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Methods of Nematode Management

by Edward Berkelaar, Ph.D.
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Introduction

Plant-parasitic nematodes are a problem for farmers throughout the tropics and subtropics. Most species of nematodes are not actually plant or animal parasites, but the ones that are parasitic make up a small but important minority.

Nematodes form a very large group of invertebrate animals in the Phylum Nemata. They are also referred to as roundworms, threadworms, eelworms, or nemas. There are over 12,000 named species and perhaps hundreds of thousands yet unnamed. Nematodes are typically worm-shaped, although some are more lemon or pear-shaped. They are usually 0.4 to 5 mm (1/16th to 1/5th inch) long. Nematodes are aquatic organisms, and are widely distributed in seawater, freshwater, and soil water. Many are free living in soil and feed on bacteria or fungi; they are important recyclers of organic matter. However, some very important nematodes are parasites of animals or plants. These include around 30 human parasites, including hookworms, *Ascaris* (an intestinal roundworm), pinworms, trichina worms, and filaria worms.

Other nematodes are parasites of plants. Some of the plant-parasitic nematodes feed on stems, buds or leaves, but most of them feed on roots. Of the root parasites, some feed on the exterior of the root and are called ectoparasites (or external parasites) while others burrow into and feed on the interior of the root

(called endoparasites or internal parasites). Probably the most important genus of plant-parasitic nematodes worldwide is the root-knot nematode (*Meloidogyne* spp.). While there are over 100 named species, four of the most widely dispersed species are *M. incognita*, *M. javanica*, *M. arenaria*, and *M. hapla*. These four species are particularly serious pests because they have wide host ranges; other species, such as the coffee root-knot nematode, are quite specific in the plant they can use as a host. Here at ECHO there are several genera of plant-parasitic nematodes, but root-knot nematodes cause the most damage by far.

Root-knot nematodes have a complex life cycle. Eggs in the soil hatch into juvenile nematodes that are worm shaped and can migrate a short distance (a few centimeters) in infested soil and water toward roots. The juvenile nematodes burrow into roots and as they mature into adults they change from a long, slender wormlike shape into a short pear shape. The nematode produces chemicals with plant hormone activity, and these chemicals alter root growth. Two large root cells called feeder cells grow near the head of the nematode. Unlike many other plant-parasitic nematodes, root-knot nematodes reproduce asexually so that normally only females develop. The female remains in one location for its entire life, where it feeds and lays eggs. The eggs are released into the soil, where they hatch and then either infect the same root or remain for a time until another crop is planted. Roots infected with root-knot nematodes have characteristic bumps called galls that are easily visible to the eye (see Figure 1). They range in size

from a pinhead on a fine root to more than 1 cm in width (e.g. after several generations of nematodes have colonized the same area of a root). Galls can be distinguished from the nitrogen-fixing nodules of legumes, because nodules appear 'loosely' attached to roots and are easily rubbed off whereas galls are incorporated right into structure of the root.



Figure 1: An example of a severe infestation of root-knot nematodes. Galls due to nematodes can also be as small as a pinhead. Photo credit: Martin Price

The length of time between when an egg hatches and when a mature female lays eggs is around four weeks, but depends on the soil temperature. Root-knot nematode eggs can survive in soil for months. Dr. Billy Crow, a nematologist at the University of Florida in Gainesville, says that temperature is an important factor in egg survival. “In northern climates eggs can overwinter for longer periods of time than in tropical areas. In tropical areas six months of clean fallow or non-host cover crop with **no weeds** should be sufficient to reduce root-knot nematodes below damaging levels in most cases.”

Nematodes damage plants in a number of ways. First of all, by feeding on plant material they cause physical damage to the root tissue and take resources (photosynthates) away from the plant. Secondly, plants with damaged roots are less able to absorb water and nutrients efficiently, so they are more susceptible to drought, heat stress and nutrient deficiencies. Finally, the damaged roots are more easily infected by bacteria and/or viruses. Some types of nematodes can transfer viruses between plants.

Levels of Damage Caused by Nematodes

The amount of damage nematodes cause to a crop varies quite a bit. It depends on the type of crop, the type and number of parasitic nematodes present in the soil at the time of planting, and environmental conditions. When nematodes are present in soil, individual plants may experience no yield loss, or they may become so infected that they die. Severe infestations of fields often can result in losses of 10 to 50%.

Table 1 presents estimated losses of several crops due to plant-parasitic nematodes.

Table 1: Estimates of production and yield losses of several crops due to nematodes.

| Crop | FAO Production Estimate (x1000 metric tonnes) | Estimated yield loss due to nematodes (%) |
|--------------|---|---|
| Banana | 2 097 | 19.7 |
| Barley | 171 635 | 6.3 |
| Cassava | 129 020 | 8.4 |
| Corn | 449 255 | 10.2 |
| Potato | 312 209 | 12.2 |
| Rice | 469 959 | 10.0 |
| Sugar beet | 293 478 | 10.9 |
| Sugar cane | 935 769 | 15.3 |
| Sweet potato | 117 337 | 10.2 |
| Wheat | 521 682 | 7.0 |

Sasser and Freckman, 1987

Identification of Nematode Infestation

Plants infected with plant-parasitic nematodes show symptoms of reduced root function, because when a root system has been damaged by nematodes, its ability to accumulate water and nutrients is reduced. Plants may tend to wilt very easily, even if they have been watered recently. Plants may also show signs of nutrient deficiency despite adequate soil fertility. Sometimes plants will lose their older leaves. Here at ECHO, we have observed nematode-infested okra with only one or two young leaves near the top of the plant. We have also seen plants wilting, even though the soil was still moist from a recent watering. Other plants of the same species located nearby were unaffected. It is important to remember that these symptoms can also be caused by other pests, by herbicides, or simply by a lack of irrigation and/or nutrients. Nematode populations can vary greatly from one area of a field to another, so damage to plants can be quite localized. A field might have an area with small, stunted, or wilted plants even though the field seems like it should be quite uniform in terms of moisture and fertility.

If certain above-ground symptoms make you think that your plants are suffering from injury due to plant-parasitic nematodes, the next step is to check for damaged roots. Root growth may appear stunted compared with non-infected plants. If root-knot nematodes are present, the roots will have characteristic galls on them (see Figure 1). Areas of the root will be very swollen and older parts of the root may be suffering from decay. Other species of plant-parasitic nematodes do not cause such characteristic damage, although if you look closely you might see dead patches on the root caused by other types of nematodes.

You can confirm the presence of plant-parasitic nematodes by collecting soil or root samples and sending them to a nematode diagnostic lab, if such a service is available in your area. We have contact information for a number of labs worldwide that will determine if soil or plant samples contain plant-parasitic nematodes. If you are interested, please contact ECHO or search for the information on our website--we may be able to provide you with a contact near your location. In these labs, nematodes are extracted from the soil or plant material and are identified and counted. Typically, the lab will send a report to you that will contain the number of various types of nematodes per 100 ml of soil. With this information, they will send a prediction of whether or not the type and numbers of nematodes present in your sample are likely to cause yield reductions in certain crops in a subsequent planting.

Methods of Managing Plant Parasitic Nematodes

Nematodes do not migrate very far in soil on their own. As aquatic animals, they live in the soil water. They can be dispersed with moving water during heavy rains or irrigation. If you have an area free of nematodes, be very careful about what you bring into that area. Nematodes can be spread from one area to another in infected plant roots, in soil, or on hand tools or farm machinery. If transplanting into the area, make sure the soil you are introducing is free of nematodes. Wash farm tools and implements well before moving from one field to another. Dr. Crow said that nematodes can move vertically four or five feet but only a short distance horizontally. He also said that “plows moving through a field or dirt adhering to hoes can be very efficient means of nematode spread.” He added, “I...spoke with a nematologist in Brazil who found soil stuck in mules’ hooves was the major means of spread in coffee plantations.”

Once you have nematodes in a given area, it is not possible to completely eliminate them from a field. However, there are several things you can do to limit the impact they have. These include: 1) using specific management practices; 2) using resistant plant species or varieties; 3) rotating your crops; 4) using organic matter and green manures; 5) growing nematode-suppressive crops; 6) subjecting growing areas to either flooding or fallow; 7) solarizing soil; 8) employing methods of biocontrol; and 9) using nematicides. Each of these will be discussed in more detail below.

Use specific management practices

If you know your soil contains nematodes, you might consider seeding plants into nematode-free potting soil and then transplanting them into the field. This will give your plants a head start over the nematodes. Instead of having the roots damaged when they are very young seedlings, they will not become infected until they have a larger root system. If potting soil is unavailable, you could sterilize

your own soil using an oven, a fire, or a sheet of clear plastic in the sun (see the “*Solarize your soil*” section later in this article). Nematodes cannot survive temperatures of 48°C (120°F) for very long.

Another important strategy is to kill your crop plants once they are no longer yielding. If plants are done producing but are still alive and are left standing in the field, nematodes in the roots will continue to reproduce and lay eggs. This will result in unnecessarily high nematode populations in the soil, and will increase the problem you will face with your subsequent crop. Killing plants that are hosts to nematodes as soon as possible stops nematodes from reproducing. It also increases the amount of fallow time between plantings, causing more nematodes to die before they come into contact with a suitable host. If you remove the root systems of crop plants that are no longer yielding, then you will also remove many freshly laid eggs, which are often attached to roots. You may choose to burn the roots, or you may decide to dry them in the sun or shade for six weeks. This will kill the nematodes and eggs. The roots can then be added to a compost pile or reintroduced to your garden.

Use resistant plant species or varieties

As is true with almost any stress, some plant species or cultivars are more tolerant of nematodes than others. If nematodes are a serious problem in your area, choose and grow species that can tolerate nematodes. Here at ECHO for example, okra, eggplant and some of the cucurbits are very susceptible to root-knot nematode injury. Corn and other grains are much more tolerant. Some tomato cultivars are much more tolerant of nematodes than other cultivars. In North American seed catalogues, relatively tolerant tomato cultivars are given the designation N, for nematode resistant. However, take note that this refers to resistance to only one of the common root-knot species.

Rotate your crops

If susceptible crops are grown year after year in the same area or field, nematode populations can quickly build up to levels that will cause serious yield reductions. If a crop is grown that is sensitive to nematode infestation, it is a good idea to follow for two years with crops that are not hosts to that particular nematode species. After two years, the nematode population will have dropped in number and the susceptible species can be successfully grown once again. Some nematodes are very host specific and are only able to parasitize one plant species, while others can infect a number of different species. Some root-knot nematode species are able to parasitize many different vegetable species, but are not able to infect sorghum, millet, or other monocots.

Use organic matter and green manures

Nematode problems are generally worse in soils with low amounts of organic matter than in soils with higher amounts of organic matter. Organic matter may do one or a combination of things. It may support higher populations of

natural pests of nematodes, such as bacteria and/or fungi; it may release compounds that are toxic to nematodes as it decays; or it may increase soil nutrient and water levels, partially overcoming the effect of having a damaged root system. Some published reports suggest that incorporating neem leaves into soil reduces injury caused by nematodes. In an experiment done here at ECHO, neem leaves were collected, run through a chipper and mixed with soil (10% leaves by fresh weight). Plants grown in this soil experienced much less injury from nematodes than plants grown in soil that was not amended with neem; in fact, in nematode-infested soil that was not amended with neem leaves, plants died. In contrast, plants in soil that was amended with neem leaves showed growth comparable to that of plants in nematode-free soil. In a follow-up experiment we amended soil with neem, chinaberry (*Melia azadirach*; a relative of neem) or napier grass (*Pennisetum purpureum*) to determine if the benefits of neem observed in the initial experiment were specific to neem, or were an effect of increased organic matter. We amended soil at a rate of 1% or 10% (by weight) to determine if the positive effect observed previously could be achieved with fewer neem leaves. Results from this experiment indicate that both neem and chinaberry are effective, but only at the high rate of application. Plants growing in nematode infested soil containing napier grass did not grow significantly better than plants in non-amended soil, suggesting that neem and chinaberry leaves have a unique ability to improve plant growth in soil containing nematodes.

In a garden or nursery setting, you could incorporate neem tree leaves into the soil immediately surrounding transplants. This technique is not very well-suited for a whole field, because at a rate of 10% you would need 200,000 lbs of neem leaves per acre! However, it might be feasible to apply leaves to rows within a field.

Grow nematode-suppressive crops

Some plant species actually reduce nematode populations in the soil where they are grown. This is a different scenario than just growing a non-host species. These species produce and release chemicals toxic to nematodes either as they grow or once they are incorporated into the soil and begin to decay. If you are faced with a nematode problem, one of these species might make a good cover crop to be grown during the off-season of a sensitive crop species. Suppressive species include marigolds (*Tagetes patula*) var. Nemagone, chrysanthemum (*Chrysanthemum moriflorum*), castor bean (*Ricinus communis*), partridge pea (*Cassia fasciculata*), croton (*Crotalaria spectabilis* and other spp.), velvetbean (*Mucuna pruriens*), common vetch (*Vicia sativa*), rapeseed (*Brassica napus*), and jack bean (*Canavalia ensiformis*). Cover crop residue can be mixed into the soil before planting your crop species.

Subject fields to either flooding or fallow

Plant-parasitic nematodes are not able to grow and reproduce in the absence of a suitable plant host. It is

possible to reduce the number of nematodes in soil by depriving them of their host. Leaving fields completely fallow (weed-free) for several months will reduce nematode populations. It is important to remember, however, that while much of the population will die, some nematodes can survive up to two years in the absence of a plant host. A fallow period will not completely eliminate your problem. If you are considering this method, you also need to consider the negative effects of exposed soil, such as erosion and the loss of soil organic matter.

In other areas it may be possible to flood your fields for a period of time. Nematodes live in water but they still need oxygen. According to Dr. Crow, several two-week cycles of flooding and draining a field are adequate to reduce populations of most nematode species. Also, when organic matter decays in low oxygen conditions, compounds such as ammonia (NH₃) and cyanide (CN⁻) may be released. These will become toxic to nematodes at high concentrations.

Solarize your soil

In areas with predictably warm and sunny weather, it may be feasible to solarize your soil. Soil solarization is a method used to pasteurize soil. To use this technique, lay clear plastic over tilled, slightly moist soil for six to eight weeks. The clear plastic acts like a greenhouse, heating the soil to the point that nematodes are killed. This technique may work even better if some organic matter (perhaps organic matter of a nematode suppressive crop such as a brassica) is mixed into the soil before it is solarized.

It may be possible to use this method on a small scale to pasteurize soil for raising transplants or for growing plants in containers. In an experiment done here at ECHO in August 2001, enough soil to fill 20 1-gallon pots was spread on several clear plastic sheets 1.5 m (5 feet) wide and 3 m (9 feet) long. The soil was spread on one half of each plastic sheet in a 1.2 m by 1.2 m (4 feet by 4 feet) square, approximately 5 cm (2 inches) deep. The soil was then covered with plastic (the rest of the plastic sheet was folded over the soil) and the edges sealed with soil. After six hours, the soil temperature reached 61°C (142°F).

We grew both okra and eggplant in nematode-infested soil that was untreated, or sun-solarized using the above method for 30 min, 1 hour, 3 hours or 6 hours. Plants growing in soil that was solarized for less than 3 hours showed characteristic nematode damage. Plants growing in soil solarized for 3 or 6 hours were larger and had very little nematode injury. (A few plants growing in soil solarized for 3 hours had minor injury.) If you try this technique, we recommend that soil be placed under plastic early in the morning and left for a day.

Employ methods of biocontrol

While nematodes are plant parasites, certain fungi and bacteria are themselves parasites of nematodes. Some species of soil fungi such as *Arthrobotrys* spp. and

Monacrosporium spp. can trap and kill nematodes. Other fungi such as *Paceilomyces lilacanus* and *Verticillium chlamydosporium* parasitize nematode eggs. Adding organic matter to soil may increase populations of these organisms. Some companies are working to formulate mixtures of these fungi, so that if you have a nematode problem you could add these species to your soil. Pasteuria (*Pasteuria penetrans*) is a bacterial parasite of nematodes. Nematodes infected with pasteuria are not able to grow and reproduce efficiently. Pasteuria are proving to be very difficult to culture in laboratories, so they are not yet available commercially. There are different strains of pasteuria, and some are very specific in which type of nematode they infect. This means that even if you introduce a strain of pasteuria into soil where you have nematodes, it may have no effect on the nematode population. Pasteuria can sometimes be found in soils that have had susceptible crop species and relatively high numbers of nematodes for several years. Here in the United States it has been observed that sometimes after several years of cultivation, damage caused by nematodes would suddenly drop. Research showed that pasteuria had naturally colonized the area and substantially reduced the nematode populations.

Here at ECHO we have found pasteuria in an area on the farm that has been used for many years to grow seeds for our seedbank. We are investigating ways to disperse the pasteuria elsewhere around the farm where nematodes are a problem. One method we are trying is to take plant roots that have been infected with both nematodes and pasteuria, and to dry them in the shade for six weeks. (Note: Drying plants in the sun would kill nematodes more quickly and would also kill other pathogens. This would be a better option if you are not interested in biocontrol using pasteuria, because the sun may also kill pasteuria spores.) Drying plants in the shade will kill nematodes and nematode eggs, but apparently will not kill pasteuria spores. The dried roots can be ground up and placed in soil when we transplant seedlings. With time, the pasteuria should spread along with the nematodes.

It is difficult to determine whether or not you have pasteuria in your soil. They can only be seen when you look at nematodes with a compound microscope under high magnification. Even so, if you remove nematode-infected roots from the ground, dry them for six weeks and then place them back into the soil, you will benefit for several reasons. Many nematodes and eggs will have been removed from the soil and killed, and organic matter will have been added to your land. If pasteuria is present in the dried roots, you will enhance their numbers and may achieve some degree of biocontrol as well. However, note that if the same or very similar crops are grown two seasons in a row, this recommendation could increase the likelihood of other diseases.

Use nematicides

Several chemicals are very effective at killing soil nematodes. Typically, these are fumigants that are injected into the soil. However, they do not kill only nematodes; they also kill other soil pests, weed seeds, and beneficial soil organisms. Another serious concern is that these compounds are usually very toxic both to people and to the environment. One compound called methyl bromide is a very effective nematicide, but it is toxic to people in low concentrations and is currently being phased out in the United States because it causes damage to the earth's protective ozone layer. Other compounds include methylisothiocyanate (MIT) liberators (they kill many seeds, bacteria, fungi, insects, and nematodes), and halogenated hydrocarbons such as 1,3-dichloropropene (1,3-D) (they kill nematodes, fungi and wireworms). Organophosphates and carbamates interfere with nematode development and reproduction.

Summary

Nematodes are small aquatic animals that live in many different environments, including soil. The presence of nematodes in general is an indicator of soil health. However, some species of nematodes are significant plant parasites. Plant-parasitic nematodes can substantially reduce crop yield. Fortunately, their presence can be diagnosed and a number of measures taken to reduce their impact on a crop.

PILLARS Guides from Tearfund

Tearfund, an evangelical Christian relief and development agency based in the United Kingdom, has developed information guides for community groups to use and discuss. The guides are called PILLARS, an acronym for "Partnership in Local Language Resources." Isabel Carter, editor of the magazine *Footsteps*, is the author of the guides.

PILLARS are designed for small group situations and contain information, Bible studies, and practical ideas to try. The guides contain illustrations to help non-literate members, and they aim to increase the confidence of group members.

According to the PILLARS pamphlet, "The PILLARS process uses these Guides as a basis for providing information in local languages. The process requires a series of three workshops with committed participants. The aim is to establish a local language committee able to translate existing Guides and then continue writing new material in their own language."

Also available from Tearfund are an optional workbook (with information about translating and printing) and a CD-ROM with formatted files (so the translated material can be inserted and printed).

Guides currently available include *Building the Capacity of Local Groups*; *Improving Food Security*; *Credit and Loans for Small Businesses*; and *Agroforestry*. The first two guides are available in French and English, and the latter two are available in English only. Guides cost US\$5.00 (£3.50) each, or all four (English) can be purchased for \$15.00 (£12). The PILLARS workbook (available in English and French) costs \$8.00 (£5). The CD-ROM with PageMaker® files is \$8.00 (£5).

To find out more about PILLARS, write to: PILLARS; PO Box 200; Bridgnorth; Shropshire; WV16 4WQ; UK. Fax: +44 1746 764594; E-mail: pillars@tearfund.org

FHIA: Source of Disease-Resistant Bananas

We were saddened to hear last spring about the death of Phil Rowe, a banana breeder who worked with the Honduran Foundation for Agricultural Research (FHIA). Phil was known to many in our network as the "Banana Man." He brought banana plantlets to ECHO's annual Agricultural Missions Conference for a few years in a row, to be distributed among the delegates. We wrote about some of the disease-resistant hybrids he has worked with in EDN 59, February 1998. In that article, FHIA and Dr. Rowe offered to provide plantlets to missionaries and development workers, as long as they would pay the postage charges for shipping plantlets. We contacted FHIA to find out how Dr. Rowe's death would affect distribution of plantlets.

Dr. Dale Krigsvold, Director of Research for FHIA, responded in the following manner: "We do not have that many tissue culture plants in the laboratory at present

because we are concentrating on producing and distributing corms in Honduras due to heavy demand here. Nevertheless, in Phil's memory, we will probably offer plants again to the ECHO people under similar terms as before." Dr. Krigsvold also asked that we share a reminder for all who received plants from FHIA. Part of the agreement was that FHIA would receive some information from recipients about the banana plantlets, such as to survival rates, production, problems, and other information. To date they have received very little feedback on plant performance.

Dr. Krigsvold told us, "...we have set up at FHIA a Phil Rowe Endowment Fund for continued research in disease resistant bananas and plantains and for distribution of these plants throughout the world." Some of the money from this fund will be used to pay for plant shipments to people who are unable to cover the costs.

For more information, contact FHIA, P.O. Box 2067, San Pedro Sula, Honduras; Fax (504) 682313.

Can You Help Us?

If you have received FHIA plantlets through ECHO (for example at our conferences) in the past and have not yet provided FHIA with any results, please write to ECHO regarding your banana performance. Include such details as your local climatic conditions and details on where the bananas were planted; information on survival, yields and production; any problems (disease or otherwise); taste; local acceptance in the community; and any other information you have on their performance. We will compile the information and pass it on to FHIA to help them in their research.

BOOKS, WEB SITES & OTHER RESOURCES

Calvin Yoke: *Management Can Be Learned* Video

By Stephen Lackey

Calvin Yoke spoke at our annual Agricultural Missions Conference several years ago and again in 2000. Both years, his talk was one of the most popular at the conference. Interest in the topic is understandable since many of the attendees, like our readers, are managing people and resources even though they have not had any training in that field. Numerous missionaries and development workers have found Calvin's insights helpful. This past

spring, ECHO invited Calvin to Florida so that a professional film crew could make a high quality recording of his presentation.

In this tape, titled *Management Can Be Learned*, Calvin presents a Christian perspective on management. His "management toolkit" includes topics such as:

- Creating and/or communicating a vision
- Finding the best people and the best in them
- Seeking solutions not judgement
- Valuing people

- Setting expectations
- Creating win/win situations
- Developing stump speeches

The 50-minute video is available on video tapes in NTSC (used in the US), PAL, and SECAM formats. The video costs \$19.95 plus shipping, and includes supplemental materials on floppy disk. It can be ordered from ECHO by phone or mail, or through our on-line bookstore. Shipping costs are \$3.95 within North America and \$4.95 (surface mail) or \$7.65 (airmail) elsewhere.

FROM ECHO'S SEEDBANK

***Sesbania rostrata*: A Green Manure Production System for Rice**

By Darrell Cox, Ph.D.

An article in the October 1997 *ILEIA Newsletter* tells the story of a land development that was established in the 1980s in Sri Lanka. Farmers were provided with one hectare of irrigable rice land that yielded five to six tons of rice without fertilizer during the initial three to four years of monocrop culture. After that, yield declines were experienced that compelled farmers to apply inorganic fertilizers to maintain yields at four and one half to five tons per hectare. The government removed subsidies on fertilizer, and the profitability of rice production declined substantially.

"One of the important reasons for yield decline in irrigated rice is nutrient mining. Total nutrient removal per hectare by a rice crop of five tons amounts to about 100 kg of nitrogen (N), 16 kg of phosphorus (P) and 128 kg of potassium (K) [220, 35, and 282 lbs. of N, P, and K, respectively]. Farmers compensate for this loss by applying about 375 kg [827 lbs.] of inorganic fertilizers which contribute 117 kg of N, 23 kg of P and 42 kg of K (258, 51, and 93 lbs. of N, P, and K, respectively)."

Researchers and extension workers in Sri Lanka began working with farmers to develop methods to maintain soil fertility. One result was that farmers began incorporating rice straw back into the soil rather than burning it during the threshing process, which was the traditional method.

Secondly, a researcher in the Sri Lankan national agricultural research system began screening a number of green manure crops for biomass production and N-content. *Sesbania rostrata* stood out among the species that were screened (others included *S. sesban*, *S. aculeata*, *Crotalaria juncea* and *C. caricia*). *Sesbania rostrata* is an annual

Sesbania species; it is an aquatic legume that can be grown before or between rice or maize crops as a green manure. *S. rostrata* is the only species of *Sesbania* that has nitrogen-fixing nodules on its stems as well as its roots.

The research results were remarkable. *S. rostrata*, planted at a rate of 60 plants per square meter, was able to produce 4000 kg of dry matter and 100 kg of N per hectare (1.8 tons dry matter and 89 lbs. of N per acre) after just 45 days of growth.

Three traits make *S. rostrata* suitable for a paddy rice / green manure production system: 1) its rapid growth and substantial biomass production in a short period of time, 2) its superior ability to fix substantial amounts of nitrogen, and 3) its ability to grow well (and fix nitrogen in stem nodules) in water-logged soil. As a result, *S. rostrata* has the potential to fit into the fallow period between rice crops in systems where two rice crops are grown in a single year in the same paddy.

When *S. rostrata* is sown for the first time in a field, the seed needs to be inoculated with a *Rhizobium* bacterium to ensure optimal nitrogen fixation. The following seed treatment was recommended in a 1991 issue of *Entre-Nous* (a newsletter for French-speaking Africa). The seed should be scarified with boiling water by pouring water over the seed and letting the seed soak overnight. (note: *Sesbania* is hardseeded and farmers must overseed their land to obtain a desired plant population. Other treatments used to break dormancy include sand scarification and treatment with concentrated sulfuric acid.)

The inoculant is prepared in the following way: put the inoculant in a plastic bag, add water, close the bag and mix well, and then leave it in a cool place overnight. After the seed has been drained (following hot water treatment), it can be mixed with the inoculant. Again, if *Sesbania* is being

planted for the first time, it is advisable also to inoculate the stems when they reach a height of about 25-30 cm (10-12 inches). The inoculant is prepared in the same way as explained above. The next day it is diluted with one liter of water and sprayed on plants using an ordinary sprayer.

I contacted AgroForester (a company that sells inoculant) to find out more about the rhizobia that is used for inoculation of *S. rostrata* seed. One of their staff persons reported, "... as I began researching the specific species name for this rhizobia, I found that *S. rostrata* has root nodules of the genus *Rhizobium* and stem nodules of the new genus and species *Azorhizobium caulinodans*." From that information he concluded that their group E inoculant should root nodulate, but may not stem nodulate *S. rostrata*. [Editor: After a more recent enquiry, we were told that the group E inoculant should work for both stems and roots. It contains a strain of rhizobium isolated from *S. rostrata*. It has been used by many for *S. rostrata*, and no complaints have been received by AgroForester.] The two companies listed in *Tree Seed Suppliers Directory* that can provide inoculant for *S. rostrata* are: 1) AgroForester, P.O. Box 428, Holualoa, HI 96725, USA, e-mail: seeds@agroforester.com and 2) Soil Productivity Research Laboratory, Private Bag 3757, Marondera, Zimbabwe.

Nitrogen fixation is a biological process and as such is affected by environmental conditions. Therefore, the amount of nitrogen fixed by *S. rostrata* will in part be determined by the growing conditions at the time. In general, nitrogen fixation can be increased by the application of P and K fertilizers when soils are low or depleted of these nutrients. However, large applications of mineral nitrogen fertilizer tend to reduce the amount of nitrogen fixation because another source of nitrogen is readily available. Recent studies on nitrogen fixation and *S.*

rostrata confirm these results. Although P and K applications may increase the amount of nitrogen accumulation in *Sesbania*, rice yields do not necessarily increase, making this treatment questionable for small farmers. Soil flooding also affects biological nitrogen fixation; if soils are flooded, nitrogen fixation by nodules on the roots does not occur. Yet, because there are nodules on the stem, nitrogen fixation is still occurring above the flooded zone. It should be possible to see nodules on roots two to three weeks after germination. Functioning nodules are pink or red inside, while nonfunctioning nodules may be white, gray, or green.

The *Entre-Nous* article recommended that *Sesbania* be planted in moist, but not submerged, rice paddies six to seven weeks before rice is to be transplanted. Spacing should be 20 cm (8 inches) between seed in a row and 20 cm between rows (36 plants per square meter). When *S. rostrata* reaches a height of 1 to 1.5 m (40 to 60 inches), the plants can be cut and chopped into pieces less than 20 cm (8 inches) in length. The green manure should be mixed into the paddy to a depth of 10 to 15 cm (4 to 6 inches). Rice can be transplanted into the paddy one to seven days after mixing in the *Sesbania*.

Mike Fennema, a past ECHO intern, worked with *S. rostrata* as a green manure as part of a project with Food

for the Hungry International (FHI) in Cambodia. I asked him to give us some perspective based on his experience. Mike said, "when I first started the project back in 1993, I talked to the staff at the International Rice Research Institute (IRRI). They had tried to promote *Sesbania* for several years, but had abandoned it. They had great results in terms of [rice] yield increases during the field trials, but the farmers did not seem to be interested in growing their own seed."

Mike indicated that two things need to be taken into consideration when contemplating the use of *S. rostrata* as a green manure in paddy rice production: 1) growing conditions, and 2) farmer initiative, especially related to seed production. Sufficient amounts of water and heat must be present during the period between rice crops to allow *S. rostrata* plants to reach about one meter before being plowed into the soil. They found this much growth is necessary to provide the nutrients and organic matter that are needed for the next rice crop.

One of the reasons that IRRI gave up on using *S. rostrata* in rice production systems was the trouble they had in getting farmers to grow it for seed. The FHI project had much greater success because development was based on farmer-led innovation. "We decided to give *Sesbania* a try by starting small and involving the farmers in every step. We obtained a small amount of seed and

encouraged the farmers to grow some for seed while experimenting with the rest. We helped the farmers to realize that we did not have the best techniques for growing and using *Sesbania* in Cambodia. They needed to help us learn about these things; when to grow *Sesbania* for green manure use, for seed collection, how long to let it grow before plowing it in, how tall it should be, etc. The goal was to build their confidence in learning how to experiment with a potential crop that could improve their farming system. By starting with an experiment, starting small, and involving farmers in the learning process, things improved, but the process was slow." As of 1998 there were 1680 farmers using *Sesbania rostrata* as a green manure. The project is a success because enough farmers have learned to grow and harvest *Sesbania* for seed; excess seed has been produced that is being sold for experiments in additional villages.

ECHO now has a limited supply of *Sesbania rostrata* seeds. If you are working overseas in agricultural development and would like a free sample packet, please contact us. If you are looking for a large amount of seeds, they can be purchased from SETROPA (P.O. Box 203; 1400 AE Bussum; HOLLAND. Fax: (31) 35 526 5424; E-mail: setropa@miconnet.nl; Website: www.setropa.com).

UPCOMING EVENTS

ECHO's Ninth Annual Agricultural Missions Conference *ECHO, Fort Myers, FL, USA* *November 12-14, 2002*

See enclosed registration information. Also note that there will be a Community Health Evangelism (CHE) workshop at ECHO directly after the conference this year. CHE is a program

that teaches missionaries and nationals to link evangelism with social development, and to discover God's deep concern for every aspect of human life and welfare. The workshop at ECHO will provide an overview of CHE.

Many Christian organizations have been trained in CHE techniques. The

methods have been used in numerous countries. A variety of models can be chosen and adapted based on one's situation (e.g. family based, church based).

More information (including exact dates and cost) for the CHE workshop will be shared in the next issue of *EDN*.

THIS ISSUE is copyrighted 2002. Subscriptions are \$10 per year (\$5 for students). Persons working with small-scale farmers or urban gardeners in the third world should request an application for a free subscription. Issues #1-51 (revised) are available in book form as *Amaranth to Zai Holes: Ideas for Growing Food under Difficult Conditions*. Cost is US\$29.95 plus postage in North America. There is a discount for missionaries and development workers in developing countries (in North America, US\$25 includes airmail; elsewhere, \$25 includes surface mail and \$35 includes air mail). The book and all subsequent issues are available on CD-ROM for \$19.95. Issues 52-75 can be purchased for US\$12, including air postage. ECHO is a non-profit, Christian organization that helps you help the poor in the third world to grow food.