not that common. In the coastal savannah, communities were identified where the use of neem to make charcoal for sale was a common activity. A few individuals were engaged in the purchase of neem seed and the manufacture of aqueous neem seed solution for sale, following exposure to the use of neem as a pesticide during MOFA/FAO IPM Farmer Field Schools. Examples of the local manufacture and sale of neem soap were also recorded.

During the course of the fieldwork, a women's group reported that they found neem was invasive on their farmlands, as wild seedlings germinated on cultivated land. Because of this the women have to rotate their land more frequently. Also in Ghana, neem is invading the dry forests on the coastal zone inselbergs, threatening already critically endangered species such as Talbotiella gentii. In the Shai Hills Game Production Reserve, the vectors for invasion are baboons, who eat the copious seed produced by neem and thus spread it (S. Rietbergen, IUCN, Geneva pers. comm.). In 1992, the abundance of shrews and rodents was studied on the Accra Plains of Ghana to measure the impact of invading neem on small mammal communities (Decher & Bahian, 1999). The study was inconclusive, although trapping success of mammals was low in areas with dense stands of neem.

The fieldwork identified a series of constraints that currently prevent the realisation of the full benefits that neem can provide to the poor. These are shown in Table 3.

The use of neem for crop protection in India

Background

Neem has been a beneficial tree to Indian farmers for many generations. It has a wide range of uses in agriculture, animal husbandry and the household. Currently there is a surge in interest in neem research and product development. In rural India, however, there is very little change in the uses and benefits of the neem tree to the local population. In spite of the importance of this tree and knowledge about its uses, there is evidence to suggest that the tree is being under-utilised in India.

Key results

Fifty-three percent of those interviewed during fieldwork indicated that they used neem for some purpose. The proportion of the population using neem is greater in Rajasthan and Uttar Pradesh than in Tamil Nadu and Maharashtra, perhaps reflecting the socio-economic characteristics of these states, the latter two being regarded as wealthier. It was clear that in Rajasthan and Uttar Pradesh, where neem use is high, the use of neem for traditional purposes (medicine, shade, protection of stored crops) was greater than where neem use is low, i.e. Maharashtra and Tamil Nadu. Conversely, the use of neem for more modern purposes (protection of field crops, soil fertility) is slightly higher in Tamil Nadu and Maharashtra than in Rajasthan and Uttar Pradesh. This implies that access to new knowledge on neem may be limited in these latter states, or if available, not taken up to the same degree.

The use of neem for the protection of stored and field crops, was reported by 32% and 10% of the total respondents, respectively. Among the rural population, 45 interviewees (25%) used neem for crop protection. However, the responses show that it is not only the rural farmer who should be targeted, or can benefit from the use of neem for crop protection, but identifies the urban/peri-urban population as a target group, especially for the protection of stored crops.

Farmers using neem for the protection of crops (either in storage or fields) were asked for how long they had been using neem. Just over half reported that they had been using neem for crop protection for more than ten years. The most common way in which neem is used for crop protection in the field is as a commercial formulation, with very few farmers (26% of those using neem for crop protection) reporting that they made their own neem preparations. Interestingly this contrasts with results from a postal survey that indicated that home-made neem pesticides were used more frequently than commercial neem pesticides in countries such as India.

The main benefits perceived by farmers in using neem for crop protection included the fact that neem is effective against a wide range of pests and that it is cheap. When farmers were asked why they chose to use neem for crop protection, the main reason cited was that it was traditional. The role of extension organisations did not rank highly. However, when farmers were asked from where they received information on the use of neem for crop protection, traditional sources and extension organisations were ranked equally as the most important sources of information. This suggests that information and extension about neem in India has perhaps been conveyed to farmers passively rather than being actively promoted.

Those using neem for crop protection were asked what were the constraints to using neem for crop protection. Surprisingly, the most frequently cited constraint was the fact that there was a lack of information. The fact that preparations were time consuming to prepare and that applications were slow to have an effect were also important.

Ninety-six percent of those interviewed felt that there is the potential for neem to be used more widely for agricultural purposes. Information and education were regarded as the most important factors likely to increase the use of neem.

Approximately 12% of respondents indicated that they, or a member of their household, are engaged in some form of income generating activity involving neem. Among the non-wood produce, seeds are the most common material sold. Most seed collectors part process seed by removing fruit pulp and drying seed in the shade.

The fieldwork identified a series of constraints that currently prevent the realisation of the full benefits neem can provide to the poor. These are shown in Table 3.

Table 3: Suggested future interventions in India and Ghana.

Level of intervention	Activity (India)	Activity (Ghana)
Institutional level	• Build capacity for co-ordinated neem research and development • Develop stronger linkages with commercial sector • Establish a national strategy for research and development activities	• Increase awareness of neem as a pesticide and enhance authorities' ability to deal with issues surrounding the registration etc. of neem-based pesticides. This is particularly important as Ghana is looking to develop its own commercial neem pesticides. • Further develop neem for protection of crops destined for export • Examine subsidies and current legislation with regard to how they could be influencing farmers decisions about using neem for crop protection
Research level	• Further information exchange to avoid research duplication • Research management regimes for the optimal yield of different neem products • Research factors concerning neem seed quality and quantity	• Provide technical support to three working groups on neem • Establish a resource centre designed to raise awareness of research done elsewhere and to prevent research duplication. Perhaps the formation of the Ghana Neem Foundation. • Promote silviculture as a priority topic • Further explore the potential for neem to be used for crop protection in Ghana • Further explore the role that neem can provide in integrated nutrient management • Monitor the potential for the invasiveness of neem
Extension/NGO level	• Initiate programmes that encourage tree planting on and around farms • Training to increase capacity of extension organisations to promote neem to target groups • Raise awareness of additional attributes of tree i.e. soil fertility • Develop and promote marketing initiatives and information on improved processing	• Carry out training to increase NGOs/extension organisations' capacity to promote neem for crop protection to appropriate and targeted groups • Raise awareness of NGOs about other potentials of the tree, including soil fertility improvement
Farmers level	• Identify communities where neem use for crop protection will bring greatest benefits • Participatory silvicultural research to examine management practices and initiate appropriate interventions • Establish farmer co-operatives to improve harvesting of neem seed and opportunities for adding value	• Identify communities where neem for crop protection will bring greatest benefits • Participatory silvicultural research to examine management practices and initiate appropriate interventions

3.2 Neem silviculture

The interest in neem as a source of botanical pesticides has prompted discussion on the need for plantations of the species. There are thought to be more than 17 million neem trees in India (Ketkar, 1976), which occur along roadsides, in field boundaries, around houses and temples, or in village centres. Pure stands, or plantations, of neem have been established recently in parts of India (R. Senrayan, pers. comm.[5]) and Brazil (P. Foerster, pers. comm.[6]), and can be found in West Africa, Australia, Saudi Arabia and Mexico (Radawanski, 1977; Ahmed *et al,* 1989; Bosselman, 1993; I. Moreno, pers. comm.[7]). In India, the Central Arid Zone Research Institute (CAZRI) are planning to conduct research on the development of plantation models for neem, based on the need to develop degraded areas and wasteland in Rajasthan (S. Vir, pers. comm.[8]). To date, however, relatively little is known about the silviculture of neem in plantation or agroforestry systems, or its optimal management for fruit production.

3.2.1 Neem trees and their management

Benge (1988) has commented that neem does not grow well in pure stands and is very competitive for water and soil nutrients. However, Radawanski (1977) noted that neem has been grown on a plantation scale in Nigeria since 1936, and that the introduction of neem to Sokoto, Nigeria was described as the boon of the century, as the trees grew quickly, meeting the local demand for firewood and timber. Ahmed *et al* (1989) have described the development and management of pure stands of neem grown in Saudi Arabia, and Bosselman (1993) assessed the site adaptation of neem plantations in Australia. Neem could also be planted in mixed stands with leguminous trees (Benge, 1988), where neem would benefit from the nitrogen fixing abilities of the legume trees, and the risk from pests may be reduced.

3.2.2 Improving the growth of trees

The annual production of biomass in neem plantations is reported to be between 3 and 10 m^3 ha^{-1} (Hegde, 1991). This classifies it as a medium fast growing species, slightly slower than fast growing species such as *Casuarina, Leucaena*, *Acacia* and *Eucalyptus*. Yield of biomass per year has also been reported to vary between 10 and 100 t ha^{-1} yr^{-1} of dried material (Michel-Kim & Brandt, 1981). These authors estimated that 40 t ha^{-1} yr^{-1} of solid wood could be harvested under appropriate site conditions. The rate of growth of neem is moderate, however, showing a mean annual girth increment of 3.2 cm. A study in western Rajasthan showed that growth is fast in the first ten years, after which it slows (Tewari *et al,* 1996). Radwanski (1977) reported that 66% of the total growth of neem trees occurred within the first three years following planting. A height of approximately 4 - 7 m is reached after three years and heights of between 5 - 11 m are obtained after five years, the rate of growth being affected by site conditions. Various yield estimates, for both coppicing and felling after different rotation lengths, have been described by Benge (1988). More recently, yield and volume tables for neem have been prepared based on plantations found in Gujarat, an arid region of western India (Jain *et al*, 1998), and plantations found in northern Ghana (Nanang, 1998).

The Arid Forest Research Institute (AFRI) based in Jodhpur, India have been researching different methods of water harvesting and moisture conservation on the growth, biomass accumulation and nutrient uptake by neem (Gupta, 1994; 1995). The ridge and furrow method of water harvesting showed a 58%, 73%, 11% improvement in height, collar circumference and crown diameter, respectively. Biomass accumulation increased by 3.8%. Neem has also been shown to benefit from both mulching and weeding, but plantation costs increased by up to 50% with the use of soil moisture conservation techniques. The growth of trees is also affected by planting density. Boa (1995) reported on the poor performance of trees planted at 4 x 4 m spacing (approximately 625 trees ha^{-1}). Hegde (1993) recommended a spacing of 6 x 6 or 8 x 8 m for neem plantations (280 and 160 trees ha^{-1} respectively), and suggests that, as it will take 8 - 10 years for trees to attain a good size, they be inter-cropped with leguminous trees on a short rotation. A density of 160 trees ha^{-1} has also been recommended by the Institute for Forest Genetics and Tree Breeding (IFGTB), Coimbatore, India. Benge (1988) recommended that wider spacings should be used on poorer quality sites.

3.2.3 Seed production and silviculture

The uses of neem are varied and it is likely that different silvicultural systems will suit different products. Appropriate rotations will vary according to whether fuel, timber or seeds are the desired end

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7 I. Moreno, Eco System del Noroeste, S.P.R. de R.I., Mexico
8 S. Vir, CAZRI, Jodhpur, India.

product. Parmar & Ketkar (1993) recommended that where neem plantations are required for several products, care is needed to ensure that meeting one requirement does not jeopardise others. For example, if firewood and seed for pesticidal compounds are required from neem, only trees that are more than 10 years old should be used to provide firewood while younger trees can be used a source of seeds. If the branches of neem are regularly pruned, then it takes some time for the tree to produce fruit again as they re-establish vegetative growth. Bahuguna (1997) suggests that further research is needed to develop suitable silvicultural practices for a range of uses including the production of seed. Table 4 illustrates a range of uses with current recommended management practices.

Table 4: Neem use and management for a range of products.

Use/Desired product	Management practice	Reference
Timber	Felling at 35 - 40 years after planting Felling at 20 years after planting	Hegde (1993) Vivekanandan (1998)
Firewood	Simple coppicing after 8 years Clear felling at 8 - 10 years	Benge (1988) Benge (1988)
Seeds	Use of improved varieties Adequate moisture supply at fruit formation	Hegde (1991)
Poles	Coppicing on an 8 year rotation	Radawanski (1977)

3.2.4 Research priorities for silviculture

In order to fill the gaps in knowledge surrounding the silviculture of neem and improve its productivity on-farm, the areas of research outlined in Table 5 might be appropriate.

Table 5: Limitations to the optimum management of neem for a range of products, and possible interventions to overcome them.

Limitation	Intervention
Lack of knowledge of how farmers manage neem trees and whether their practices might be appropriate	Traditional knowledge research surrounding the management of neem could provide insights into ways in which neem could be managed for a range of products, including seed. This could lead to the development of management techniques appropriate to farmers and their production systems
Lack of information on practical management regimes for a range of neem products	Research to test the recommendations on spacing distances and possible pruning regimes for a range of products
Lack of information on the factors controlling seed production in neem	Research to investigate the role of soil moisture and nutrient availability on seed production and oil and azadirachtin content of the seeds

3.3 The genetic improvement of neem

Many organisations around the world have been working on the genetic improvement of neem in response to international, national and local research needs. A number of research institutes, particularly in south and south-east Asia have established provenance trials of neem or have micro-propagated clonal material from plus tree selections (Chamberlain, 1999). The Forest College and Research Institute of Tamil Nadu Agricultural University (TNAU) has some of the oldest provenance trials in India, dating back to 1991 (TNAU, 1999). They have trials of material from Tamil Nadu only and material collected from all over India. The main selection criteria in the TNAU trials have been stable production of seeds with high azadirachtin and oil content. In 1992, AFRI established a large provenance trial of neem containing 40 provenances from 10 Indian states representing different agro-climatic zones of the country (Mishra, 1995). In 1994, the National Research Centre for Agroforestry (NRCAF), Jhansi, India, established a provenance trial of neem with 26 provenances collected from central India (Solanki, 1998). The NRCAF also collected seed from plus trees selected on the basis of bole straightness, high fruit yield and canopy shape. The Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad, India has described a procedure for the selection of plus trees based on multiple traits, and the mass micropropagation of clonal plants (Venkateswarlu *et al*, 1999). The Research Section of the Royal Forest Department of Thailand has established a clonal gene bank of 32 plus trees selected from three regions of Thailand (Boontawee *et al*, 1993).

Other genetic improvement activities with neem have centred on the INN, a programme co-ordinated by the Food and Agriculture Organisation (FAO).

3.3.1 International Neem Network

In 1994, the International Neem Network was established with the long-term objective to improve the genetic quality and adaptability of neem, and to increase its utilisation throughout the world, as a contribution to development, with a particular focus on meeting the needs of rural people (Thomsen & Souvannavong, 1994). The Network collaborators decided to undertake activities in relation to provenance exploration, seed collection and exchange for the establishment of internationally co-ordinated trials. They also decided to undertake research on seed physiology and technology, genetic diversity and reproductive biology, as well as studies on the variation in chemical compounds.

The national institutions of 21 countries, in Asia, Africa, Latin America and Europe, are collaborating in the Network. The Network is co-ordinated by a panel formed by the Indian Council for Forestry Research and Education (ICFRE, India), Royal Forest Department (Thailand), Institut Sénegalais de Recherche Agronomique, (ISRA, Senegal), Département Forestier du Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD-Forêt, France), DANIDA Forest Seed Centre (DFSC, Denmark), FORTIP and the FAO. Global co-ordination is entrusted to FAO, which facilitates inter-regional co-operation and exchanges of information and genetic material.

Provenance exploration, collection and testing

Twenty-five seed sources, representing the entire eco-geographical variation in the distribution range of neem were identified for seed collection and exchange among Network collaborators for the establishment of international provenance trials (Hansen *et al*, 1996). All seed sources included in the international trials have been described using a common set of descriptors, including maps (FAO, 1998). Seed collection took place between March and August 1995 and followed common procedures determined by a working group of the Network (FAO, 1995a). Immediately after collection and appropriate processing, seed from the 25 provenances was rapidly dispatched among collaborators in 19 countries. Nursery production of seedlings followed common guidelines developed by a working group of the Network (FAO, 1995b). The nursery production was successful in most countries, and a sufficient number of plants of acceptable quality were raised for trial establishment.

The design and establishment of international provenance trials

The objective of the international provenance trials of neem is to study, on multiple sites, the genetic variation, overall adaptation and growth of the provenances included in the trials, and to assess site/provenance interactions. Guidelines for trial design and establishment were prepared by a working group (FAO, 1996). Considering the extent of variation, across the Network, in trial site conditions and number of seedlings available, it was not considered realistic, nor desirable, to use one single design for all the trials. Instead, the guidelines were designed to provide practical advice for the design and establishment of statistically sound, robust trials, adapted to local conditions and available resources. A total of 36 provenance trials were established during 1995-1997 in Bangladesh (2), Burkina Faso (1), Chad (1), India (6), Lao (1), Mali (2), Myanmar (3), Nepal (2), Nicaragua (1), Pakistan (1), Philippines (2), Senegal (3), Sri Lanka (1), Sudan (1), Tanzania (4), Thailand (2) and Vietnam (2). However, due to low survival rates, the trials in Chad, Nicaragua and the Sudan have been closed. In the remaining trials, the number of provenances per trial varies between 15 and 25. In addition, some countries included local seed sources. The funding for the establishment and maintenance of trials was the responsibility of each collaborating country in the Network.

Supportive research components

In addition to the main Network activities on seed exchange and the establishment of international provenance trials, the network has a number of supportive research components, related to genetic variation and reproductive biology, seed physiology and technology, and genetic variation in chemical compounds.

Genetic variation and reproductive biology

This component is co-ordinated by CIRAD-Forêt, France. A research proposal was prepared by CIRAD-Forêt in co-operation with concerned INN collaborators. The proposal was presented to the Government of France, but was not accepted for funding (Hansen *et al*, 1996).

Seed physiology and technology

This component is co-ordinated by the DANIDA Forest Seed Centre, Denmark and has been incorporated into a collaborative research project entitled 'Project on handling and storage of recalcitrant and intermediate tropical forest tree seeds'. The project is funded by the International Plant Genetic Resources Institute (IPGRI) and DANIDA and has participation from research institutions in some 20 countries. Neem is one of 30 tree species being tested in the programme. Work on neem has concentrated on seed storage and seed desiccation studies, and a number of countries, which have agreed on common objectives and goals, are collaborating within this group.

Component on genetic variation in chemical compounds

This component is co-ordinated by the Indian Council for Forest Research and Education (ICFRE). Research on this topic is on-going among a number of Network collaborators, but development of this component will not proceed until trees in the trials begin flowering and fruiting. Activities have included the estimation of azadirachtin content and fatty oil variation in neem seed, plus isolation and characterisation of active constituents in these compounds.

Network programme and future activities

The Network is currently concentrating on the continued management and care of the established international provenance trials (Hansen *et al*, 1996). Assessment of trials started in 1997, and guidelines for trial assessment, including the identification of characters to assess and assessment methodology, have been developed. Seed characteristics and azadirachtin content in neem seed will be assessed for the first time in year four. Only those collaborators with an interest in this area and with equipment available for the analysis of azadirachtin content will assess these traits (Chamberlain, 1999). Future activities of the Network include further assessment of the genetic variation in neem, conservation (*in situ* and *ex situ*) of the genetic resources of neem, genetic improvement and production of improved planting material in countries concerned, further studies on chemical compounds and their genetic variation, linked and co-ordinated with other genetic diversity studies.

3.3.2 Limitations to current genetic improvement programmes

From the research undertaken to date, there appear to be a number of limitations to the current improvement programmes on neem (Table 6).

Genetic variation in seed azadirachtin and oil content

The INN is currently focusing on assessing growth characteristics and not seed azadirachtin or oil content. This emphasis should diminish as the trees mature and begin fruiting. The methodologies for measuring growth characters have been standardised across the Network, but there is currently no standard methodology for estimating azadirachtin content available to the collaborators (C.J.S.K. Emmanuel, pers. comm.[9]). This is important when comparing results between sites, and may assist in understanding the effect of the environment on azadirachtin content. Work was undertaken by GTZ to develop a standard assay for azadirachtin, but has not been completed because of lack of research funds (Chamberlain *et al*, 1999). The establishment of a large set of neem trials in differing environments needs to be capitalised upon, and a standard assay developed as soon as possible. If developing country partners are unable to

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assay neem seeds for azadirachtin content themselves, then collaboration with a laboratory that can should be sought.

Genetic variation and reproductive biology

The results of the INN should yield information about the role of the environment and genotype on the reproductive characteristics of neem. Although little is known about the control of flowering and fruiting in neem and the affect of environment on this trait, data on flowering and fruiting phenology is available from a number of sites. Knowledge of reproductive biology can provide information on the species' sexual and mating systems and the role of pollinator behaviour on fruiting, allowing improved seed orchard design and optimal management techniques for seed production.

Reliance on the micropropagation of plus trees

The micropropagation of neem has been the focus of research at many institutions world-wide. However, micropropagation is only a viable and long-term improvement option when genetic material of known quality is available for propagation. To get such material a programme of selection and testing of germplasm is needed, and there is little point in the expensive mass propagation of untested material, a strategy that has been followed by a number of research organisations.

Information exchange

There appears to be a lack of exchange of information on neem despite the existence of several local and international neem newsletters. This limitation is not confined to research on genetic improvement, but is common to several research and development themes. Lack of a broad and effective means of exchanging information on neem has been cited by several researchers (see Chamberlain *et al*, 1999), who suggested means of overcoming this constraint, e.g. simultaneous, subject-specific conferences in several countries, an interactive neem database, electronic discussion group, or supra-regional office for information exchange. As a partial response to this, a neem discussion group was set up in early 2000 and currently has 60 members.

3.3.3 Can the rural poor benefit through the genetic improvement of neem?

This is a key question in the current study. The results of the postal and farmers' surveys (Childs *et al*, 1999; Manu *et al*, 1999; Naik *et al*, 1999) indicated that lack of access to neem trees or seed material was a limitation to the further use of the species in crop protection. This was especially relevant in areas where neem has been introduced. More productive trees that produce seeds with higher azadirachtin contents could be very beneficial to resource-limited farmers, but currently the limitation seems to be lack of trees, rather than lack of productive trees. Lack of access to neem material was ranked alongside the constraints that neem applications were slow to have an effect and were time-consuming to prepare. Appropriate extension and education services could therefore have a more significant impact on the use of neem for crop protection than genetic improvement by itself.

If neem is being used as a cash crop, i.e. through the sale of seeds for oil or pesticide manufacture, then the role of improved varieties may be a little more difficult to predict. Low prices are paid for seed that is of poor quality, i.e. whole fruits, seed mixed with plant debris and soil, seed subject to fermentation or fungal attack. Improved methods of seed harvesting and processing are likely to increase the price paid per unit of seed, and could potentially generate greater income than varieties with improved seed production, or higher azadirachtin content. Again, appropriate extension and education services could have a more significant impact on the income generated through the sale of neem seed than genetic improvement by itself. Greater quantities of seed in the market place could in the long-term keep the price paid for neem seed low, although with increasing demand in the short-term, increasing seed prices could be observed. It is likely, however, that a high price will always be paid for high quality seed and that this may be more beneficial to the rural poor than quantity *per se*.

Where neem is being introduced to a new area then it will be appropriate to plant improved material if it has been site tested and its growth and reproductive performance are known. It will be important that the improved material is genetically diverse to avoid the risk of susceptibility to pests and diseases.

Table 6: Limitations to current genetic improvement programmes on neem and possible interventions to overcome them.

Limitation	Possible interventions
Lack of a standard methodology for estimating azadirachtin content within the International Neem Network	Develop a standard assay
Lack of necessary facilities for assaying azadirachtin content in Network collaborating countries	Initiate collaboration with a suitable laboratory Devise rapid and effective means of transporting neem seed between countries
Lack of information on the factors controlling seed production in neem	Research reproductive biology and seed production Research optimum silvicultural practices for seed production Determine the effect of the environment on seed production in neem
Reliance on the micropropagation of neem	Initiate programmes of selection and testing prior to the mass micropropagation of neem
Poor information exchange	Develop new structures for the dissemination of information, e.g.: • Interactive database • Neem discussion group • Simultaneous, subject-specific conferences • Supra-regional office offering a broad and effective means of disseminating information

3.4 Commercialisation of neem and associated income generating activities

3.4.1 Background

Neem products can contribute to both the local and national economy and can provide a means of generating household income. Most trade appears to be in seeds, with collectors adding little value to the products they sell. Commercial activities involving neem have had the most impact in India where neem fruits have the greatest potential, despite only an estimated 25-30% of fruits being collected per annum (Hegde, 1993). The majority of neem seeds are crushed for oil of which 95% is used for soap production, with neem seed cake being produced and sold as a by-product.

Neem seed prices vary across the season. In 1998, the neem seed harvest in Andhra Pradesh, India, was relatively poor, hence the price for seed was low at the beginning of the season (US \$0.05 kg^{-1} but increased to US \$0.12 kg^{-1} towards the end (Chamberlain, 1999). Higher prices are paid for neem seed kernels (e.g. US \$0.25 kg^{-1} in Uttar Pradesh, India), but seed collection and processing is labour intensive and does not compare favourably to the salary paid for unskilled labour.

Labour costs also have bearing on the commercial production of neem pesticides. In the Dominican Republic, the relatively high cost of labour means that a neem oil processing plant imports seeds from Haiti where labour is cheaper (B. Cooper, pers. comm.[10]). Jelosie Company Limited (Ghana) who are considering setting up a manufacturing plant feel that they would have to import seed from Nigeria, rather than buy internally, because of both labour costs and quantity of material available in Ghana (M. Ansare-Ansah, pers. comm.[11]).

3.4.2 Seed marketing and associated constraints

Seed collection, marketing and harvesting

The collection and sale of neem seed in India is based around an auction system, which has been running for 20 - 30 years (ten Kate & Laird, 1999), with seed being collected from wild trees on community lands or trees on owned land (Naik *et al*, 1999).

In the current study, 12% of those interviewed during fieldwork in India, reported that at least one member of their household collected neem materials for sale. Among the non-wood produce, neem seed was the most commonly sold material, the price of the seed depending on the proximity to the market or processing unit as well as year to year variation in the quantity of seed available. An individual can collect up to 30 kg of neem fruits in a day. This equates to about 15 kg of seed with a total value of between Rs 60-150 (US$1.45 – US $3.60). The total amount of neem fruits collected annually in India is estimated to be 90,000 t, equivalent to about 45,000 t of seed.

Neem tree owners may collect the fruits fallen under the trees themselves or allow others to do it. Those who collect fruits from other individuals' trees may pay an amount to the tree owner. In general, collection appears to be predominantly carried out by women, children and more marginalised groups. During the electronic workshop one participant alluded to the fact that, because prices received for seed are poor, seed collection is becoming further confined to women and children, especially where seeds are not processed.

Higher prices for seed can be obtained if the fruits are processed by removing the skin and pulp covering the seed and drying under shade, or are processed to produce seed kernels. Processing ensures better quality material, with a higher azadirachtin content, although the technology and space required to do even the most minimal amount of processing is often not available at the household level. However, in the current study 94% of neem seed collectors in India part-processed the seeds (generally dried the seeds) before they were sold.

Processed and unprocessed seed is sold to a trader who takes the seed to a district level market. In some cases, the seed collectors bring the seeds to these markets in anticipation of better returns for their labour. At market, seed may be sold to neem product manufactures (oil mills, pesticide manufacturers) or, where there is a high volume of trade, the seed is auctioned, e.g. at Khamman, Bharsi and Selem.

During the current project it was found that, in general, prices for seed vary from Rs 4 - 10 (US $0.09-0.22) per kg. Generally, seed collectors sold the seed directly to buyers representing oil extraction mills or middlemen, who in turn sell it to the mills or factories. It is estimated that currently the middleman can make 50 - 170% profit on the trade of seed (Childs *et al,* 1999). By trading directly with the manufacturer, the number of intermediaries could be reduced and the remuneration the collector receives increased.

In recent years, there has been a greater demand for neem seed because of the expanding use of neem oil in cosmetic and pesticide formulations. This has resulted in seed traders by-passing the auction and selling directly to processing units at higher prices. In order to increase returns for seed, traders may store seed harvested between June and September, until prices increase. According to P.J. Margo, a neem pesticide manufacturing firm based in Bangalore, the quality of such seed is sometimes low because of the high moisture content of seed and improper storage conditions. Some neem product manufacturers have their own purchasing agents and specifications for seed quality.

Commercial neem pesticides

Of commercial neem products, neem-based pesticides have probably received the most attention in recent years. The number of neem pesticide manufacturers in India has increased and many products are now available in the market. Some of these products are shown in Table 7. Some of these companies have been producing synthetic pesticides, but have now added neem to their list; others produce neem and other organic pesticides exclusively.

10 Dr Brian Cooper, Ministry of Agriculture, Antigua

11 Mike Ansare-Ansah, Jeloise Company Limited, Kumasi, Ghana.

Table 7: Neem-based pesticides available in India.

Product	Active ingredients
Azadi	Azadirachtin (3.0, 0.15 and 0.03%)
Fortune Aza	Azadirachtin (3.0, 0.15 and 0.03%)
Godrej Achook	Azadirachtin and other limonoids
Margocide	Azadirachtin and other limonoids
Neemarin	Azadirachtin (3.0, 0.15 and 0.03%)
NeemAzal Technical	Azadirachtin (25% w/w; other limonoids 30 - 50% w/w)
NeemAzal T/S	Azadirachtin (1.2% w/w; other limonoids 2.8% w/w)
Nimbecidine	Azadirachtin
Nimorich	Azadirachtin (1.0, 0.3, 0.15 and 0.03%)
Repelin	Neem, karanja, custard apple and castor products
Vijay Neem	Azadirachtin (3.0, 0.15 and 0.03%)
Wellgro	Powder formulation

Constraints to the collection, sale and marketing of seeds

There is no doubt that the demand for neem products is increasing, and that this demand represents opportunities for the poor in terms of seed collection and sale. At present, however, there are a number of constraints to neem seed collection.

Collectors constraints

In the course of the postal survey organisations were asked what were the constraints to the further development of neem as a commodity crop. Overall the most frequently cited constraints were information-based, for example, a lack of education on neem as a commodity, a lack of information on neem processing and a lack of information on neem harvesting. A lack of access to resources (trees) did not rank highly, which was not unexpected given the small proportion of communities engaged in this activity.

Manufacturers constraints

Within the course of the current project several commercial companies were identified and asked what were, if any, the current constraints to the collection and sale of neem seeds. The main points raised are listed below.

- Neem cultivation is not organised in the way other agricultural commodity crops are.
- Neem seed collection is not organised properly by the vendors and is a low profile activity.
- Marketing of neem-based pesticides is still a niche market.

Both the constraints identified by collectors and manufacturers affect the price of seed and support observations made by previous researchers relating to factors that prevent higher prices being obtained for seed. These factors are summarised in Table 8.

Table 8: Constraints to neem seed collection and marketing.

Constraint	Explanation
Lack of knowledge about seed collection, leading to the sale of poor quality seed mixed with gravel and soil	Seeds only partially processed therefore quality reduced. Low prices received for low quality material.
Poor marketing system	Marketing is unorganised and under-developed. Co-operatives for marketing and oil extraction could help increase prices received by seed collectors. Manufacturers benefit from more efficient marketing by receiving better quality material.
Lack of knowledge about seed handling, leading to poor quality fruits and seed.	Seed stored until higher prices can be achieved. Storage and handling is often poor, therefore quality is reduced.
Sale of unprocessed seed and very little opportunity to add value	Unprocessed seed sold, although manufacturers will buy processed products such as oil. If a farmer collects 50 kg seed (100 kg fruit) then a price of US $ 4-8 can be realised. To obtain this price farmer must depulp fruit and dry seed. If the farmer has access to a cold press, then seed can be processed to oil. 50 kg of neem fruit will result in 25 kg of kernel and 25 kg of neem seed coat. The oil content of neem kernel is 40% by weight and therefore 10 kg of oil and 15 kg of neem seed cake can be recovered. The oil could be sold for US $6.59, the neem seed cake for US $2.63 and the seed coat residue for US $1.65. This results in a gross profit of US $10.87. Therefore if seed sold for US $0.09-0.18 per kg then processing to oil is cost-effective.

Village neem related industries

As well as the collection and sale of neem seeds to commercial manufacturers, there are a number of small-scale cottage industries and individual enterprises that form income-generating options for those with access to neem. Often these enterprises spring up informally, individuals having gained exposure to the potential value of neem. For example, the sale of small neem trees, has been initiated following the Neem Awareness Programme implemented by the International Centre for Insect Physiology and Ecology (ICIPE) in Kenya. In Ghana, following exposure to neem as pesticide in farmer field schools, some individuals have taken both to purchasing neem seed and to manufacturing home-made neem pesticides for sale to other farmers. The constraints associated with manufacturing home-made pesticides, outlined in Section 3.1, encourage the manufacture and sale of half finished neem products, for example neem seed powder for pest control. These half-finished products partially overcome the storage and labour constraints of home-made neem pesticides and are cheaper than commercial neem pesticides.

The most widespread processing activity involving neem at the village scale is probably the manufacture of neem-based soaps. The degree of technology required for this enterprise ranges from the use of simple and common household tools, i.e. pestle and mortar, to more sophisticated tools such as oil presses. A women's group in Northern Ghana visited a community in Burkina Faso, where they were exposed to a number of village level income-generating activities. From these they chose to become engaged in the production of neem soap as they felt that it was the most suitable activity for their group. In spite of the ease of access and low entry costs for such activities, some larger scale cottage industries have had difficulties competing in the commercial market. For example in Tamil Nadu in India, Sarvodaya Sangh, a company engaged in cottage industry scale manufacture and sale of neem soap is no longer finding detergent soap making a profitable venture. There are several reasons for this. Firstly a large soap manufacturer entered the market as a buyer of neem oil about five years ago and as a result neem seed and oil prices have risen steeply. Secondly, private soap producers add synthetic substances to increase foaming of soaps, whilst the cottage industry lacks such research and development. Thirdly, the cottage industry does not advertise its produce, therefore, the demand for neem based soap produced by the Sarvodaya Sangh has decreased dramatically. It is possible that these factors could be overcome through sale to niche markets, i.e. community-based or fair trade markets (Naik *et al*, 1999).

3.4.3 Neem plantations

Neem seed production still remains a largely unorganised activity. The increasing demand for neem pesticides, both within countries such as India and Ghana, and for export, is acting as a catalyst for the establishment of neem plantations. There is some speculation that plantations may adversely affect those involved in the collection of neem seeds for sale. However, Murkumbi Bioagro Ltd. has 28 000 neem trees planted on its own land and remains dependent on the harvesting of neem seed by local communities for the bulk of its supplies (ten Kate & Laird, 1999). At a conference in Pune, the potential impact of plantations was discussed and it was concluded that plantations would not adversely affect current neem seed collection activities (Childs, 2000).

The economics of village neem plantations in India

Hegde (1993) estimates that an average neem tree can generate an annual income of US $1.25. A hectare of trees (150 - 200) could therefore generate an income of approximately US $350, which is more than the returns received for some food crops. Ruthyunyaja & Dayanatha (1993) highlighted a number of issues that have to be addressed prior to farmers establishing neem plantations. They also provide a list of the shadow prices that should be taken into account in order to assess correctly the income generated from a neem plantation. A list of factors that will affect whether a farmer is willing to establish a neem plantation is provided in Table 9 together with possible solutions to the problems encountered.

It should be noted that in addition to neem plantations providing seed, they could also be established to provide timber and fuelwood. Kalla *et al* (1975) calculated that returns from a commercial neem fuel plantation were low in comparison with *Acacia tortilis*, *Albizia lebbek* and *Prosopis juliflora*. However, Ruthyunjaya & Dayanatha (1993) argued that if the multiple uses of the neem tree were taken into account then returns could exceed those derived from *Albizia lebbek* and *Prosopis juliflora*. In addition to the multiple uses of the tree, calculations should also examine the multiple uses of a single product such as fruits. Marz (1989) reported that the value of neem fruits was increased by up to 50% when the use of neem cake as a soil amendment was taken into account.

Table 9: Factors affecting the establishment of village neem plantations.

Problem	**Explanation**	**Possible solution**
Fixed cost	The establishment of a 1 ha plantation would require an investment of Rs 3 650, equivalent to approximately US$ 128 (Hegde, 1993). It is therefore likely that access to credit is required.	Create mechanism for credit provision
Income generation	The plantation will not become productive until five years after establishment. Therefore, no income can be realised from the portion of land under neem. Intercropping may alleviate this problem, but at the same time farmers have to take into account the opportunity cost of not having that land under full crop production.	Generate income through intercropping with food crops (coriander, cowpea, peerkai) up to year five Generate income through intercropping with fast growing leguminous tree crops for fodder and mulch up to 8 - 10 years Provide credit and support in first few years
Management	Labour requirement is high in the first few years after establishment. Seedlings need to be watered, depending on site conditions up to year five. Weeding is also required, and the plants should be protected from cattle.	Manage plantations on a co-operative basis
Finding a site	May mean a reduction in common grazing land, land available for food production, etc.	Organise plantations at the village scale on a co-operative basis which are more likely to succeed Establish plantations along field boundaries, or around the home to minimise the reduction in land available for grazing or food production
Theft	Neem products may be stolen, or trees and fences vandalised	Employ village guards to protect trees (Vivekanandan, 1998)

The economics of commercial neem plantations

Considering the expanding market for neem-based products, it is likely that commercial companies may explore the possibilities of developing their own neem plantations. At least two Indian companies represented at the World Neem Conference 1999, Canada, had already started to develop plantations. One company has established a plantation of 60 000 trees in a southern part of Tamil Nadu using local seed sources, and a second aims to have a plantation covering 800 hectares (Naik *et al*, 1999). The latter company has identified trees with high azadirachtin content and hopes that the cultivation of their progeny will reduce the cost of producing neem pesticides substantially. It would seem clear that commercial ventures and companies acknowledge the variation within the species for both azadirachtin and oil, and are willing to invest in the establishment of plantations. Plantations have also been established in Australia, Columbia and Mexico.

Currently, however, an optimum management regime that provides a high economic return is likely to be a constraint to the establishment of commercial plantations. Marz (1989) calculated an internal rate of return (IRR) of 10 - 30% for a 24-year rotation cycle, when both wood and fruit were harvested. Ruthyunjaya & Dyanatha (1993) studied the economics of plantations and calculated that an IRR of 46% could be achieved if total output (fruits, fuel, wood, twigs and top feeds) were brought into the equation for a 23-year rotation cycle. They identified additional factors for consideration, which included a range of management and policy issues, and calculated that a positive cash flow from a neem plantation would only be achieved in the 5th year, i.e. the time the tree starts producing fruit (Chaturvedi, 1993). A newly established plantation in Australia provides a calculated IRR of 20%, based on a 12-year rotation.

3.4.4 Future research and development interventions

There is a clear need for increased understanding about a range of factors involved in the trade and marketing of neem seeds. A list of possible research and development interventions, together with their associated activities is given in Table 10.

Table 10: Research and development interventions for increasing the benefits the poor can gain from neem product commercialisation.

Intervention	Activity
Market development for processed products	Develop links between farmers and manufacturers
	Develop marketing initiatives and communicate information on processing techniques to village industries using neem
	Explore the utility of half-finished neem products
	Identify communities interested in village industries using neem
	Develop links between farmers and manufacturers
Development of farmer's co-operatives/ village industries	Identify communities interested in village industries based on neem
	Develop marketing initiatives and communicate information on processing techniques to village industries using neem
Improvements in farm, harvesting, processing and storage	Develop links between farmers and manufacturers
	Increase price commercial companies are prepared to pay as a premium by providing high quality seed
	Encourage farmers to store seed for sale when prices might increase at the end of the season
Improved access to technology by commercial ventures	Encourage companies with information on processing
	Provide funding for investment
Improved access to technology by village industries	Develop links between village industries and manufacturers
	Develop links between village industries and consumers
	Develop marketing initiatives and communicate information on processing techniques to village industries using neem

4 FUTURE RESEARCH AND DEVELOPMENT INTERVENTIONS INVOLVING NEEM

A prioritised assessment of research and development requirements for the improved use of neem by poor farmers was determined as a means of focusing donor and research funds for work on neem and its products for crop protection.

4.1 Method and background

The results of the postal survey (Childs *et al*, 1999) and farmer and market surveys in India and Ghana (Manu *et al*, 1999; Naik *et al*, 1999) were used to identify the limitations of the use of neem for crop protection by poor farmers in developing countries. These results were used on the assumption that they represented the views of stakeholders, including farmers, who had an interest in neem for crop protection. The limitations to the use of neem were visualised graphically using MindManager (MinJet, 1999), computer software for organising and prioritising tasks. The results were then used to prioritise research, development and commercial interventions that could solve or ameliorate the limitations identified. MindManager was then used to visualise these interventions and prioritise them on the basis of the number of times each intervention appeared at the branch end of the Mind map.

It should be noted that only the results from the postal, farmer and market surveys were used for this process. The literature review also generated a number of possible research and development interventions, and these are shown in Table 11.

4.2 Results

The following limitations of the use of neem by poor farmers in developing countries were identified:

- **Poor access to neem material and products**, i.e. poor access to neem trees, seasonality of the product (seed) and a lack of quality assured commercial products in some cases.
- **A perceived lack of effectiveness of neem pesticidal products**, i.e. farmers perceive neem products to have a slow effect, they are time-consuming to prepare, they maybe poorly prepared and stored, farmers do not have access to demonstrations of neem's efficacy and inaccurate information is sometimes disseminated leading farmers to expect that neem has a 'knock down' effect.
- **A lack of information and extension services**, i.e. information is not always communicated effectively and accurately to farmers, farmers have inadequate information on seed harvesting, processing and tree management techniques, extension agencies lack appropriately trained staff and may not have the facilities to demonstrate neem's efficacy.
- **Poor access to neem product markets**, i.e. a low price is paid for seed, the market structure may favour middlemen, or be undeveloped, and there are few village industries based on neem processing or, where they exist, they may not be competitive with more sophisticated manufacturers.

The limitations were categorised as natural resource (NR) researchable, developmental or commercial constraints. A prioritised summary of possible interventions that could ameliorate these constraints was developed and discussed at a project maturity workshop held on the 3 - 4 April 2000 in Pune India. A range of stakeholders were present at the meeting representing researchers, extension workers, international, government and non-government organisations, and neem pesticide manufacturers. The interventions suggested were critically appraised and re-prioritised during the meeting. The results are shown in Table 12a-c.

Table 11: Possible research and development interventions suggested by the literature review.

	Constraints	Possible interventions
Biological	Poor understanding of the effect of andromonoecy on seed production in neem Poor understanding of the environmental and genetic control of flowering and fruiting Unknown qualities and potential benefits of neem hybrids Potential for the invasiveness of neem poorly understood No comprehensive and range-wide molecular diversity study completed Lack of farm-scale seed harvesting, drying and storage methods	Research the role of andromonoecy in neem Research the effect of environment on seed production in neem Develop hybrids of neem and assess their qualities Research the biological and participatory monitoring and evaluation of neem's invasiveness Research the molecular diversity of neem Research farmer harvesting, drying and processing techniques to identify constraints and solutions
Silvicultural	Lack of information on optimum management regimes and silvicultural practices for a range of neem products	Research optimum silvicultural practices for seed production Silvicultural research to identify current practices and areas of weakness
Technical	Incomplete information on the commercial production of tissue-cultured material for azadirachtin production No clear information on neem product-crop-pest packages Lack of a standard methodology for estimating azadirachtin content Lack of information on the role of neem in IPM and INM programmes Lack of information on the use of neem as a fodder for livestock Lack of research on the use of neem in veterinary and human medicine	Provide funding to complete study Synthesise the large body of literature on neem's target organisms and efficacy Develop a standard methodology for estimating azadirachtin content Research the role that neem can have in IPM and INM programmes further explored Research neem's fodder qualities Research neem as a source of veterinary products Research neem as a source of medicinal products for humans

Table 11: Continued

Socio-cultural	Poor awareness amongst farmers and extension services of the benefits of neem to farming systems	Raised awareness amongst extension services and NGOs of neem role in farming systems
	Lack of accurate information disseminated to farmers	Train extension staff
	No targeting of communities for whom neem could be beneficial	Participatory farmer research to identify groups of farmers most likely to adopt and benefit from neem products
	No socio-economic studies that assess the social, economic and environmental benefits of the use on neem products on farms	Carry out socio-economic studies to assess the social, economic and environmental benefits of the use on neem products on farms
	Poor market structure for neem products.	Research the commodity chain
	Low prices are paid for seed, which limits income-generating activities based on neem	Participatory farmer research to identify communities interested in village industries based on neem
Genetic improvement	Lack of funding and support for the supportive research programmes within the International Neem Network	Research the role of reproductive biology, and genetic and environmental factors controlling seed azadirachtin content
	Lack of necessary facilities for assaying azadirachtin content in Network collaborating countries	Initiate collaboration with a suitable laboratory
		Develop means of rapidly and effectively transporting neem seed between countries
	Reliance on the micropropagation of neem as a genetic improvement activity	Initiate programmes of selection and testing prior to the mass micropropagation of neem
	Poor information exchange	Develop new structures for the dissemination of information, e.g. interactive database, neem discussion group, simultaneous, subject-specific conferences, supra-regional office offering a broad and effective means of disseminating information

Table 12a: Prioritised research themes that could have a positive impact on the livelihoods of the poor.

Priority	Research themes	Activities	Implementers	Funding source
1	New harvesting and processing techniques	Participatory research on farmer harvesting, drying and processing techniques to identify constraints and solutions Explore the utility of half-finished neem products	NGOs State extension services Research institutes	International donors Government agencies
2	The commodity chain	Participatory research to determine constraints in the commodity chain Participatory research on farmer harvesting, drying and processing techniques to identify constraints and solutions Explore the utility of half-finished neem products	Agricultural Universities NGOs (BAIF, IFFDC)	International donors Government agencies Manufacturers
3	Improved seed quality and quantity Farm-level seed storage methods Management regimes for different products	Research the factors controlling seed production in neem (both genetic and environmental) Participatory research on farmer harvesting, drying and processing techniques to identify constraints and solutions Develop seed storage methods appropriate to resource-poor farmers Participatory silvicultural research to identify current practices and areas of weakness Develop appropriate management regimes for a variety of products for poor farmers Establish suitable propagation methods (seedlings vs direct sowing), vegetative propagation	NGOs State extension services Research institutes Universities	International donors Government agencies
4	Inclusion of neem in IPM and INM programmes Access to superior germplasm for a range of products.	Further explore the role that neem can have in IPM and INM programmes Participatory research on farmer harvesting, drying and processing techniques to identify constraints and solutions. Explore the utility of half-finished neem products Analyse azadirachtin content of seeds from trials in the International Neem Network (INN) Disseminate germplasm and information from the INN	NGOs State extension services Research institutes Universities International Neem Network	International donors Government agencies

Table 12b: Prioritised development themes that could have a positive impact on the livelihoods of the poor.

Priority	Themes	Activities	Implementers	Funding source
1	Government support established	Discuss local and international expertise at institutional level Demonstrate benefits of neem to target persons	International organisations (GTZ, FAO, ICIPE) Agricultural universities	Host government (support in kind??) International donors
2	Communities identified where neem could have greatest impact	Develop regional/area focus groups Participatory farmer research to identify groups of farmers most likely to adopt and benefit from neem products Target interventions at cash crops	Local institutes Commercial companies National or International co-ordinator	Low cost activity: Funding sources include host government.
3	Improvements in the quality of information communicated to farmers	Improve means of information exchange Train NGOs Make available information on harvesting and processing	NGOs such as BAIF and GOAN Commercial companies International organisations (GTZ)	Commercial companies UNEP/ UNDP International Donors such as GTZ

Table 12c: Prioritised interventions for the commercial sector that could have a positive impact on the livelihoods of the poor.

Priority	Intervention	Activities	Implementation	Funding source
1	Development of farmer's co-operatives/village industries	Develop links between collectors and manufacturers Participatory research to identify communities interested in village industries using neem Increase price commercial companies are prepared to pay as a premium by providing high quality seed	NGOs Manufacturers	Manufacturers Self-financing Government donors International donors
	Improvements in farm harvesting, processing and storage	Develop marketing initiatives and communicate information on processing techniques to village industries using neem Farmers store seed for sale at end of season when prices may increase		
2	Market development for processed products	Develop links between farmers and manufactures Develop marketing initiatives and communicate information on processing techniques to village industries using neem Explore utilisation of half-finished neem products Participatory farmer research to identify communities interested in village industries using neem	Manufacturers NGOs	Government organisations Manufacturers International donors
3	Improved labelling and description of products	Label products in local languages Clearly describe product use and shelf life Clearly describe pests that can be targeted and effects expected Raise product awareness through workshops	Manufacturers Government organisations NGOs	Manufacturers Government organisations International Donors

4.3 Forthcoming projects

A number of new research and development activities have been funded, or are under consideration for funding by government agencies and international donors which will contribute to some of the activities prioritised above:

- UK Department for Environment, Transport and the Regions' Darwin Initiative - Framework for the monitoring of invasive tree species in Ghana. Purpose: To develop a practical methodology for monitoring and evaluating the changes in biodiversity wrought by invasive tree species (to include neem) as perceived by different sectors of the rural community.

- Government of Finland and ICIPE, Kenya - Phase two of research and development work on neem and its use in agriculture, the environment, and human and animal health.

- Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ, Germany) - Information dissemination through GATE. Research on the commercialisation of neem products in West Africa funded by the EC.

- FAO's International Neem Network. Purpose: To improve the genetic quality and adaptability of neem, and to increase its utilisation throughout the world, as a contribution to development, with a particular focus on meeting the needs of rural people.

- Kenya Forest Research Institute. Research on the production and storage of seed, management of neem for different products, use of neem as a timber and for wood carving.

- Research organisations within the Indian Council for Forestry Research and Education - Various activities on the biology, silviculture and improvement of neem.

Research and development work with neem continues to be a priority for donors, developing countries and the commercial sector. The human and animal health sectors are likely to become the focus of considerable research and product development where work is needed and there is considerable commercial potential. The Potential of neem in crop protection has not yet been realised, and the poor can benefit through the validation and improvement of current practices, income-generating activities and as the recent rejection of a patent on the fungicidal effects of neem has demonstrated, perhaps their traditional knowledge can be protected.

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