Neem: A Tree for Solving Global Problems (1992)

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What's in a Neem

Neem protects itself from the multitude of pests with a multitude of pesticidal ingredients. Its main chemical broadside is a mixture of 3 or 4 related compounds, and it backs these up with 20 or so others that are minor but nonetheless active in one way or another. In the main, these compounds belong to a general class of natural products called "triterpenes"; more specifically, "limonoids."

LIMONOIDS

So far, at least nine neem limonoids have demonstrated an ability to block insect growth, affecting a range of species that includes some of the most deadly pests of agriculture and human health. New limonoids are still being discovered in neem, but azadirachtin, salannin, meliantriol, and nimbin are the best known and, for now at least, seem to be the most significant.

Azadirachtin

One of the first active ingredients isolated from neem, azadirachtin has proved to be the tree's main agent for battling insects. It appears to cause some 90 percent of the effect on most pests. It does not kill insects—at least not immediately. Instead it both repels and disrupts their growth and reproduction. Research over the past 20 years has shown that it is one of the most potent growth regulators and feeding deterrents ever assayed. It will repel or reduce the feeding of many species of pest insects as well as some nematodes. In fact, it is so potent that a mere trace of its presence prevents some insects from even touching plants.

Azadirachtin is structurally similar to insect hormones called "ecdysones," which control the process of metamorphosis as the insects pass from larva to pupa to adult. It affects the corpus cardiacum, an

NONTARGET SPECIES

As has been mentioned, neem extracts proved to be "soft" on unintended targets. Further examples follow.

Earthworms

In greenhouse studies, when neem leaves and seed kernels were incorporated into potting soil containing earthworms *(Eiseniafoetida),* the number of young worms produced increased 25 percent.[20] In field trials there were no differences in the number of worms, but the average weight of each worm was highest in neem-treated plots. Thus, it seems possible that neem products can favor earthworms, at least under certain conditions.

Beneficial Insects

Neem seems remarkably benign to spiders, butterflies, and insects such as bees that pollinate crops and trees, ladybugs that consume aphids, and wasps that act as parasites on various crop pests.[21] In the main, this is because neem products must be ingested to be effective. Thus, insects that feed on plant tissues succumb, while those that feed on nectar or other insects rarely contact significant concentrations of neem products.

All this is coming clearer from recent research. For example, only after repeated spraying of highly concentrated neem products onto plants in flower were worker bees at all affected. Under these extreme conditions, the workers carried contaminated pollen or nectar to the hives and fed it to the brood. Small hives then showed insect-growth-regulating effects; however, medium-sized and large bee populations were unaffected. [22]

Under laboratory conditions the larvae of ladybugs and lacewings have shown some insect-growth-regulating effects from neem picked up from the bodies of other insects. However, in greenhouse trials in Florida, neem products proved essentially nontoxic to predators and parasitoids of the cotton aphid and the sweet potato whitefly. Neither the amount of predation nor of parasitism was notably reduced. [23]

A census of natural aphid enemies collected from seven different field trials indicated that neem has no detrimental effects on either predators (coccinellids, chrysopids, syrphids) or parasitoids (ichneumonids, braconids). The aphids in the neem-treated plots were actually carrying more parasites than were those in either the control plots or the plots treated with the insecticide pyrethrum.[24]

PLANT VIRUSES

Plant viruses pose some of the most severe threats to world agriculture. Because they invade the crop's cells and cloak themselves with the plant's normal life processes, they are far more difficult to control than free-living organisms such as bacteria, protozoa, or fungi. At present, we can only try to halt their spread—something nearly impossible to achieve under even the best of circumstances—because viruses "hitch rides" in insects such as aphids, as well as on dirty tools, blowing dust, or spreading floodwaters.

A few virus-inhibiting chemicals are known for treating human and animal diseases (AZT for AIDS, for instance), but at present, none are available for treating plants. Neem might be the first. Crude extracts seem to bind certain plant viruses effectively, and so limit infection.[13]

However, for the moment at least, neem seems most effective at interfering with the transmission of plant viruses carried by insects. This conclusion is drawn from several successful tests of neem's effects against insect vectors of plant viruses.

These tests include the following:

- A trial in the Philippines where rice fields sprayed with neem oil had significantly lower incidence of the ragged-stunt virus, which affects rice and is transmitted by the brown planthopper;[14]
- A second trial in the Philippines where mixtures of neem oil and custard-apple oil interfered with the transmission of tungro virus, another rice pest;[15]
- Experiments in India where neem-leaf extracts reduced the transmission of tobacco mosaic, a virus that seriously affects several vegetable crops;[16]
- Field trials in the Philippines where fields treated with urea and neem cake were found to be lower in viral diseases than those treated with urea alone;[17] and
- Enzyme-linked immunosorbent assays showing that rice seedlings grown in soil treated with neem cake were significantly freer of rice tungro viruses (transmitted by green rice leafhopper) than those in untreated control plots.[18]

On the other hand, not all trials have been this successful. In the United States, daily applications of neem leaf extracts over a month's time to turnip plants infected with cauliflower mosaic virus did *not* reduce viral infection.[19]

FUNGI

Neem has demonstrated antifungal activity. Should this prove widely applicable, the availability of a natural fungicide that can be grown, extracted, and applied by farmers themselves could be of great consequence to worldwide agriculture and food supply. Fungi attack crops in countless numbers and forms. They are constantly evolving enemies of farms and forests. Many can reach epidemic proportions, a few have no cures, and some can make certain crops impossible to grow. And, despite the best of modern science, they still threaten wheat, corn, rice, and other plants that feed the world.

Not a lot is known about neem's practical use against rots, smuts, wilts, mildews, die-backs, and other fungal plant diseases. However, several tests have indicated considerable promise.

In one test, neem oil protected the seeds of chickpeas against the serious fungal diseases *Rhizoctonia solani, Sclerotium rolfsii,* and *Sclerotinia sclerotiorum.* It also slowed the growth of *Fusarium oxysporum* but did not kill it. In addition, neem cake incorporated into the soil completely blocked the development of the resting forms of *R. solani*—thereby interfering with the long-term survival of this devastating fungus.[8]

In another, neem-seed extracts showed beneficial effects against leaf fungi. Spraying crude neem oil on lilac bushes, when done before any sign of outbreak, prevented powdery mildew from breaking out for the rest of the season. This protectant also gave essentially 100 percent control on hydrangeas in greenhouses—better than Benlate ® (benomyl), the standard mildew treatment in much of the world.[9]

In the case of bean rust, neem extracts have given 90 percent control when applied before the plants were exposed to the fungus. However, they worked poorly once rust was established.[10]

In addition to affecting root-knot nematodes, treating soil with neem can reduce the populations of pest fungi in the rhizosphere that attack and feed off plant roots.[11]

Aflatoxin

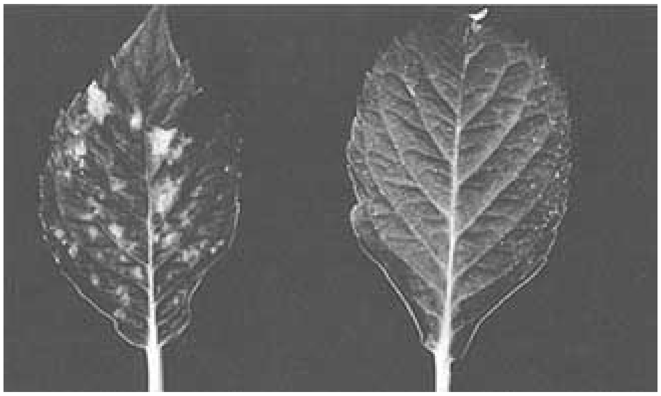
A truly unusual and potentially notable connection between neem and fungi has recently been reported from Louisiana.[12] In trials there, neem-leaf extract failed to kill the fungus *Aspergillus flavus,* but, against all expectations, it completely stopped it from producing aflatoxin (see side

Neem Oil Fungicides

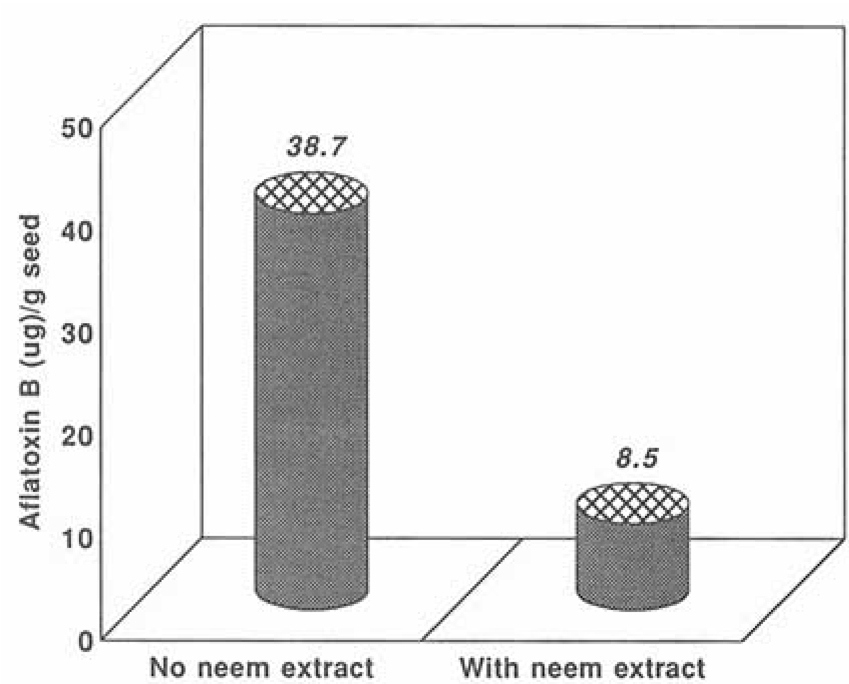
So far, almost all studies on neem pesticides have employed limonoids extracted from the seed kernel. Neem oil has seldom been considered because its chemical makeup is not very different from that of common seed oils such as soybean or olive oil. However, U.S. Department of Agriculture researchers have recently found that, surprisingly, neem oil has its own valuable pesticidal properties. In particular, it is very successful against fungi that cause certain plant diseases. In both laboratory and field trials, neem oil has controlled the diseases known as rust and powdery mildew—and it did so without harming the plants.

In the first of these trials, James Locke, a plant pathologist, emulsified neem oil in water, sprayed it over various types of ornamental plants in pots, and then subjected the plants to rust or powdery mildew. "We had success with emulsions containing as little as 0.25 percent oil," Locke says. "The oil was both insecticidal and fungicidal. We don't really know why, since it contains no azadirachtin, but it does work."

In greenhouse trials, plant pathologist J. Rennie Stavely found that neem oil is nearly 100 percent effective against rust on beans. Although its effectiveness was slightly less dramatic on bean plants in the field, neem oil still reduced this serious fungal disease enough to be cost-effective.



Hydrangea leaves exposed to powdery mildew. One (left) became badly infected with the fungus. The other, protected by a dilute solution of needseed oil in water, grew to full size and was almost unaffected. (J. Locke, Agricultural Research Service, USDA)



Neem-leaf extracts affect the fungus *Aspergillus flavus* in an unusual way. The fungus appears to grow normally, but it produces far less aflatoxin. This is important because aflatoxin is a powerful carcinogen that is of increasing concern in the world's food supplies. The levels shown here were measured in samples of the fungus grown on developing cottonseed. (D. Bhatnagar)

Greenhouse studies have since confirmed these laboratory findings. The extracts appear to halt the formation of substances called polyketides, which the fungi convert into aflatoxin. The enzymes for the conversion remain in place, but key chemicals they need to synthesize the feared toxin are no longer available.

It proved easy to take advantage of this in practice: neem leaves were mashed in water, the liquid separated, and it was applied without further refinement. This crude liquid extract turned off aflatoxin production in both laboratory cultures and cotton bolls on living plants.

These findings could be of immense significance. Aflatoxin causes liver cancer, and under hot and humid conditions, where fungi thrive, it can form on peanuts, corn, cottonseed, and other widely eaten food crops. It is of great concern these days; it not only threatens health, it also promises economic catastrophe. For example, the United States may soon be banned from exporting cottonseed to feed Europe's cattle. The U.S. aflatoxin limit is 20 parts per billion (ppb), but Europe's goal for the future is a mere 2 ppb in feed and only 0.5 ppb in milk. Also, aflatoxin-contaminated local foods and feeds are causing increased concern in Asia and Africa.

The Cancer-Causing Fungus

While growing up in Rajasthan, India, Deepak Bhatnagar was impressed with neem's qualities. He often saw his parents using the leaves to keep insects out of the wheat they stored in their home. He also saw how well these leaves worked against skin infections when they cured a persistent ulcer on his leg—one that had baffled the best of medical practitioners.

Today, Bhatnagar works at the U.S. Department of Agriculture and has taken up the study of neem's effects on certain fungi. In tests in his laboratory in New Orleans, he ground up (or boiled) neem leaves in water (or in potassium phosphate-buffered solution to remove any possible pH effect) and applied the resulting solutions to *Aspergillus flavus.* This fungus, one of the most deadly on earth, grows on various foods and produces chemicals called aflatoxins that are highly carcinogenic. When Bhatnagar looked at the fungal cultures four days later, they seemed normal. But when he tested them chemically, he could find only 2 percent of the aflatoxin that the fungus normally would have produced. Neem had left the microbe alive, but had switched off its ability to produce aflatoxins.

Bhatnagar then moved on to greenhouse studies. He injected neem solutions into cotton bolls, and later infected the bolls with the fungus. Again, aflatoxin production was inhibited (see diagram opposite).

Experiments are now under way to determine which components in the neem leaves are responsible for the bioactivity. Once they are identified, cost-effective and efficient delivery systems can probably be developed to control aflatoxin synthesis by the fungus on various crops.

Bhatnagar says that the results are ''promising but preliminary." But if his work proves that neem is safe and effective for aflatoxin control, it may open the door to a simple, inexpensive method for protecting stored foods using locally produced materials, even in the remotest rural villages.

This is especially significant these days. With the availability of ever more sensitive chemical analyses, health officials are becoming alarmed at aflatoxin's widespread occurrence and potential hazard. Anything that might protect food supplies in tropical regions that can ill afford synthetic fungicides and have difficulty keeping foods fungus-free could be of immense significance.

5
Effects on Insects

The growing accumulation of experience demonstrates that neem products work by intervening at several stages of an insect's life. The ingredients from this tree approximate the shape and structure of hormones vital to the lives of insects (not to mention some other invertebrates and even some microbes). The bodies of these insects absorb the neem compounds as if they were the real hormones, but this only blocks their endocrine systems. The resulting deep-seated behavioral and physiological aberrations leave the insects so confused in brain and body that they cannot reproduce and their populations plummet.

Increasingly, approaches of this kind are seen as desirable methods of pest control: pests don't have to be killed instantly if their populations can be incapacitated in ways that are harmless to people and the planet as a whole. In the 1990s this is particularly important: many synthetic pesticides are being withdrawn, few replacements are being registered, and rising numbers of insects are developing resistance to the shrinking number of remaining chemical controls.

The precise effects of the various neem-tree extracts on a given insect species are often difficult to pinpoint. Neem's complexity of ingredients and its mixed modes of action vastly complicate clarification. Moreover, the studies to date are hard to compare because they have used differing test insects, dosages, and formulations. Further, the materials used in various tests have often been handled and stored differently, taken from differing parts of the tree, or produced under different environmental conditions.

But, for all the uncertainty over details, various neem extracts are known to act on various insects in the following ways:

- Disrupting or inhibiting the development of eggs, larvae, or pupae;
- Blocking the molting of larvae or nymphs;
- Disrupting mating and sexual communication;
- Repelling larvae and adults;
- Deterring females from laying eggs;

Insects Affected by Neem Products

Neem is known to affect more than 200 species of insects. Here we present brief information on a sampling of them to show the range of effects and the range of species affected.

Insect	**Effects**
Mediterranean fruit fly	Disrupts growth, toxic
Oriental fruit fly	Arrests pupae development, retards growth, toxic to larvae
Face fly	Retards growth, toxic
Horn fly	Repels, retards growth, disrupts growth
Whitefly	Repels, retards growth, inhibits feeding
Housefly	Inhibits feeding, disrupts molting, repels
Sorghum shoot fly	Inhibits feeding
Yellow-fever mosquito	Kills larvae, disrupts molting
House mosquito	Toxic to larvae
Flea	Retards growth, repels, inhibits feeding, disrupts growth, eggs fail to hatch
Head lice	Kills, very sensitive to neem oil—traditional use in Asia
Spotted cucumber beetle	Retards growth, inhibits feeding
Mexican bean beetle	Retards growth, inhibits feeding, disrupts molting
Colorado potato beetle	Eggs fail to hatch, larvae fail to molt with azadirachtin levels as low as .3 ppm, inhibits feeding
Flea beetle	Khapra beetle
Inhibits feeding	Inhibits feeding, disrupts molting, toxic to larvae
Confused flour beetle	
Japanese beetle	

Red flour beetle	Inhibits feeding, toxic
American cockroach	Reduces fecundity and molts, reduces number of fertile eggs
Bean aphid	Reduces fecundity, disrupts molting
Rice gall midge	Toxic
Insect	**Effects**
Western thrips	Retards growth
Diamondback moth	Strongly suppresses larvae and pupae, retards growth, inhibits feeding
Webbing clothes moth	Inhibits feeding, disrupts molting
Gypsy moth	Retards growth, inhibits feeding, disrupts growth
Corn earworm	Retards growth, inhibits feeding, disrupts molting
Pink bollworm	Retards growth, inhibits feeding
Fall armyworm	Retards growth, repels adults, inhibits feeding, disrupts molting, toxic to larvae
Tobacco budworm	Inhibits feeding
Tobacco hornworm	Inhibits feeding, disrupts growth, toxic
Cabbage looper	Inhibits feeding
Leafminer	Retards growth, inhibits feeding, disrupts molting, toxic
Serpentine leafminer	High pupal mortality, retards growth, inhibits feeding, disrupts molting, toxic to larvae
Brown planthopper	Inhibits feeding, repellent, disrupts growth, mating failures and sterility
Green leafhopper	Inhibits feeding
Migratory locust	Stops feeding, converts gregarious nymphs into solitary forms, reduces fitness, adults cannot fly
House cricket	Disrupts molting
Large milkweed bug	Toxic, disrupts growth
Mealy bugs	Repels, inhibits feeding
Milkweed bug	Difficulty in escaping the "skin" of the last molt, disrupts molting
Fire ant	Inhibits feeding, disrupts growth
Boll weevil	Inhibits feeding
Cowpea weevil	Inhibits feeding, toxic
Rice weevil	Inhibits feeding, disrupts growth, toxic

Coleoptera

The larvae of all kinds of beetles—especially those of phytophagous coccinellids (Mexican bean beetle and cucumber beetle, for example) and chrysomelids (Colorado potato beetle and others)—are also sensitive to neem products. They refuse to feed on neem-treated plants, they grow slowly, and some (such as the soft-skinned larvae of the Colorado potato beetle) are killed on contact

Lepidoptera

From numerous field trials (notably on various moths), it appears that larvae of most lepidopterous pests are highly sensitive to neem. Indeed, it seems likely that armyworms, fruit borers, corn borers, and related pests will become the main targets of neem products in the near future. Neem blocks them from feeding, although this effect is usually less important than the disruption of growth it causes.

Diptera

Many species of dipterous insects—fruit fly, face fly, botfly, horn fly, and housefly, for example—are targets for neem products. Mosquitoes, too, are a possibility.

Hymenoptera

The freely feeding and caterpillar-like larvae of sawflies are target insects as well. In this group, neem's antifeedant and growth regulatory effects are both important.

Heteroptera

The "true" bugs—including many pests such as the rice bug, the green vegetable bug, and the East African coffee bug that suck juices from crops and trees—are affected by neem products. Neem's systemic qualities affect their feeding behavior and disrupt their growth and development.

EXAMPLES

As discussed, neem's effects vary with different insects. Some effects on a small selection of major pests are summarized below.

Desert Locust

Recent laboratory research has shown that neem oil causes "solitarization" of gregarious locust nymphs.[2] After exposure to doses equal to a mere 2.5 liters per hectare, the juveniles fail to form the massive, moving, marauding plagues that are so destructive of crops and trees. Although alive, they became solitary, lethargic, almost motionless, and thus extremely susceptible to predators such as birds. Neem affects grasshopper nymphs similarly.

This discovery differs from earlier ones on locusts. Those first approaches used alcoholic extracts and were aimed at disrupting metamorphosis or at stopping adult locusts from feeding on crops. The new approach uses neem oil enriched with azadirachtin to prevent locusts from developing into their migratory swarms. It apparently blocks the formation of the hormones and the pheromones needed to maintain the yellow-and-black gregarious form, which plagues arid Africa and the Middle East. In an interesting aside, it has been shown that neem oil destroys their antennae, even when applied to the abdomen.

Neem trees grow well throughout the locust zones of Africa and the Middle East, and thus, in principle at least, the means to control the plagues could be locally produced.

Cockroach

Neem kills young cockroaches and inhibits the adults from laying eggs. Baits impregnated with a commercial preparation of neem-seed extract proved to retard the growth of oriental, brown-banded, and German cockroaches.[3] First-instar nymphs of all three species failed to develop, and all died within 10 weeks. Last-instar nymphs exhibited retarded growth, and half of them died within 9 weeks. After 24 weeks, only 2 out of the 10 surviving German-cockroach nymphs had reached adulthood.

In a "taste test," American cockroach adults preferred neem-treated pellets over untreated ones, but neem-treated milk cartons repelled them.[4]

Brown Planthopper

Neem cake (the residue left after oil has been removed from the kernel) has proved so successful that Philippine farmers are already

For instance, it inhibits the fall armyworm, one of the most devastating pests of food crops in the western hemisphere. It has, however, been found necessary to treat the crop before the insects arrive. If this is done, they "march right on past the fields," but once they have taken up residence, it is harder to get them to move on.

Colorado Potato Beetle

In advanced trials in the United States, neem extracts have controlled the Colorado potato beetle.[9] This is a significant pest in North America and Europe that is becoming increasingly resistant to broad-spectrum insecticides.

In experiments in Virginia, for example, neem-seed extracts (at relatively low concentrations of 0.4 percent, 0.8 percent, and 1.2 percent) were tested in potato fields both with and without the synergist piperonyl butoxide (PBO). All treatments significantly lowered the potato beetle populations and raised potato yields; however, the extracts containing PBO were the most effective. The sprayings were most effective when the larvae were young, and were best when conducted as soon as the eggs hatched.[10]

Leafminers

When birch trees were sprayed to control the birch leafminer *(Fenusa pusilla),* neem extract seemed to perform as well as the registered commercial pesticide Diazinon®. It was, however, slower acting, and the insects continued to damage trees before they died. This leafminer is a serious pest in parts of North America, often browning the crowns of entire forests.

The U.S. Environmental Protection Agency has approved a neemseed-extract formulation for use on leafminers. This commercial product, now available almost nationwide, is expected to be especially useful against those leafminers that attack horticultural crops. Added to the soil, neem compounds enter the roots and move up into the crop's leaves so that leafminers munching on the leaves get their molting-hormone jammed, and they end up fatally trapped inside their own juvenile skins.

European Corn Borer

The European corn borer, a highly adaptable pest of corn and other crops, was introduced to North America in 1917 and subsequently

slashed Canada's corn yields in half. Today, it infests 40 million acres of corn in the United States each year, and in just an average year American farmers spend an estimated $400 million on chemicals to fight it.

Laboratory tests using neem products on this corn borer larvae produced 100 percent mortality at 10 ppm azadirachtin; 90 percent mortality at I ppm. Lower concentrations (0.1 ppm azadirachtin) left the larvae apparently unaffected, but the adults that later emerged had grossly altered sex ratios (there were many more males than females) and the few remaining females laid fewer eggs and laid them too late. This combination of effects suggests that azadirachtin could be effective for controlling this terrible pest.[11]

Mosquitoes

The larvae of a number of mosquito species (including *Aedes* and *Anopheles)* are sensitive to neem. They stop feeding and die within 24 hours after treatment. If neem derivatives are used alone, relatively high concentrations are required to obtain high mortality.[12] Nonetheless, the use of simple and cheap neem products seems promising for treating pools and ponds in the towns and villages of developing countries. In one test, crushed neem seeds thrown into pools proved nearly as effective at preventing mosquito breeding as methoprene, a rather expensive pesticide that is usually imported in developing countries.

Aphids

In the Dominican Republic, water extracts of neem seed proved effective against *Aphis gossypii* on cucumber and okra and against *Lipaphis erysimi* on cabbage.[13] This was in direct-contact sprays.

As noted earlier, neem extracts applied in a systemic manner (that is, within plants) usually have little effect on aphids. Apparently, this is because aphids feed only on the phloem tissues, where, for some unknown reason, neem materials accumulate least.

Fruit Flies

Fruit flies (including the notorious medfly) are among the most serious horticultural pests. They cause millions of dollars in damage to fruits, and their very presence in the tropics is keeping dozens of delicious fruits from becoming major items of international trade. But, at least in experiments, the medfly is proving susceptible to neem. This insect pupates underground, and in trials in Hawaii, spraying dilute neem solution under fruit trees resulted in 100 percent control.[14]

More important, the neem materials were compatible with the biological-control organisms (braconid wasps) used to control fruit flies. When neem was applied to soil at levels that completely inhibited the pest from emerging from pupation, the parasites developing in these pupae emerged and exhibited normal life spans and reproductive rates. Thus, neem is compatible with biological control of fruit flies. Diazinon ®, the current soil treatment for fruit flies, kills not only fruit flies but their internal parasites as well.[15]

Gypsy Moth

The U.S. Environmental Protection Agency has approved a neemseed-extract formulation for use on gypsy moth, a pest that is ravaging forests in parts of North America. In laboratory trials, a commercial neem formulation (Margosan-O®) produced 100 percent kill at very low concentrations (0.2 liters per hectare). After 25 days, the larvae were shrivelled, had stopped eating, and were dying. Field tests are in progress.

Horn Flies

Ground-up neem seed and stabilized neem extracts can prevent horn flies from breeding in cattle manure. In recent U.S. Department of Agriculture trials in Kerrville, Texas, cattle were fed a diet containing these neem materials in the feed. The animals readily consumed feed containing 0.1-1 percent ground neem seed. The neem compounds passed through the digestive tract and into the manure where they kept the fly larvae from developing.[16]

Blowflies

In Australia neem products have been tested against blowflies on sheep. The larvae of these pests penetrate and burrow under the skin of sheep. They are a major economic burden to Australia's farmers because many of the sheep die. In the tests, azadirachtin kept blowflies from "striking" (that is, laying their eggs on sheep).[17]

As a result of the excitement this discovery engendered, 1,000 hectares of neem have been planted in Queensland at a cost of more than $4 million. At least one Australian company has been established to produce and distribute neem products to sheep farmers.

Cardamom growers in South India are already using neem cake to control nematodes. Of 19 growers interviewed recently, 17 said that nothing works as well. These were sophisticated farmers who monitor world cardamom prices regularly and use synthetic chemicals for controlling other pests in their fields. In other words, they weren't using neem out of ignorance or poverty. They incorporate 100-259 kg per hectare of neem cake in their cardamom fields every year. About 3,000 tons of neem cake are now used annually in India's Cardamom Hills. It is sold by pesticide dealers, who transport it from 250-300 km away. [3]

SNAILS

Various neem extracts kill snails. This appears to be beneficial in some cases.

In laboratory tests, for example, ethanol extracts proved toxic to the aquatic snail *(Biomphalaria glabrata),* a species that is necessary to the life cycle of the parasite causing schistosomiasis (bilharzia). The extracts killed both the adult snail and its eggs.[4] This raises the possibility that neem products may find a role in controlling schistosomiasis, a horrible scourge that infects some 200 million people in the tropics.

In another test, an aqueous solution of neem fruit resulted in a 100-percent kill of *Melania scabra.*[5] This snail, common throughout the Orient, is a vector of lung flukes, a parasitic flatworm that encysts in the lungs of livestock, wildlife, and people, causing debilitation and sometimes death.

CRUSTACEANS

Little is known about neem's effects—beneficial or detrimental—on crustaceans. However, in one intriguing set of experiments in the Philippines, it proved beneficial.

In rice paddies, the ostracod *Heterocypris luzonensis* feeds on the blue-green algae that fix nitrogen from the air. This minute aquatic crustacean thereby reduces a source of fertilizer for the crop. Killing this tiny creature thus would indirectly boost the nitrogen available and probably increase rice yields.[6] Aqueous neem-kernel extracts have killed it very effectively under laboratory conditions.[7]

6
Effects on Other Organisms

Although neem's effects on pestiferous insects are by far the best known, the tree's various products can influence other pest organisms as well. In the long run, these may well prove the most important of all. At present, however, the effects on noninsect pests are poorly understood. This chapter highlights some of the findings to date.

NEMATODES

Neem products affect various types of nematodes. This may be significant because certain of these thread worms are among the most devastating agricultural pests and are also among the most difficult to control. In addition, an increasing number of synthetic nematocides have had to be withdrawn from the market for toxicological reasons.

Today, there is a small but increasing body of evidence that neem might provide useful replacements. Certain limonoid fractions extracted from neem kernels are proving active against root-knot nematodes, the type most devastating to plants. They inhibit the larvae from emerging and the eggs from hatching, and in at least one test they have done so at concentrations in the parts-per-million range.[1] Water extracts of neem cake (the residue remaining after the oil has been pressed out of the seeds) are also nematocidal.

In a careful trial in Aligarh, India, amending soil with sawdust and neem cake dropped the root-knot index to zero and, of all the treatments tested, gave the greatest growth of tomatoes, a crop that is very sensitive to these nematodes.

In tests in a greenhouse and in the field in Germany, tomato plants were obviously improved by neem products, but there was no significant difference in the numbers of some nematode species in the soil. However, among treated and untreated soils the majority was extracted from the roots of plants in untreated soil.[2]

using it on a trial basis against the brown planthopper (and other rice pests).[5] Neem oil is being employed as well. Five applications of a 25 percent neem-oil emulsion sprayed with an ultra-low-volume applicator is said to protect rice crops against this increasingly severe scourge. It has been estimated that one neem tree provides enough ingredients to protect a hectare of rice. This use alone exemplifies the economic importance of further developing the neem tree for pest control.[6]

Stored-Product Insects

Neem shows considerable potential for controlling pests of stored products. This is one of the oldest uses in Asia, and the literature contains many references to its benefits. In the traditional practice, neem leaves are mixed with grain kept in storage for 3-6 months. The ingredients responsible for keeping out the stored-grain pests are not yet identified—but they work well.

In this connection, repellency seems of primary importance. For instance, treating jute sacks with neem oil or neem extracts prevents pests—in particular, weevils *(Sitophilus* species) and flour beetles *(Tribolium* species)—from penetrating for several months. For this use, the degradation problem caused by sunlight is less of a concern because the products are mostly away from the sunlight, inside jars or other containers.

Neem oil is an extremely effective and cheap protection for stored beans, cowpeas, and other legumes. It keeps them free of bruchidbeetle infestations for at least 6 months, regardless of whether the beans were infested before treatment or not.[7] This process may be unsuited for use in large-scale food stores, but it is potentially valuable for household use and for protecting seeds being held for planting. The treatment in no way inhibits the capacity of the seeds to germinate.

Neem has also been used in India to protect stored roots as well as tubers against the potato moth. Small amounts of neem powder are said to extend the storage life of potatoes 3 months.

Armyworm

Azadirachtin has proved an effective prophylactic against armyworms at extremely low concentrations—a mere 10 mg per hectare.[8]