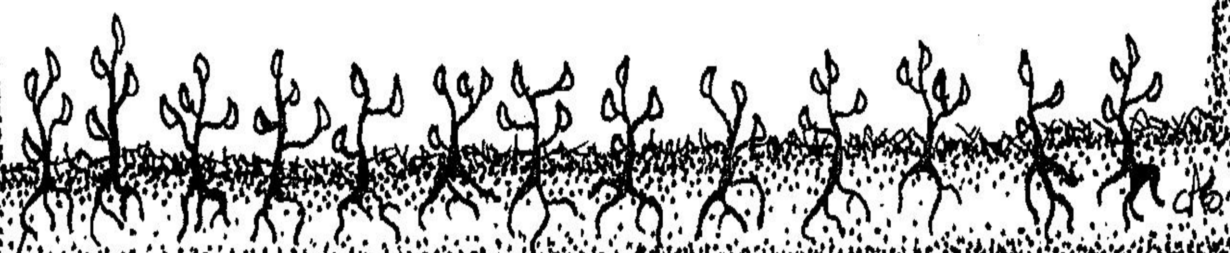
CHAPTER 6:

SOIL HEALTH AND PLANT NUTRITION



Productive, resistant plants start with healthy soil. Crops need not only adequate nutrients, but a favorable soil structure and environment for optimal growth. In the tropics, soil conditions vary widely, and many small farmers are forced to grow their crops in very poor soils which require special methods for food production. Green manures and cover crops, which afford some protection from weathering elements and may improve the soil, have proven themselves in the field for their contribution to soil health and conservation. This chapter also offers some ideas on planting materials and fertilizers for improved plant nutrition.

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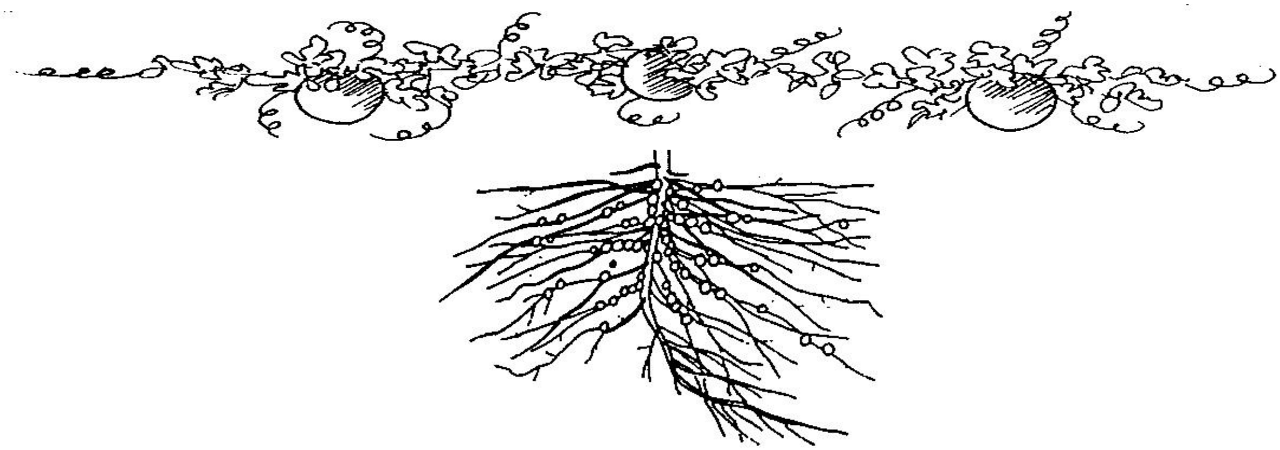
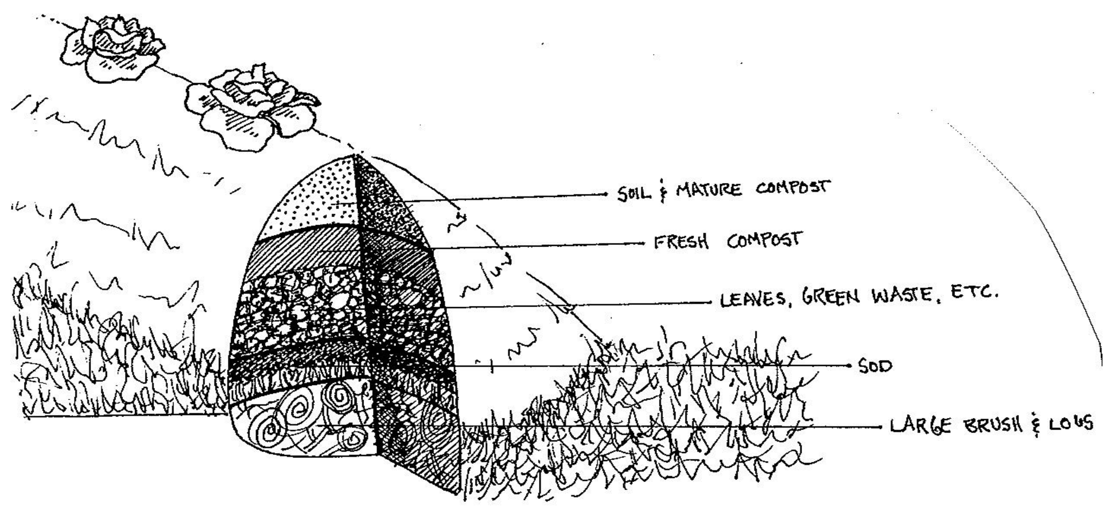


SOIL TYPES

COMPOSTING AND HILL CULTURE. There are three problems with the "proper" way to make fine compost. First, it is more work than most of us, including the subsistence farmer, have time to do. Secondly, most garden and farm residue is too big to decompose quickly unless a lot of work is done with a machete or shredder. Thirdly, humans like immediate gratification, something that only the most elegantly constructed compost piles can offer; the others take forever. We have been working on some methods to get around all of these problems, but now find they have already done that in Germany, with "hugelkultur" (hill culture). The following is taken from *The Avant Gardener* monthly newsletter.

"A hole 6 inches (15 cm) deep and 5 to 6 feet (1.7 m) wide is dug of any desired length and running north-south. In the bottom, twigs, branches and rotting logs are laid [I would put things like broccoli stems here too]. Then the sod removed when making the hole is laid face down on the wood layer. On top of this goes a deep layer of rotting leaves ...and green wastes.... Next comes a layer of fresh, nearly finished compost. Finally all this is topped with soil mixed with rich, mature compost. The completed mound can be as high as 30 inches (76 cm). Hugelkultur experts advise planting leaf and head vegetables such as lettuce, spinach, cabbage and cauliflower, plus tomatoes and cucumbers, the first year when there is considerable heating from the composting. The next year ... root crops can be added. The mound will last 7 years, its height gradually lessening and in the final year a perennial such as asparagus is planted."



[Subscriptions to *The Avant Gardener* for a year are $20 in USA; $24 overseas. Write to The Avant Gardener, Box 489, New York, NY 10028, USA. Though it is definitely oriented toward temperate horticulture, often ornamental, some of our tropical readers will find some articles helpful and interesting from time to time.]

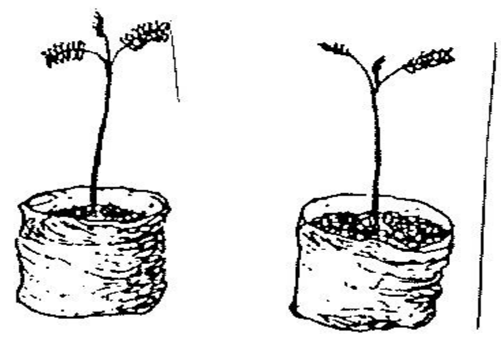
The systems we are trying are quite similar. We make layers of whatever material we have available. By being able to plant immediately we not only get that "instant gratification" but also are able to make better use of scarce land by continuing to use the area for planting. Because it is in use, there is no hurry for the whole pile to decompose so there is no need for turning or chopping up the coarse material. You also have all the advantages of a raised bed. We are using fertilizer at least this first season because our top compost layer is thin and the decay inside may cause nutrient deficiencies at first. If we had manure tea we would water with it frequently. Instead we often use a soluble fertilizer, pouring it right over the leaves. Since we never seem to have enough compost, I will tear up some of these "hills" after a year or so rather than following the German scheme exactly.

Heat from decomposition may not be too serious a problem on a smaller scale. We have very nice carrots right now in a 12-inch (30 cm) tall 2 x 4 foot (60 x 120 cm) bottomless box that we placed on a cement slab and filled to the top with grass clippings and a bit of fertilizer. We then placed about 3 inches (7 cm) of potting mix on top and planted the seeds. By the time the roots reached the grass it had apparently cooled down.

Those of you with large amounts of rainfall are often discouraged to see the bit of fertilizer you were able to procure leached away by rains. Hill culture might help because the microorganisms that decay the organic matter in the interior of the hill use the same nutrients that plants use. As nutrients are leached into the pile they are "recycled" by these microorganisms and turned into compost.

THE HAITI MIX FOR STARTING SEEDLINGS. Many formulas for artificial potting soil give outstanding results when starting vegetable, flower or tree seedlings. The problem is that ingredients are expensive or not available in many locations. For example, at ECHO we start our seeds in a 1:1:1 mixture of peat moss, perlite and vermiculite. When Tom Post in Belize asked about using sugar cane for such a mix, I asked Jerry Larson with Double Harvest in Haiti about their experience. In the process of growing millions of tree seedlings, they have acquired a lot of experience with what they now call the "Haiti mix." His comments follow.

The basic ingredients are 5 parts sugarcane bagasse, 1 part rice hulls and 1 part sandy loam soil. Before they are mixed the sugarcane bagasse must be well decomposed. The best indicator is the color. Bagasse with a light yellow color has decomposed very little and must not be used. As decomposition proceeds the color goes through shades of red to dark brown or almost black. A dark cinnamon red color verging on brown indicates that the bagasse is acceptable, but the darker color is preferable. It is important that no undecomposed bagasse get into the mix.



The decomposed bagasse is finely shredded in a silage chopper and mixed with the other ingredients. A heating and sterilization process is initiated by adding urea to the mix at the rate of 1 pound per cubic meter of mix. [Ed: If you do not have urea, I would imagine other nitrogen sources could be used. Even ordinary fertilizer could probably be used, but it would make control of nutrients in the final mix less precise.] There is usually sufficient moisture in the bagasse to "kick off" the heating process. Within 2-3 days the temperature in the center should be about 145°F (62°C). Next the pile is turned inside out so that all parts will be heated equally. After just one more day the pile is flattened and packed down to stop the heating process. At this point the mix is in an unstable state and thorough packing is necessary if the heating process is to be controlled. Continued heating not only burns up nutrient value in the mix but, if allowed to continue unchecked, will chemically alter the mix and make it toxic to plants.

An effective method of packing is to drive over the flattened pile with a tractor. After that the pile can be left for several weeks or months with no damage. If the pile cannot be packed that tightly and if it is to be used within a short time span (several days), then it is permissible to have several men pack it by walking over it until it is as tightly packed as they can get it. Just before the mix is used, it is passed through a 3/8 inch hardware cloth to remove the larger particles. Five to six pounds of 12-35-24 fertilizer (depending on the stage of decomposition of the bagasse) is added per cubic meter along with 2 ounces of F-5-3 micronutrients. The mix should be used immediately because the fertilizer will otherwise cause it to heat up again and alter the nutrient balance. In this last stage, only as much mix as is going to be used each day should be prepared.

A PEAT SUBSTITUTE MADE FROM COCONUTS. [The following is based on an article by Alan Meerow in *Country Folks Grower South*, November 1993.] Coir is the fibrous part of the coconut husk. The long fibers are "extracted and sold to make brushes, automobile seats, mattress stuffing, drainage pipe filters, twine, etc. Traditionally the short fibers and dust left behind have accumulated as a waste product for which no industrial use had been discovered." Tests in Australia and Europe show that this product makes a remarkably adequate substitute for peat. "The Lignocell company in Sri Lanka (where over 2.5 billion coconuts are processed each year) has become the leading processor [of coir]."

Coir has a high lignin cellulose content, which keeps the piles that traditionally accumulate around processing plants from breaking down. The same property inhibits breakdown of coir pith when used as a growing medium.

The pith is very similar to peat in appearance. It is light to dark brown, with 0.2-2.0 mm particle size. "Unlike sphagnum peat, there are no sticks or other extraneous matter." A study in Australia found "superior structural stability, water absorption ability and cation exchange capacity compared to sphagnum peat." There are reports that coir from sources other than Sri Lanka have contained chlorides at levels toxic to many plants. Perhaps this is a result of the processing method. In any event, watch out for that if you begin using the pith.

"Lignocell processes the pith into highly compressed bricks roughly 8x4x2 inches (20x10x5 cm), each weighing 1.5

pounds (0.7 kg). They are exported for the retail market in 12-brick packages. The 12 bricks fluff out when re-wet into 4 cubic feet (0.1 m^3) of ready-to-use material. Each brick absorbs about 2 gallons (7.6 liters) of water. I have been impressed by the ease with which coir pith re-wets after it has been thoroughly dehydrated."

The February 1996 *HortIdeas* cites research which cautions that coir can contain high levels of chlorine, which could affect seed germination. Leaching reduces chlorine levels quickly, and it is best to use coir that has been aged for at least one year.

[Ed: When I (LSM) was an intern at the Royal Botanic Gardens, Kew, we used coir rather than peat because of the adverse environmental impact on British peat bogs. Most of the horticultural staff preferred it to peat anyway. It worked well with nearly all plants, though they said it was not sufficiently acidic for the carnivorous plants. The coir surface can appear dry even when saturated below, so be careful to avoid overwatering.]

REMOVING SALTS FROM CONTAINER-GROWN PLANTS. I [MLP] vividly remember as a toddler watching my father boil down a can of saline water to show all the salt that was left behind. I think of that when week after week I water a potted plant during a long dry season or in a greenhouse where it never receives rain. As the water evaporates or is taken up by the plants, more and more salt builds up. Sometimes you can even see a white crust appear on top.

David Silber writes in the June 1992 issue of *The Fruit Gardener* that one way to correct this problem is to "semi-annually leach the soil with tap water (rainwater is better) that has been acidified to a pH of 4.0. I use a commercial grower's acid blend containing nitric and phosphoric acid. But you can also use vinegar as an acidifier: 2 tablespoons per gallon of water will yield the desired pH. The solution should be flushed through the growing container three times. In my experience the leaching water went in at a pH of 4 and came out at 6.5. This effectively removes lime and bicarbonates as well as sodium. I've used this on miracle fruit, coffee, pitomba, jaboticaba and lychee. The plants responded within two weeks with a new flush of normal leaves."

ECHO used this technique in the greenhouse where we grow rain forest plants. Plants were not thriving and leaf margins were turning brown on some species. They seemed generally healthier after the treatment.

The Fruit Gardener is published six times yearly by the California Rare Fruit Growers chapters. Membership/subscriptions: $16 in USA; $25 Canada/Mexico; $30 foreign surface mail; $40 foreign airmail. Write: California Rare Fruit Growers, The Fullerton Arboretum, California State University at Fullerton, Fullerton, CA 92634 USA.

SALINE AGRICULTURE: SALT-TOLERANT PLANTS FOR DEVELOPING COUNTRIES is a 143-page book published by the National Academy of Sciences (1990). Like the other NAS books of this nature, it is a very readable overview of lesser-known resources for a difficult situation. Salt-tolerant crops (halophytes) might utilize land and water that are unsuitable for salt-sensitive plants. Looked at from a different angle, farmers whose poverty limits them to their present location where soils or water are salty might eke out a better living.

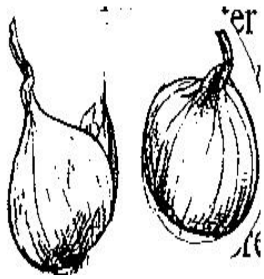
There are limitations, in part because relatively little agricultural research has been done with these crops. Salt-tolerant plants usually have poor agronomic qualities (e.g. there may be wide variations in germination and maturation times). Seeds of grasses and grains tend to shatter and fall to the ground. The foliage may not be suitable for fodder because of its high salt content. Nutritional (or anti-nutritional) characteristics have, in many cases, never been studied in the laboratory.

Sections are devoted to food, fuel, forages, and fibers. FOOD: grains and oilseeds, tubers and foliage, leaf protein, fruits, traditional crops. FUEL: fuelwood trees and shrubs, liquid fuels, gaseous fuels. FODDER: grasses, shrubs, trees. FIBER *ET. AL.*: essential oils, gums, oils and resins, pulp and fiber, bioactive derivatives, landscape plants.

Some of the plants we have talked about in EDN are discussed as having some degree of salt tolerance. The leucaena tree, *Leucaena leucocephala*, has been grown on coastal sandy soil in Pakistan through irrigation with saline water. Trees even survived when 20% seawater was used in the irrigation water, although yields were reduced by 50%. [See below for more information.] Jojoba (*Simmondsia chinensis*) is relatively salt tolerant, growing near the Dead Sea with brackish water irrigation in Israel. Quinoa (*Chenopodium quinoa*) germinated in a mixture of 1/3 sea water and 2/3 fresh water, though it would not continue to grow at that salinity. In the salt flats of southern Bolivia, quinoa is one of the few crop plants grown. In this arid region (230 mm/9 inches) rainfall, quinoa is planted in holes about 40 cm

(16 inches) deep where the soil is damp. As the plant grows, soil is filled in around it. With wide stretches of salt beds nearby, the environment is certainly saline, but no measurements have been reported. [The book does not say whether they are using specially selected strains of quinoa.] Neem (*Azadirachta indica*) seedlings have been grown successfully in Pakistan on sandy soil using irrigation water with approximately 10,000 ppm salt. [Pure sea water is 35,000 ppm.] A neem plantation has been established near Mecca in Saudi Arabia to provide shade for Muslim pilgrims. Water with approximately 2500 ppm salt was used for irrigation.

Only two conventional crops have halophytic ancestors: beets and date palms. Both can be irrigated with brackish water without serious loss of yield. Asparagus is remarkably tolerant of salt. In Tunisia, where irrigation water



contains 6,500 ppm salt, asparagus yields are about the same as in areas irrigated with fresh water. [ECHO staff Cory Thede comments that he remembers reading somewhere about applying salt for weed control in asparagus.] Barley is the most salt-tolerant cereal grain. At the University of Arizona, a special strain of barley yielded 4,000 kg per hectare when irrigated with groundwater with half the salinity of seawater. Selected strains were grown at the University of California on sand dunes with the following yields in kg/ha and salinities: 3,102 with fresh water; 2,390 for 1/3 sea water; 458 for 100% seawater. (Unfortunately the book says very little about vegetables. For some help on that subject, see "Helpful Facts About Salinity" below.)

Anyone working with salinity problems will surely want this book. If you are working with a governmental or non-profit organization, you may write the NAS on official letterhead, explain your work in no more than one paragraph, and ask if they might send you a free copy. The price in the US is $15. The address is Board of Science and Technology for International Development, Publications and Information Services (HA-476E), Office of International Affairs, National Research Council, 2101 Constitution Avenue, Washington, D.C. 20418, USA.

SALT TOLERANCE IN LEUCAENA? Dr. James Brewbaker at the University of Hawaii commented on the note above that leucaena has salt tolerance. "Leucaena's salt tolerance is effective only along shore lines where calcium levels are high. As with many other plant species, the tolerance of 'salt' is a complex subject, for salt can represent a great assortment of chemicals. Generally, the major difference is seen when comparing coastal salinity (highly calcareous) with inland evaporative salinity (e.g. Salt Lake), which is usually not calcareous. Leucaena tolerates the former, not the latter."

Calcareous refers to soils with high calcium content, primarily coral-derived soils with accompanying high pH. Arid regions naturally have areas of high salinity due to evaporation and salt accumulation; such soils are often lower in calcium, higher in sodium, and thus more toxic to plants.

A few nitrogen-fixing trees do handle the salty non-calcareous soils. The best work with these is at CAZRI (Central Arid Zone Research Institute of India) in Jodhpur, India. (Please send us their complete address and more information about their work if you know it. Thanks!)

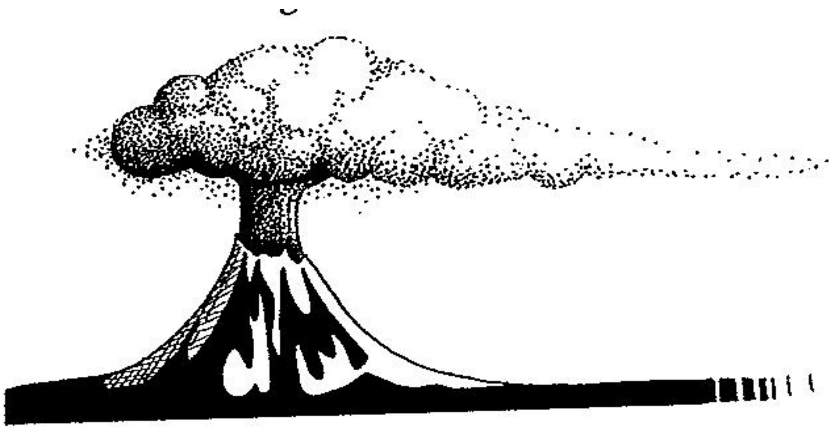
SOME HELPFUL FACTS ABOUT SALINITY. I pulled the following facts from *Knott's Handbook for Vegetable Growers*. On units of measurement: The following gives a helpful perspective when reading salinity literature that talks about ppm and millimohs per cm (sometimes written mmho/cm). 1 ppm (part per million) = 1 gram in 1,000 liters of water; ppm x 1,000 = 1%; 1,000 micromhos per cm (a unit of measure for electrical conductivity) = approximately 700 ppm; 1,000 micromohs per cm means that one ton of salt would be in the water that would cover one acre of land to a depth of 1 foot.

The handbook lists several vegetables and the mmho/cm in the soil that reduce yields by 25%. Beet (10), spinach (7), tomato and broccoli (6), cabbage, cucumber, muskmelon, potato, corn and sweet potato (4), lettuce, pepper, radish, onion and carrot (3), bean (2). So beets would be the best vegetable for saline soils, beans the worst.

Some general rules listed for likely crop response to salinity follow. 0-2 mmho/cm, mostly negligible; 2-4, yields of very sensitive crops may be restricted; 4-8, yields of many crops restricted; 8-16, only tolerant crops yield satisfactorily; above 16 only a few very tolerant crops yield satisfactorily.

PLANTING IN FRESH VOLCANIC ASH. Two members of our network in the Philippines asked what we could find out about this subject. Planting season is now near for farmers near Mt. Pinatubo. We called Dr. Allen Busacca at

Washington State University about gardening in volcanic ash and what impact layers of ash will have on agricultural soils.



"Most of our experience has been with revegetation of natural areas (Mt. St. Helens) rather than agricultural lands. While we generally think of volcanic soils as rich agriculturally, that is only after thousands of years of weathering. It has been my experience that ash is relatively neutral. Initially it is silica-rich, like crushed glass. In the case of the Mt. St. Helens volcano it was not very toxic. It is probably best to incorporate it up to maybe 6 inches (not an easy thing to do without equipment)."

"Not all volcanic ash is created equal. The best way to deal with a larger quantity depends upon whether it is light and fluffy or a fine, coarse pumice."

He referred us to Dr. Jeff Smith who was involved in some agricultural studies for the USDA. Dr. Smith said that there has been surprisingly little study of agriculture in fresh volcanic ash. "It will probably be a bit on the alkaline side and almost certainly will contain a lot of salts. So the first year only the most salt tolerant vegetables and grains should be grown. He is pretty sure that if they plant salt sensitive vegetables directly into the ash they will not thrive. On the other hand, there are volcanos where the ash was more like glass. Incorporating into the soil seems to help a lot."

There are no extension bulletins on the subject that he knows about. This would be a good research topic for one of our readers in the scientific community. If anyone has ever seen an extension bulletin or especially helpful research paper, or if you have had personal experience, we would like to hear from you.

ECHO's network shared quite a few helpful experiences. Ken Turner with Mercy Corps sent an interesting letter and pictures. "I guess I'm your reporter on the spot. Our community and my home (until the eruption) is 15 km from Mt. Pinatubo. We evacuated June 7, two days before the first major eruption. One of our staff returned a few weeks later. It looked pretty dismal.

"Now it is a different story. Some pretty amazing harvests have drawn a lot of attention. Banana planted a few weeks before the eruption produced a good crop. Most amazing was the watermelon harvest--more than twice the yields of past years, melons (sugar baby variety) twice the size on the average and still sweet, and vines more than twice the usual length.

"The ash is now about 8 inches (20 cm) deep. The soil has remained moist (and I suspect cool) under the sand, even after 3 months of dry weather. I did not check the pH, but 30 km from the mountain the pH is about neutral. It appears that sweet potato is thriving in rice fields 30 km from the volcano.

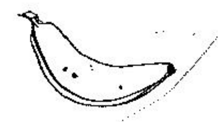
"The crops and generally lush growth is encouraging farmers to return, even though the road is likely to become impassible early in the rainy season. "

Victoria Coronel with IRRI sent very specific and helpful recommendations. Highlights are summarized. The eruption of Mt. Pinatubo brought havoc to more than 38,000 ha of farmland. Even though the Philippines has several active volcanos, they could find no published reports of studies on revegetation.

Some findings from the Mt. St. Helens volcano in the United States are relevant. (1) Ash has a lower permeability than soil. This means that flood water will remain longer on the surfaces of the ash-covered soils. (2) The ash layer acts as a surface mulch both reflecting solar radiation (increasing photosynthesis) and impeding water flow and evaporation from the soil to the atmosphere. An estimated 40-60% of the light is reflected. Peak daytime soil temperatures beneath 2-3 cm of ash were 6-10°C lower than adjacent sites where ash had been incorporated into the soil. (3) The abrasive effect of ash particles is harmful to insects. Unfortunately beneficial insects were the most affected.

Studies from Mt. Galunggung in Indonesia provided the following insights. (1) Crop yields were still high in areas with up to 20 cm of volcanic materials. Productivity declined with greater amounts. (2) Yields of rice and other food crops were high when the ratio of volcanic materials to soil were as high as 5:5 and 7:3. If there is less than 20 cm of ash, plowing into the soil seems the easiest solution. If deposits are deeper, adding organic matter may be needed (20 t/ha manure or other organic materials). Dumping organic waste from Manila has been suggested, but transportation is a problem. Green manure crops may be the answer.

The following cropping pattern was suggested if volcanic materials are less than 20 cm and the irrigation system is intact. After plowing 30 cm deep (a 7:3 ratio of volcanic materials to soil), plant rice-rice-corn/ soybean or rice-rice-leaf onion. For 20-30 cm thick deposits, plow the volcanic material when dry, incorporating any organic material that is available. Food crops can be planted in the early rainy season. Rice and corn are not generally recommended. If volcanic materials exceed 50 cm, pineapple would be suitable since it thrives well in sandy soil with pH range of 4.5-7.l5 and requires minimum care and inputs. Hybrid coconuts can also be planted. Fruits like guavas, nangka [jackfruit], papaya and banana grew well, even better than before the eruption of Mt. Galunggung.



Preliminary tests show some rice varieties do better than others. The top 3 were all varieties grown in acidic areas of Indonesia. In one area, corn exhibited early leaf yellowing (corn requires a lot of nitrogen). Sweet potato gave the best growth, followed by kangkong and cassava. Green manures also gave initial excellent growth. A second eruption destroyed the experiment.

IRRI recommends that the above fruit trees be planted as quickly as possible for the longer term; that sweet potato, cassava, kangkong and green manures be planted for the intermediate term; that livestock that eat roots (e.g. swine) be associated with sweet potato and cassava growing; that aerial seeding of green manures, including ipil-ipil [leucaena], be considered.

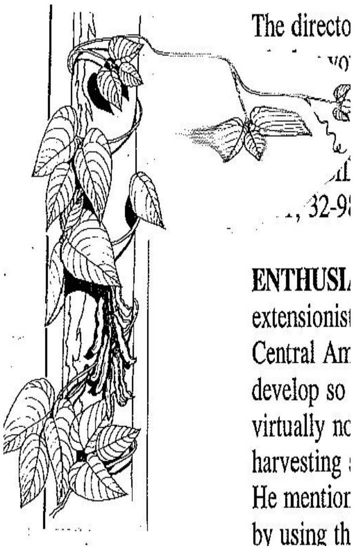
Scientists desiring to see the entire report, "Mt. Pinatubo--Controlled Revegetation" by B. S. Vergara and V. Coronel can write to Dr. Coronel at IRRI, P. O. Box 933, 1099 Manila, PHILIPPINES. Workers outside of Asia can write to ECHO.

RESOURCES ON SOIL HEALTH. We asked Marianne Sarrantonio, author of the handbook *Methodologies for Screening Soil-Improving Legumes* and professor of agroecology at Slippery Rock University, Pennsylvania, USA, to recommend a few hands-on resources from the emerging science of soil health (or soil quality). (This book is available in English and Spanish from Rodale Institute, 611 Siegfriedale Rd., Kutztown, PA 19530, USA.) "Local extension groups in your area are a good place to check for hands-on manuals on composting and green manures. I think that Grace Gershuny's books *The Soul of the Soil* and *Start with the Soil* are excellent for those without science training." Contact John Doran (ARS-Nebraska, USA, 402/472-1510) after mid-1996 about his how-to manual for measuring and monitoring soil health.

GREEN MANURES AND COVER CROPS

THE INTERNATIONAL COVER CROP CLEARINGHOUSE (CIDICCO is the Spanish acronym, for Centro Internacional de Información sobre Cultivos de Cobertura) was established in 1990 to provide an exchange of ideas, information and experiences among groups and individuals interested in promoting cover crops among village farmers. They collect and distribute information on leguminous cover crops and green manures from both scientists and practitioners in the field, document field experiences with cover crops, publish technical reports and the newsletter "Cover Crop News," and coordinate networking among members. (ECHO is normally able to provide packets of seed for any of the plants they mention.)

The publications are often field experience-based descriptions of cover cropping systems (highlighting velvet bean, lablab, jack bean, and other legumes) and management practices. Clear information regarding cultivation is given to help you adapt the system in your area. The publications give a very balanced perspective on the use of cover crops, defining where they can be useful as well as mentioning limitations for the farmer. Most are available in Spanish and English and cost $1.50-2.50; write CIDICCO for a publications list.



The director of the program is Milton Flores. Milton would love to hear from you whether you are experienced with green manures or just beginning to try them. You do not need to be an "expert." If there is something going on in your community which he might like to see, be sure to describe it. To receive their newsletter write: Milton Flores, CIDICCO, Apdo. 4443, Tegucigalpa, MDC, HONDURAS; phone (504) 32-7471, 32-9870, 39-5851; fax (504) 39-9896; e-mail cidicco@nicarao.apc.org.

ENTHUSIASM FOR COVER CROPS is contagious. Roland Bunch wrote, "Our extensionists in Honduras who have worked in some of the most successful programs in Central America told me several times that they have never before seen a technology develop so much enthusiasm and take off with so little program effort. They have done virtually no promotional work on it, yet it is taking off like wildfire. The program is harvesting seed by the 100 pound bag and cannot meet even a fraction of the demand." He mentioned that one farmer told him he is saving $100 per year in coffee purchases by using the roasted beans of one ground cover, velvet bean, as a coffee substitute. Doug and Ruth Welch mentioned that it is used in this way in Zaire also.

GREEN MANURE CROPS OFFER TREMENDOUS ADVANTAGES TO THE SMALL FARM IN THE THIRD WORLD (1985). By Roland Bunch, at the time with World Neighbors, Honduras. (Now a consultant with COSECHA, Apdo. 3586, Tegucigalpa, HONDURAS, Central America.)

Green manure crops are crops which are grown to be turned under to increase soil fertility. Leguminous green manure crops, i.e. those which can make nitrogen fertilizers from atmospheric nitrogen, can offer small-scale third world farmers a tremendous number of advantages:

1) They provide large quantities of nitrogen for the soil.
2) They add many tons of organic matter to the soil, thereby improving topsoil depth, water-holding capacity, nutrient content, friability, and texture of the soil.
3) Since the green manure crop grows in place, it presents no transportation problems, in contrast to either compost or chemical fertilizers.
4) Green manure crops require absolutely no capital outlay after the initial purchase of seed. They require no chemical inputs, so dependency on outside sources of fertilizer, nutrients, and pesticides is reduced.
5) Green manure crops can shade the soil up to eleven months out of the year, a factor extremely important in tropical climates for preservation of soil moisture and organic matter.
6) The cover they provide for the soil protects the soil from wind or water erosion.
7) Green manure crops provide generous amounts of high protein fodder for animals, which can be especially valuable if it is available during the last months of the dry season (since fodder at this time of year is the limiting factor in traditional animal-raising in much of the third world).
8) Some green manure crops provide human food, including various kinds of edible beans, peas, and pods.
9) Green manure crops can provide a cash income, by selling firewood, food or feed (and maybe seed).
10) They often provide an incentive for people to abandon harmful traditional practices, such as burning crop residues or letting animals loose in the dry season to devour everything in sight.
11) Some green manures can control weeds when intercropped with grains, eliminating costly weeding operations.

Something like 30% of all the increases in harvests achieved by small farmers in the third world during the last three decades has been achieved through the use of chemical fertilizers. Should petroleum prices shoot up once again, as could easily happen sometime in the next decade, prices of chemical fertilizers could easily become too expensive to be economically feasible for use with traditional basic grains. Almost overnight, third world basic grain production could plummet, causing famines the extent of which would make the present situation in Africa seem mild by comparison. Widespread use of green manure crops could avert much of this impact.

<u>Comparison with Compost.</u> As composting is a technology that is often recommended for third world development programs, it might be useful to compare composting with the use of green manure crops.

1) Compost merely decomposes the organic matter one already has, whereas a green manure crop can often add over 40 tons of additional organic matter per hectare. Inasmuch as organic matter is often in short supply on villagers' farms (or is already being recycled), this is an important consideration.

2) At best, compost will return to one's field about 98% of the nitrogen one started out with. A green manure crop, however, will add considerable quantities of new nitrogen to the system.

3) A compost heap takes a tremendous amount of work, as anyone who has made one can attest. Though compost will often pay in a vegetable garden, it is not economical when used on basic grain crops such as corn or millet. On the other hand, although a green manure crop takes a bit of labor to plant (using a dibble stick) and a fair amount of labor to incorporate, it takes *much* less labor then a compost heap. And in some cases where the green manure crop is intercropped among traditional crops (such as corn, sorghum, or millet), it covers the ground so well that one or even two weeding operations can be eliminated, thereby actually bringing a net savings in labor.

4) Compost heaps require water, so they are made near a water supply but at a distance from where they will be applied. Green manure crops take advantage of available rain water, and are planted where they will be used.

5) Compost cannot be used as a food source, either for animals or humans.

A Few Ideas About What to Look For. The major problem with green manure use around the third world is that village farmers cannot afford to give up land in order to grow "just" a soil amendment. Or when they have the land, they cannot spare the labor. However, there are three ways in which these objections can be overcome. In many situations only one of these will be appropriate, in others two. Only rarely is none of them appropriate.

1) Green manure crops can often be planted among traditional row crops, especially corn, sorghum, and millet, without decreasing the production of the main crop at all the first year, and usually with major increases in the major crop in succeeding years. The major instance in which this is not possible is when people are already intercropping two or three other crops with their major grain.

2) Green manure crops can often be intercropped with basic grains toward the middle or end of the growing season, with the idea that their major growth would occur during the dry season, thereby using land that would not ordinarily be under cultivation.

3) Where multiple-year fallows and/or shifting agriculture is used, green manures can be planted on land the first year it is to go fallow, cutting the fallow period to one year instead of 3-15 years.

What characteristics should we look for, then, in a legume that will be useful under these circumstances?

1) It must be a non-woody annual with vigorous growth.
2) It should grow well in the poorest of soils in the area, without needing any kind of fertilizer.
3) One must be able to plant it in local fields with no special soil preparation, and either with a dibble stick or, preferably, by broadcasting the seed.
4) The plant must have few natural enemies so that it will grow vigorously without pesticides or major labor requirements.
5) The legume should either be very shade-resistant (for intercropping) or drought-resistant (for growing into or through the dry season).
6) If possible, it should first cover the ground well, then climb any stalks that remain in the field.
7) If possible, the green manure crop should be edible by animals and/or humans.

Some Already Known Possibilities. For details on species used as green manures, see the following article.

Miscellaneous Observations.

1) What can be done in areas where animals are let loose during the dry season while the green manure crop is still growing? One approach is to first show people the results of the green manure plant on an enclosed piece of land. Next get a good number of people to try it out, perhaps timing the planting to get a good start before the animals are let loose. Those who experiment first can often be motivated to spread the word to others with the idea that the destruction for each person will be less if more people plant it. Eventually, if enough people plant it, community pressure will make everyone keep his animals locked up (except in cases where the person with all the animals is a large landowner).

2) On very steep hillsides, something must be done to keep the organic matter from washing away. Piling crop residues along rough contour lines can help, as can contour ditches. Another possibility is incorporating the green manure immediately after cutting it, but this is hard work before the rains come (if the soil is a heavy one), and once the rains have come, people generally do not have extra time.

3) On flatter land, the green manure should usually be cut and allowed to dry for a couple of weeks before incorporating it (if during the dry season). The labor saved in incorporating it will be worth more to the farmer than the small amount of fertility lost. In one case farmers cut holes in the *Canavalia* (jack bean) cover to plant corn when the rains came, cut down the *Canavalia* entirely about two weeks later and replanted the *Canavalia*. Then, two weeks later, they incorporated the dead *Canavalia* vegetation. In this manner, they avoided both weeding operations in their cornfields!

4) Where weather is unreliable, a combination of similar plants, one of which is more drought-resistant (e.g. jackbean and velvetbean) reduces risk of total loss, yet assures a vigorous crop if rains are plentiful.

5) In West Africa, we are trying a system of planting a perennial every sixth row (pigeon pea), and then gathering the corn or millet residues under the pigeon pea plants at the end of the year, to be distributed six months or so later when well-mixed with pigeon pea leaves, which have a better carbon-to-nitrogen ratio. The presence of the pigeon pea trees (already known as a cash crop) will also prevent burning of residues.

6) On South and Southeast Asian hillside areas, *Leucaena leucocephala* is planted as a contour barrier and constantly pruned, thereby providing erosion protection, some green manure, and firewood (see the booklet produced by World Neighbors called "*Leucaena*-based Farming"). This produces less green manure than other systems, but can be used where green manure cannot be intercropped among traditional crops.

7) We certainly would welcome any experience you have in this subject. Much more information and experimentation must be done. We are still learning about this, but the positive response from hundreds of villagers and dozens of other programs has made us decide to share what little we know as soon as possible so we can all work together to learn more about it. I would think that, right now, the most important subjects we need to learn more about are: a) What legumes will work above 1,800 m? b) What additional plants will work at any elevation? c) Do adaptive research to see which of these technologies will work outside the Southern Mexico/Central American habitat that this information comes from. d) Which legumes can be broadcast rather than planted with a dibble stick? e) Which of these green manure crops provide the best yield increases with which basic grain crops? f) What green manure crops would be best under high rainfall conditions?

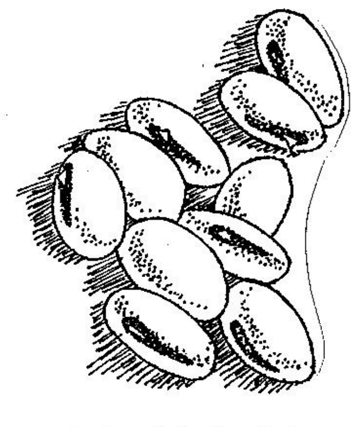
WHAT WE HAVE LEARNED TO DATE ABOUT GREEN MANURE CROPS FOR SMALL FARMERS (1987, contributed by Roland Bunch). [CIDICCO (see above) now offers the recent technical report "The Use of Green Manures by Villager Farmers" (1995, 7 pp., by Roland Bunch) in English or Spanish for US$3 including postage. Those considering implementing and promoting a green manure (GM) system would benefit from reading this article. It outlines the following topics: advantages and disadvantages of GMs for villager farmers, achieving the adoption of GMs, research priorities, and promising species for low, intermediate, and high elevations.] Here we present a few other insights from Roland Bunch regarding GM systems and the species often incorporated into the system.

In spite of the advantages of green manures, their use seldom became common among farmers in the third world. They cannot afford to give up scarce cropland just to grow a soil amendment. If they do have the land, they cannot afford the labor. Nor are they generally willing to spend money to improve crops grown for subsistence, because they earn no money from them with which to replace what they have spent.

World Neighbors/Central America has found a number of ways to overcome most of these problems to the extent that farmers have accepted green manures faster than any other agricultural technology with which we've worked through the years. One program sold 65 pounds of seed last year to local farmers and 1500 pounds this year in the same area with minimal promotion.

To summarize some ways to produce green manure without reducing at all the land used for other crops: (1) Plant among traditional row crops. (2) Intercrop near harvest of the first crop timed so green manure will grow primarily during the dry season. (3) Where shifting agriculture is practiced, plant during the first fallow year to shorten the fallow period. (4) Plant under fruit or coffee trees. (5) Plant leguminous trees along soil conservation ditches on hillsides. (6) Alley cropping. In Central America our work has used the first four possibilities. We have had the most success with jack bean and velvet bean.

Jack bean (*Canavalia ensiformis*) is an incredibly drought-resistant, shade-tolerant, hardy legume that grows well in extremely poor, droughty soils (and apparently less well in fairly fertile soils). There are two kinds of jack bean, one that climbs and thoroughly covers the soil, and another that has a bushy growth habit and does not climb at all. It begins flowering after 4-5 months, then produces seed pods continuously for at least the next year. It will grow through some 5-6 months of dry season if above about 600 meters and can serve to shade the soil during this time to prevent loss of organic matter. Under 500 meters it will often stop growing after about 3 months without rain and may even drop its leaves if soils are thin and temperatures exceptionally high. The stem will become somewhat woody, but only if left for seed and under fairly warm conditions.



Jack beans grow vigorously at sea level, and can be used as a green manure crop up to about 1600-1800 meters. It does not thrive in soils with excess water. They do very well in corn fields, but are preferred over velvet beans only when it is too dry for velvet beans to thrive. This tends to be the case where corn has been replaced with sorghum or millet due to insufficient rainfall. I have seen it grow vigorously on soil so badly eroded and depleted that no weeds would grow there at all.

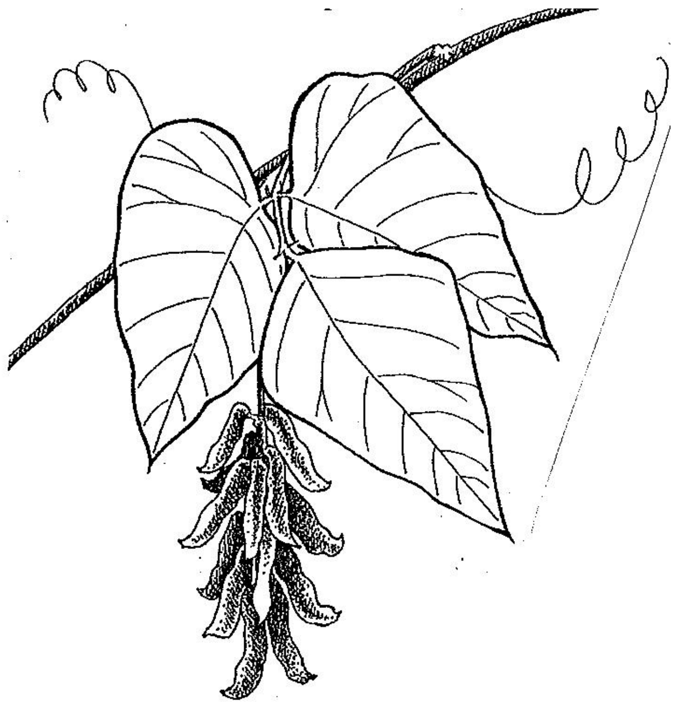
The jack bean will be eaten by grazing animals, but is liked less than other green manures. Hence jack beans are preferable where animal damage is feared. Non-climbing varieties are proving to be very good for weed control and nitrogen fixation under fruit trees. It has virtually no natural pests or diseases. Its leaves are sprinkled on leaf-cutter ant hills to eliminate them. [Ed: I am told that ants carry leaves into the mounds as food for the fungi upon which they live. Jack bean leaves reportedly kill the fungi. Dr. Warwick Kerr in Brazil writes that planting sesame near the mounds has a similar effect].

Jack bean should be planted in soil that has been cultivated within 3 years and weeded very recently (although at elevations below 500 meters or in sandier soils, cultivation may not be needed). We use 4-5 seeds per square meter in order to control weed growth. (In corn fields an important advantage of this and the velvet bean is that use of these plants may entirely eliminate at least the second weeding). Jack bean has even been planted in fields already intercropped with both corn and beans in Haiti (Bois de Laurence) without much adverse effect on even the beans. If planted in a corn or sorghum field, it should be seeded within 15-30 days of the primary crop, depending on climate, speed of growth of the other crop, etc. It can be planted with a dibble-stick (at 2 seeds/m^2) or broadcast (at 4 seeds/m^2), though if broadcast it will take another 2 weeks or so to germinate unless soaked in water overnight before planting.

People can eat immature pods like green beans when they are about 7-8 inches long. In Southeast Asia the mature beans are eaten, but we have not been able to find out how. Cooking must be sufficient to eliminate certain substances in the mature bean that inhibit the assimilation of calcium by the body.

In summary, jack bean can be used in grain fields, under orchard trees or to shorten fallow periods, but is not as vigorous as the velvet bean and should be used only when conditions are too severe for the velvet bean to do well. Under borderline conditions, perhaps mixtures of the two would function best.

Velvet bean (*Mucuna* spp. and other scientific names) is by far the most promising green manure that we have worked with in Central America. It covers the soil completely and then climbs as high as its support allows (up to well over 6 meters). It is highly palatable to animals and has found wide acceptance in our Honduras program areas as a coffee substitute. Especially encouraging is that there are at least 4 large areas where velvet bean use has spontaneously spread from village to village without any outside intervention (in Mexico to shorten fallows and in Honduras to intercrop with corn).



Velvet beans first cover the ground almost completely, then climb vigorously. Where corn stalks are present, it will eventually form a mat of leaves at about the top of the stalks, with little more than stems and pods underneath. Stems remain thin and nonwoody throughout the plant's life. The plant dies after it has set seed. [Ed: Seeing velvet bean growing to the tops of pine trees at ECHO prompts many to ask if it might not take over like kudzu in the southeastern USA. This might happen were it not that the plants die after seed set. It was a major U.S. crop for years, and I never heard of such problems.]

Sometimes velvet bean roots produce solid clusters of dark red nodules that are 4 cm. in diameter. We think that heavy nodulation occurs most frequently in infertile or sandy soils. Like jack bean, the velvet bean will volunteer heavily the second year if seed is allowed to mature and fall on the ground. In fact, farmers in Chiapas get good growth each year in their corn fields without bothering to reseed it. They harvest 4 T/Ha. of monocropped corn planted year after year on the same land under typical jungle conditions, using chemical fertilizer plus velvet bean.

About the only soils in which velvet bean has not done well for us are those that are waterlogged or have a pH of 4.5 or less. Like the jack bean, it needs to be planted in a field that is either sandy or has been cultivated within the last 3 years. Velvet bean will take a bit cooler climate than jack bean, but still does best at sea level and does poorly over 2,000 meters. In cool climates it will grow 3-4 months into the dry season, but is not as drought-resistant as jack bean. Velvet bean grows even more vigorously than jack bean under less harsh conditions, but in areas of severe drought, jack bean will out-perform velvet bean.

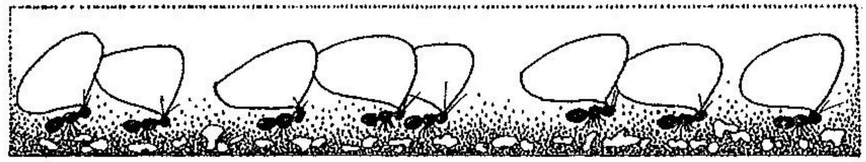
The velvet bean is presently our species of choice, in most cases, for growing in corn fields, rehabilitating depleted land, and weed control. It has been used in Guatemala and parts of Honduras to eliminate serious weeds such as nutgrass (*Cyperus rotundus*), Bermuda grass (*Cynodon dactylon*) and imperata grass (*Imperata cylindrica*). I am not aware of what is required to do this, though I would guess that the grass must be cut back and the velvet bean then allowed to grow a full 6 months in order to choke out the weeds.

It is an extremely good, fairly palatable high-protein fodder for most animals, especially cattle, and is eaten by virtually all animals except, sometimes, chickens. Thus, like the lablab bean, it can be an important source of high protein fodder well into the dry season, when many domestic animals are losing weight for lack of food.

We were taken off guard by the degree of acceptance of the dry beans as a coffee substitute. Having introduced it as a coffee stretcher (to be used 50-50 with coffee), we found that people were soon drinking it straight. Use is so widespread after just one year that a group of women is roasting and grinding the bean and selling some 40 pounds a week under the name "nutricoffee."

Like the jack bean, velvet bean is native to Central America. However, there are two kinds. The more common one has an extremely irritating itchy powder on the mature pod. Villagers who know this plant will not want to plant the non-itchy-powder varieties until they have been shown that the pods are harmless. We would under no circumstances recommend that anyone use the irritating kind with small farmers.

Slugs damage velvet bean in warm climates (though much less than regular dry beans). Rabbits, leaf-cutter ants (its only serious insect pest here) and iguanas are other pests. In some locations rats used the velvet bean stems to climb up and eat the corn. Planting the beans later or cutting its tendrils when it gets too large has helped with this problem. It must be watched and cut back if planted near trees.



Everything said above about planting jack bean also applies to velvet bean. However, fine tuning is needed to determine when to plant velvet bean in local corn fields. This is affected by speed of growth of the native corn, climate, soil fertility and existence of problems with rats. One should plant as soon after the corn as possible to get maximum velvet bean growth and weed control, but not so soon that the velvet bean outgrows the corn or causes rat problems. Especially in fertile or heavily fertilized soils, the velvet bean grows very rapidly and may even need to be pruned once to retard its progress.

Corn crops growing where velvet bean or jack bean have been incorporated can often do extremely well without any initial fertilization with chemicals, but will often show signs of nitrogen deficiency by tassling time. Farmers in our programs in Honduras almost always add a side dressing of urea to these crops. In general we recommend this practice where fertilizer is available and affordable. Over the long run, one would think phosphorous would also be needed, but in the short-run neither visible symptoms nor level of yields would indicate much problem with this element. Quite likely the increased organic matter is increasing the availability of soil phosphorous enough that deficiencies are not yet a problem.

In corn fields, the velvet bean produces an average of about 6-7 pounds of above-ground organic matter (wet weight) per square meter (30 T/Ha), but has produced twice that. The effect on subsequent plantings is roughly equal per pound to that of cow manure or half that of chicken manure, although this varies from field to field. When incorporated into the soil, the velvet bean often approximately doubles subsequent corn yields and when used as a mulch increases yields by about 35%. Even dry bean yields following velvet beans have shown yield increases of over 100%.

[Ed: Even though leaving the residue as a mulch has many benefits (erosion control, weed control, moisture retention), the greater effect on corn yields after incorporation might lead you to incorporate residues rather than leave them as a mulch. All nutrients probably become available in one season when incorporated, whereas they are more slowly released when left as a mulch, accounting for the greater effect. However, almost surely some or much of the remaining nutrients will benefit the second and subsequent corn crops. Roland and I asked during a regenerative agriculture conference at Rodale International for a perspective on this question. The consensus was that over several years the total amount of nutrients available for plants is about the same whether residues are left as a mulch or incorporated. We would welcome your input on this question. I recommend a no-till approach except in famine situations where immediate yield is imperative.]

Farmers in areas with enough moisture for two crops of corn or sorghum started doing the following. The green manure (velvet bean or jack bean) is intercropped with the first grain crop. After harvesting the grain they cut the residue and green manure down, leaving this on the surface as a mulch. The second crop is planted 20 days later with a dibble stick right through holes cut in the mass of dead velvet bean. There is usually a net saving of labor because planting and cutting of the green manure requires less work than the two weeding operations that are thus saved with the second crop. This is the sort of technology one dreams of, but rarely finds: net savings of labor, zero cash cost, decreased risk (the mulch gives some protection from erosion and drought), increased productivity, increased soil fertility and increased protein intake for animals or people.

In Togo velvet bean grew well and was incorporated into the soil 5 months before planting corn. There was virtually no response to the green manure. Our hypothesis is that the green manure was burned or leeched out. We are now testing whether under such conditions a green mulch (jack bean for instance) throughout the dry season will be able to reduce surface temperatures sufficiently to maintain organic matter. We have serious doubts about the claims that organic matter in tropical soils are impossible to maintain.

Recently villager nutrition groups have discovered that by toasting the velvet bean somewhat less than they do to make coffee, they have been able to produce a really passable hot chocolate. By grinding the flour finely, they have even been able to use a recipe for soybean cake to make "velvet bean cake." [See the chapter on Human Health for information on using velvet bean as a food source.]

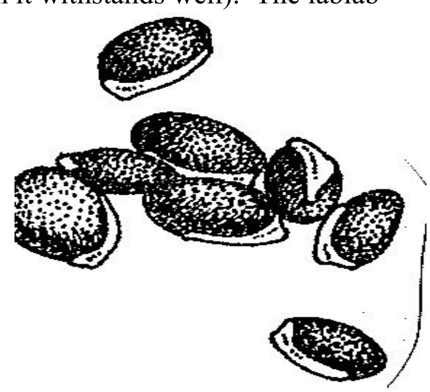
The **Lablab bean** (*Dolichos lablab* or *Lablab purpureus*) is a legume very similar in appearance to the velvet bean, but even faster growing where soils are fairly fertile. It has not been as valuable to us because of its need for somewhat more fertile soils and occasional insect problems, but may well be important to us later on when the other green manures have raised fertility sufficiently. The lablab bean is almost as drought-resistant as the jack bean, is very shade-tolerant, and is among the most palatable of legumes for animals (definitely preferred over velvet bean or jack bean). Lablab beans grow well from sea level up to about 1,500 meters. They require well-drained soils.

Lablab beans start flowering after 3 months and continue most of the first year, producing seed as well as remaining green. If soils are deep enough and other conditions permit, it will grow right through the dry season. I have seen plants that survived 3 years in droughty areas of the central plateau of Haiti. [Ed: In the sandy soils at ECHO lablab beans get nematodes so badly that it is difficult to keep them alive an entire year]. It nodulates profusely, producing mostly white nodules. Whereas the velvet bean growth is reduced if it has nothing to climb, plants in thick stands of lablab beans will begin to climb up each other. Another difference from the velvet or jack bean is that the lablab bean can be cut off nearly at ground level and will grow again, although with somewhat less vigor.

Lablab beans are traditionally planted toward the end of the agricultural cycle in some villages in Honduras to provide dry-season pasture for animals. It is also edible, and in some places, such as Haiti and West Africa, is widely appreciated as a regular food. Young pods or immature beans can be eaten green (beans taste similar to a sweet pea--a white-seeded variety is best for this). Dry lablab beans can be substituted for dry beans in most recipes. [Ed: Young pods of some varieties are quite tasty when cooked. Dr. Andrew Duncan recently told me that he saw a variety with an exceptionally wide pod growing on sides of village houses in Bangladesh.]

Where it grows well, the lablab bean has produced a phenomenal 11 kg per square meter (110 T/Ha) of above-ground organic matter (wet weight). Though we have had problems with insect attacks, its growth is so vigorous that it still usually grows as fast as the velvet bean. It grows so quickly that it should not be planted in corn until at least two months after corn is planted. Because animals prefer it to almost anything else, lablab beans cannot be grown where animals run free.

In pure stands, lablab beans should be planted about 10/m^2. We have not found a good system yet for planting in corn fields because of its rapid growth, but it should be possible with heavy pruning (which it withstands well). The lablab bean requires either a recently cultivated or a sandy soil.



Many other species and varieties may already be present in your area and better-suited than these species. Other possibilities for **low elevations** (0-1500m, warm) include: *Clitoria ternatea* (butterfly pea; very drought-resistant but small-leaved, not covering the soil well, grows well at sea level), *Canavalia gladiata* (sword bean, like jack bean), various native *Vigna*s, *Crotalaria*s, *Cajanus cajan* (pigeon pea), *Pueraria phaseoloides* (tropical kudzu, different from the temperate weedy species) and many others. For **intermediate elevations** (1500-<3000 m): *Phaseolus coccineus* (scarlet runner bean, 'chinapopo'; reseeds naturally, does not need pruning; see the excellent CIDICCO full-color report on this species, 48 pp., US$8), *Melilotus albus* (sweet clover; may be difficult to eradicate), *Lathyrus nigrivalvis* (choreque; Guatemalan highland crop for the dry season, produces much biomass, but requires very fertile soil and a few years to produce well in new areas; needs cold but is not frost tolerant; grown on fertile land 1800-2100 m) non-leguminous *Raphanus sativus* (forage turnip; very fast production of much biomass) and *Avena* spp. (oats), *Pisum sativum* (peas) and *Vicia* spp. For **high elevations** (>3000 m), options are much more limited: *Lupinus mutabilis* (tarwi; excellent fixer of nitrogen) and *Vicia faba* (fava bean, broadbean). There is much room and need for experimentation and developments on the scientific and community levels with additional species.

Continuing research needs. If you have been experimenting with green manures, CIDICCO, Roland Bunch, and ECHO would like to see whatever information you have put together. Among the most important subjects we need to learn more about are: (1) What legumes will work above 1,800 meters? (2) What additional plants will work at any elevation? (3) What GMs will work best under wet tropical conditions? (4) In what ways must these recommendations be modified for areas outside of the Caribbean basin area from which they have come?

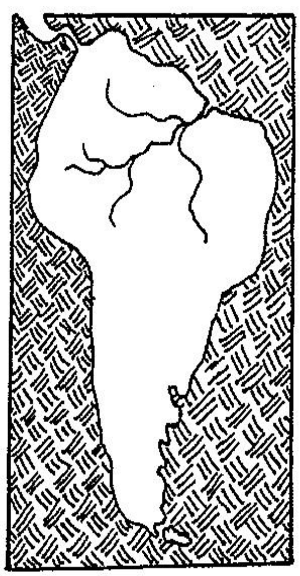
We still need tremendous amounts of information on GM systems. We need to learn about additional species for intercropping with major crops, for rotation with other GMs, and species suitable for various niches. Much more data is needed on how to manage these GMs in different soil and climatic conditions and the best techniques for management of the system. Attention to how various species can be grown together is also needed.

[Ed: ECHO has small packets of seed of many (but not all) of these species available for trial. We usually have: velvet bean, jack and sword beans, lablabs, pigeon pea, butterfly pea, tropical kudzu, and fava beans. (If you have seed of other species available you can share, let us know and we will send you our plant import permit.) Please note that our packets are for small trial plots; we do not have large quantities. If you want to buy larger quantities we will try to send you a source. We also have the "90-day" velvet bean that was grown in the southeastern part of the USA 50 years ago. At the time of the last corn cultivation farmers would plant this velvet bean. Both corn and beans were left in the field. Cattle were allowed to feed in the fields a couple of hours each day in the fall and winter, reportedly getting very fat. This variety is not sensitive to day length so produces 3 months after planting. The tropical kind only produces when days are short (flowering starts in November at ECHO). The 90-day kind has <u>some</u> of the itch-producing hairs Roland refers to, but not nearly as many as I have seen on the wild "pica-pica" in Honduras.]

INNOVATIONS IN GREEN MANURES (1995). Roland Bunch sent an intriguing report on his visit to the state of Santa Catarina in Brazil to see the work of EPAGRI. "It was, technologically speaking, the most impressive piece of work with small farmers that I have ever witnessed: highly innovative, aimed at a crying need throughout the third world, very popular with the farmers, widely disseminated, and with results in better economic standards among the farmers."

"Probably the most important issue of all is that we must get away from the escalating dependency on velvet bean (at least in Central America)." The following is abstracted from Roland's report.

The project has been continuing for 13 years, on both flat coastal areas and mountains. The technologies include contour grass barriers and orienting crop rows on the contour, but by far the most popular aspect of their work is green manures/cover crops (GMCCs). These plants are used to fertilize and condition the soil, usually left on the soil surface rather than buried. They are valued both as green mulches while growing and dead mulches after being cut. The vast majority of farmers use a traditional animal-drawn tool called a "rolo-faca" (knife roller?) which knocks over and cuts up the GMCC. Then with other animal-drawn instruments, they clear a narrow furrow from the mulch and plant their next crop. The resulting mulch both reduces or simplifies weeding and noticeably increases soil fertility. The majority of farmers who have used any of these systems for more than 5-6 years are no longer plowing, evolving from a minimum-tillage system to a <u>no-till system</u>. Seeds of the succeeding crop are merely hand-drilled into the soil. Some farmers' animal-drawn plows are rusting in abandonment.



The project works intensively with some 60 species of GMCC and have seen widespread adoption of about 25. We very much need to continue finding new species and varieties of GMCCs. Also, if we are to avoid having more and more insect and disease problems with GMCCs, we must <u>practice rotation</u> with them just as we rotate major crops. Furthermore, we must avoid becoming dependent on one or two species, lest we fall into the trap that *Leucaena*-based programs did in Southeast Asia when psyllid insects defoliated thousands of hectares of the world's most successful alley cropping. More specifically, for those many programs totally dependent on the velvet bean as a green manure crop, it should be noted that in southeastern Paraguay, a fungus has wiped out two of the four varieties of velvet bean that were previously used in the area.

<u>Maintaining soil cover</u> is much more important in preventing erosion than terraces or soil conservation barriers, live or dead. Roland says, "This is the first program I have seen which took this fact to heart, and was able to convince the farmers of its value through their own observation and experience. Thus, one more nail has been pounded into the coffin of our old bag of tricks, which featured contour ditches, grass or tree barriers, and contour rock walls. We are not ready to abandon these practices entirely, but certainly we are in the middle of a process of re-examination which will probably result in a major de-emphasis in our use of at least rock walls and contour ditches."

"The overall quantity of biomass is more important, relative to amount of nitrogen fixed, than we had previously assumed." For example, both oats and turnips are widely used as GMCCs. This makes sense if covering the soil and achieving a no-till system are as important to the farmer as are supplying nutrients to the soil.

The possibilities of GMCCs to fit into a wider and wider number of cropping systems was confirmed. Farmers were using GMCCs in cropping systems based on corn, onions, cassava, and fruit trees. Also Roland was shown photographs of GMCCs associated with wheat, grapes, tomatoes, soybeans, and sorghum. There is a tremendous need for farmer experimentation to discover new species and ways to adapt to differing agricultural systems. No agronomist-staffed research stations will ever be able to investigate and refine all the possibilities.

Probably the single most important result of the Brazilian work is that by eliminating the need for most of the weeding and all of the plowing, the small farmer is at much less of a competitive disadvantage with the large, mechanized farmer. Small farmers, especially on hillsides, were never able to carry out the really heavy and expensive labors of plowing and weeding as cheaply as could the mechanized farmer. The answer lies not in the mechanization of these jobs, but in their elimination.

Roland cites a study by Flores and Estrada which compared no-till velvet bean-based system with a neighboring mechanized modern system in Honduras. The velvet bean system was less productive, but the costs per ton of corn produced were 30% less.

JACK BEAN REPORT from Don Mansfield in Mali: "I planted jack beans (*Canavalia ensiformis*) in terrible soil (red clay with very little top soil). They were planted September 26 and are growing like mad, yet we have had no rain since October 9. I planted them as a ground cover for land just cleared and a green manure. We have been staking the ox there. He eats the grass and does not touch the jack beans. I am really surprised and pleased at how well they are doing. I had the seed and figured I had nothing to lose by planting them."

AN OBSCURE USE FOR JACK BEANS (for your interest only). Terry Waller sent us an article in the *San Angelo Standard Times* about a Texas couple that grows 5 acres of jack beans every year. A chemical company in Oklahoma, "Organon Teknica Corp., uses them to make the chemical that filters blood in a dialysis machine. They say jack beans are the only way they can make it."

COMMERCIAL LABLAB BEAN VARIETIES. Lablab beans (*Dolichos lablab*) are one of the "big three" green manure crops that our readers have been requesting since Roland Bunch's articles in EDN. Because so many of you are now growing lablab beans, we thought you might like to compare their growth to two top commercial varieties in Australia. We purchased varieties 'Rongai' and 'Highworth' from Sauers seed company (P.O. Box 117, Rockhampton 4700, Queensland, AUSTRALIA; fax 61-79-22-2219).

The catalog describes the two. 'Rongai' was derived from the original introduction of lablab from Kenya in 1952. It was released in 1962. It has white flowers and brown seeds. 'Highworth' came from southern India. It was selected from a large range of lines for its early flowering, high seed yield and satisfactory dry matter production. Both varieties have similar vegetative growth, but Highworth flowers are purple and the black seeds are slightly smaller. Flowering begins 3-4 weeks earlier than Rongai in northern Queensland and up to 6 weeks earlier in Central Queensland. Pod maturity of Highworth is more uniform and because the pods are borne well above the foliage, seed harvesting is simplified and seed yields are higher.

SUNN HEMP AS GREEN MANURE. Fr. Gerold Rupper reports that sunn hemp is receiving widespread acceptance as a versatile green manure in East Africa. His sunn hemp seed bank distributed 150 tons of seed last year. He sent information about his work with sunn hemp in Tanzania, as well as seed of the species he grows, *Crotalaria ochroleuca*.

Though sunn hemp has a totally different growth habit than the green manures we have featured in the past, it has many of the same uses. It is a vigorous upright legume growing 2 meters tall. (The velvet bean, jack bean and lablab bean are all vines.) Among other things, they use it to improve the soil, kill weeds, feed livestock, and control erosion.

It is especially suited for fruit groves because, unlike vining ground covers, continual vigilance to keep it from covering the trees is not necessary. They are using it with banana, plantain, citrus, and coconut. It can be cut at any time and left in the field as mulch. If it is cut one foot (30 cm) from the ground it will grow a second time. He stresses that not less than 10 kilo of seed per acre must be planted.

Fr. Rupper wrote, "In Hanendi, sunn hemp was planted in an orchard affected badly by insects. When it had grown a bit, the insects left the trees and started to live on the sunn hemp. When the sunn hemp was cut for mulching, the insects returned to the orange trees." "Just this week we were informed that insects which attacked the freshly planted maize moved to inter-cropped sunn hemp, ate the roots and are perishing."

Crotalaria is known to contain toxins, but this variety is free of toxin (except perhaps the seed) and is fed to livestock. It is cut about 3 months after planting. It is best cut in the morning, but keeps until evening. Later in the season cattle can be allowed to graze in the sunn hemp field, but they must not be allowed to spend more than about one hour in the area. [He does not say why.] Later he wrote us that "this year our farmer stopped cutting sunn hemp, instead allowing his 120-cow herd to feed freely in fields after first spending an hour in a grass field. The cows even ate dry stems." Fr. Rupper also says that the seeds should not be stored in a closed room where people are working.

The seeds are used to keep weevils from stored rice and maize. Sunn hemp seeds are spread over the ground and bags put on top of the seeds. This procedure is continued, layering sunn hemp seed and bags of stored grain. After about 9 months, the process must be repeated. As with velvet bean, farmers are especially appreciative of its usefulness in controlling weeds and improving the texture of the soil. He tells farmers, "If you have no chemical fertilizer when the season starts, plant sunn hemp between your food crops. If fertilizer arrives you may still be able to use it. If not, use sunn hemp and you will at least get a modest crop." Other uses are applying the dry stems and any husks to trees or gardens as mulch, or as bedding for livestock.

The seeds, about the size of millet, are mixed with two parts of coarse sand and broadcast by hand. They do not need to be covered, although it might be well to draw a branch across the newly planted field. They sprout after a few days and develop a strong root. Growth is rather slow until they reach about one foot, then they quickly grow to 2 meters or more. It is fairly drought resistant, recovering well when rains return. Plants bear seed after 3-4 months and die after 6 months. However, if they are cut back to about one foot (30 cm) above the ground, they again develop new leaves.

If planted densely in a well-prepared field, no further work is needed (except to keep out animals). Sometimes it is interplanted with maize. Some species of *Crotalaria* are useful in suppressing nematodes, but we do not know if this is one of them.

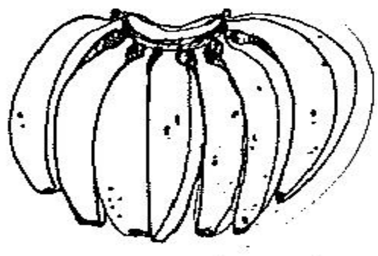
Another species of crotalaria, *Crotalaria juncea*, was released by the University of Hawaii (but no longer distributed by them; now available from Hikiola Coop, P.O. Box 231, Hoolehua, HI 96729, USA; phone 808/567-6774). 'Tropic Sun' is included in rotation with vegetables, ornamentals and others to add nitrogen, organic matter, suppress weeds, control erosion and reduce root-knot nematodes. In 60 days it can produce 145 pounds of nitrogen and 3 tons of dry matter per acre. Seed should be broadcast at the rate of 40-60 pounds per acre and covered 1/2 inch deep. High populations make the stems more succulent and hence better for incorporation into the soil. If allowed to grow too tall, stems become fibrous and difficult to deal with. Seeds can be inoculated with cowpea inoculant to maximize nitrogen fixation [presumably not needed where cowpeas are commonly grown]. It also lacks the poisonous alkaloids that make some *Crotalaria* species poisonous to livestock.

ECHO has trial-size packets of both species. For larger quantities of *C. ochroleuca* write to Fr. Rupper; St. Benedict's

Abbey; P. O. Peramiho, TANZANIA, East Africa. (Seed is $7 per kilogram including postage and he always offers phytosanitary certificates.)

TROPICAL KUDZU USED AS GREEN MANURE IN ZAIRE. Pete Ekstrand just visited us and had this account from the Paul Carlson Medical Program in Zaire. They have found that *Pueraria phaseoloides* (tropical kudzu or puero) grows vigorously and can even smother the vigorous native imperata grass if the grass is manually bent over. (This is not the same kudzu, *P. lobata*, that took over so much land in Alabama and elsewhere.) They then cut circles perhaps 2 meters wide and plant fruit trees, coffee etc. in the middle. It had not rained for 60 days when he visited and the ground in the circles was hard and dry. But one arm length under the ground cover the soil was moist and could be molded with the hand!

VELVET BEAN SUCCESS IN THE REPUBLIC OF BENIN. Velvet bean, *Mucuna* spp., has probably had more impact on farmers lives than any plant distributed from our seedbank. For review: velvet bean is an extremely vigorous vine that grows well in moderately poor soil, is drought resistant, and fixes a lot of nitrogen on its roots. It is interplanted with corn as a green manure. Soon after the corn matures, it covers the entire field, killing weeds. It can even kill vigorous grasses like imperata grass. It is cut back and left in place just before corn planting time. This kills the vine, which now protects the soil from erosion, retains moisture, and eventually turns into compost.



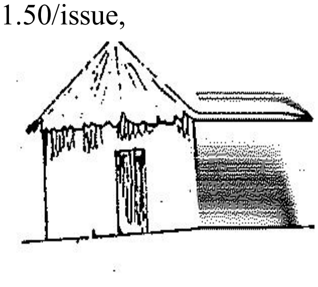
How effective can it be? Tom Post reported that in Belize it had doubled and, in some cases even tripled, corn yields. A Project Global Village publication in Honduras reported up to 4-fold increases in corn yields. The amount by which velvet bean can increase yields clearly varies greatly from place to place. If the soil is sufficiently depleted, it has the potential to make an enormous difference.

The latest annual research from the International Institute for Tropical Agriculture in Nigeria reports on their experience in Benin. Demonstration plots of different kinds were established in farmers' fields. Groups of farmers met periodically to observe the results and to discuss what experiments they would want to do on their own fields. They were especially impressed that velvet beans could smother young shoots of the vigorous weed "spear grass" (*Imperata cylindrica*). Farmers harvested 80% more corn with velvet bean than on continuously cropped land. Farmers that chose an alternative experiment (pigeon pea) had only a very modest improvement.

Next farmers with "completely depleted fields" were given two optional experiments: plant acacia trees for a multi-year fallow or velvet bean. Many planted velvet bean one month after sowing corn, during the first rainy season, then let it grow into a dense cover during the second rainy season. The results were dramatic. They recorded, on average, a 10-fold increase in corn yield (from 200 to 2,000 kg per hectare). National extension authorities are now applying this technology in all zones where soils are depleted and imperata is a problem.

The article ascribes the success of the effort to several factors. Farmers were not just involved in the experiments but also in choosing which experiments to do. A range of options were presented. Farmers had a chance to see demonstration plots showing the effects of technologies before they made a selection. They were not simply told about hypothetical benefits and asked to make a selection. Finally, the effect of velvet beans on corn yield plus the bonus of imperata control had a decisive impact.

LEGUME COVER CROPS IN ORCHARDS OR PLANTATIONS. This is the theme of "Cover Crop News" #7. A brief summary of the insightful six-page report follows. For a copy or to receive this bulletin (US$1.50/issue, published twice a year), write CIDICCO, Apdo. Postal 4443, Tegucigalpa MDC, HONDURAS, Central America; phone 504/32-7471 or 39-9870; fax 504/39-9896; e-mail cidicco@nicarao.apc.org.



Since the early 1900s legumes have been used as cover crops in oil palm plantations in Asia. More recently it is being evaluated for other trees: soursop (*Annona muricata*) in Costa Rica, citrus in Honduras and Surinam, bananas in Panama, etc. Primary benefits are controlling weeds, reducing production costs and use of chemicals, and increasing yields.

The largest oil palm plantation in Honduras has had an aggressive program of intercropping legumes for 15 years (at least 1,000 hectares). Weeding is one of the greatest expenses in the early years of establishing oil palms. They begin producing after three years, but it is six years before the canopy is dense enough to restrict weed growth. Many fruit trees never provide enough shade to substantially restrict weed growth.

Tropical kudzu (*Pueraria phaseoloides*) is the most commonly used legume. Seeds are small and slow to emerge, so one must start with a weed-free field, planting 5-8 kg of seed/ha. Full soil coverage occurs in about 10 months, so some weeding is required. Once established, the vine tends to climb trees. Cutting circles around the trees is the main labor in established fields.

There is so much shade in an established oil palm plantation that kudzu growth is reduced. At that time a more shade-tolerant legume, *Desmodium ovalifolium*, is planted at this particular plantation. A further benefit is that it does not climb trees. In Belize, "A privately owned farm called Parrot Hill operates several hundred hectares of citrus plantations covered with *Desmodium*."

Often farmers grow corn between rows in a new plantation. In this case, the legume of choice is velvet bean because it is much faster to establish. The drawback to velvet bean is that its vigorous growth requires much more frequent pruning around trees. [At ECHO velvet beans easily reach the tops of pine trees, though they have never hurt the trees.] CIDICCO is a networking organization. If you have had experience in this area, they (and ECHO) would like to learn details from you, especially from readers in Asia.

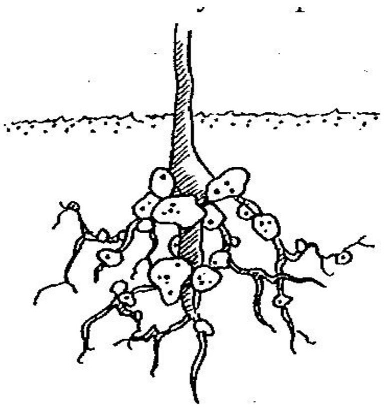
FERTILIZERS

"WHAT ABOUT RHIZOBIA INOCULANTS? I don't recall any mention of them in the 'Seeds Available from ECHO' listing. Isn't it likely that many of the legume seeds will need rather specific rhizobia inoculants at planting time?" wrote Bob Tillotson in Thailand. "Does the seed [velvet bean] need to be inoculated to fix nitrogen or will it naturally do it on its own?" from Jim Triplett in Guam. Similar questions regarding legume inoculation come up often. The following attempt to answer these questions is based on an article by Dr. Paul Singleton with NifTAL which was sent to us by one of our readers, Brian Hilton. The article, "Enhancing Farmer Income Through Inoculation of Legumes with Rhizobia: A Cost Effective Biotechnology for Small Farmers," addresses a series of questions. We will summarize these and add a few others.

What are rhizobia and what do they do? *Rhizobia* is a genus of soil bacteria that infect the roots of legumes and can fix (make available to the plant) atmospheric nitrogen. Unlike disease-causing bacteria, rhizobia enter into a symbiotic relationship with the plant. The legume provides the bacteria with energy and the bacteria provides the legume with nitrogen in a form it can use.

Does one rhizobium work with every legume? No, rhizobia are selective and grouped according to which legume species they will colonize. The rhizobia of some species, e.g. leucaena, are very specific. Others cross-inoculate many species. For example the "cowpea family of inoculant" will inoculate *Acacia albida, Cajanus cajan* (pigeon pea), *Desmodium* spp., *Lespedeza* spp., *Mucuna* spp. (velvet bean). Some species, such as peanut, called "promiscuous," can be inoculated with any of a number of rhizobia. Often one rhizobium strain will provide some biological nitrogen fixation (BNF) but will be less effective than another. Unless some strain of inoculant suited to the legume species you are growing is present in the soil, no BNF will take place.

Which of my crops are most likely to respond to inoculation? Responses are likely from species whose rhizobia are quite specialized such as soybeans and leucaena. Areas with a distinct long dry season of 6-8 months are also likely to respond due to existing rhizobia populations dropping off more quickly under these conditions.



How do I know if I need to inoculate my plant? Rhizobia live in nodules on the roots and can be easily seen. Well nodulated legumes will have nodules on the tap root. (Dig the plant and remove the soil carefully or the nodules will fall off.) Not all nodules are effective, however. Cut several nodules in half. Nodules that are effectively fixing nitrogen will usually be red or pink inside.

How are rhizobia introduced? Most commonly legume seeds are coated with the appropriate inoculant just prior to planting. A sugar or gum arabic "sticker" is used to attach the powdery inoculant to the seed. If healthy, nodulating plants of the same species are already growing in the area the proper rhizobia should already be available and need not be purchased. Just add about 5 g of soil from such a plot to each hole as seeds are planted.

Can I maintain my own inoculant? Yes. After a successful crop, soil will always retain some inoculum until the next season. Replanting the same species in the same soil year round will serve to increase inoculum for that crop. But, this practice may also increase the occurrence of some diseases.

Why doesn't ECHO carry inoculant for the legume seeds it distributes? This would seem to be the wise thing to do. However, it is challenging enough to preserve and monitor the viability of our stored seeds. Viability of inoculum is even more difficult to monitor and maintain which is why we leave this enterprise to those set up to do the job well.

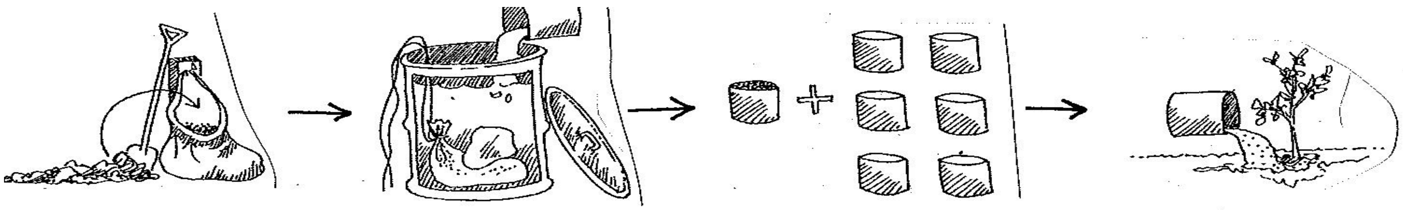
How much rhizobium is needed to inoculate a seed? It takes about 100 grams of inoculant to sufficiently treat one pound of leucaena seeds. A hectare of soybeans requires 286 grams of inoculant. Quality is more important than quantity. The best inoculant contains a billion rhizobia per gram, but it doesn't take long for quality to drop. This is why inoculation is done just prior to planting. Since you can't tell if inoculant is good or bad by looking at it, care should be taken to purchase from a good source and handle it properly. Inoculant should be protected from heat, light and desiccation and used as soon as possible. If a cool storage area is not available, a pot buried in a shady area is a good option. If transportation is required, a container covered with a damp cloth works well.

Where can rhizobia be obtained? Many countries manufacture inoculants for a number of crops. Contact your local agricultural extension agency or national department of agriculture to see if they have the inoculant you are looking for. If it needs to be imported, probably the best source for trees would be AgroForester Tropical Seeds (P.O. Box 428, Holualoa, HI 96725, USA; phone 808/326-4670; fax 808/324-4129; e-mail agroforester@igc.org). Liphatech Company (3101 West Custer Avenue, Milwaukee, WI 53209, USA; phone 800/558-1003 or 414/351-1476; fax 414/351-1847) has inoculant of many species, including GMCCs which are not trees. ECHO has a running list of sources we have come across to date; let us know if you cannot find a source. More information on this topic can be obtained by contacting the University of Hawaii NifTAL Center (Nitrogen fixation by Tropical Agricultural Legumes; 1000 Holomua Road, Paia, HI 96779, USA; phone 808/579-9568; fax 808/579-8516; e-mail NifTAL@.hawaii.edu). Other possibilities include the international agricultural research center nearest you (e.g. CATIE, CIAT, ICRISAT, IITA, IRRI, etc.), UNESCO (Microbial Resource Centre, Karolinska Institute, 10401 Stockholm, SWEDEN), or the BNF Resource Centre (Soil Microbiology Research Group, Rhizobium Building, Soil Science Division, Department of Agriculture, Bangkok 10900, THAILAND; fax 662-5614768).

Some concluding remarks: Each situation is different. If farmers can obtain inoculant quickly and reasonably it can be a low-cost input with high returns. If planting something like soybeans for the first time in an area, special efforts should be made to obtain proper inoculant. Legumes will grow without rhizobia, they will just require mineral sources of nitrogen like other plants. Even with proper inoculation, factors like low phosphorous, low pH and insect damage will limit yield. It should also be noted that it can take up to 20 days for biological nitrogen fixation to get going, so an application of nitrogen just after germination can help even if rhizobia are present.

HOW ADEQUATE IS CHICKEN MANURE TEA AS A FERTILIZER? One aspect of ECHO's ministry is behind the scenes for most of our readers. We help college professors and students in the sciences identify research projects that would be of benefit to the small farmer. Several ideas that could be done at an undergraduate level are written up in what we call Academic Opportunity Sheets. Nathan Duddles, while an undergraduate at California Polytechnic University, did an outstanding job answering the above question. I should think his 100-page report is of master's thesis quality.

He placed fresh chicken manure in a burlap bag, added a rock to make sure it did not float, and set it in water in a 35 gallon garbage can. If you were making such a tea, how long would you let it set to get out most of the nutrients? Nathan measured nitrogen in the "tea" each week and found that with 20 pounds of manure the maximum was nearly reached after only 1 week. It took 3 weeks with 35 and 50 pounds. However, the concentration apparently became so high that bacteria stopped working because he got even less nitrogen with 50 pounds than with 35 pounds.

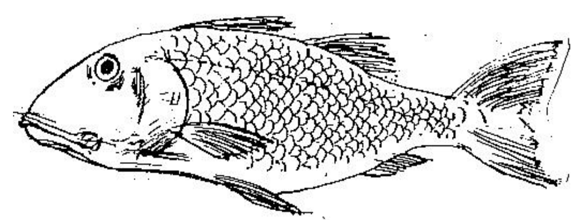


How does the tea compare to an ideal hydroponic solution? He measured several nutrients in the tea made from 20 pounds after 4 weeks. After diluting it to a fourth its original concentration he compared it to one such standard hydroponic solution. The tea concentrations followed by the standard are: total nitrogen (219; 175), nitrate (4; 145), ammonium (215; 30), phosphorous (54; 65), potassium (295; 400), calcium (6; 197), sodium (62; 0), magnesium (0; 2), iron (0; 2), manganese (0; 0.5), copper (0; 0.03), zinc (0.05; 0.05). The major nutrients and zinc are adequate. Only calcium and tiny amounts of iron, manganese and copper would need to come from another source. Unless you are growing hydroponically where all nutrients must come from the tea, these should be available from the soil or compost. He suggests that lowering the pH from 7.3 to near 6 might provide some of these, or some might come from dilute sea water.

Total nitrogen was ideal, though it would preferably be in the nitrate rather than ammonium form. However, the tomatoes grown with the tea or a hydroponic solution (somewhat different and less ideal than the one above unfortunately) grew only marginally better with the chemical preparation.

Tomatoes were grown in wood chips to see how the tea would work with our rooftop gardens and in sand or sawdust for comparison. Growth in wood chips was superior in every case, apparently because the other two were so wet that roots could not get enough air. He analyzed the concentrations of nutrients present in plant tissues and found that the only significant difference was that plants grown with manure had more sodium. The micronutrients must have come from the growing medium. We have a Technical Note on this subject for those interested in more details.

HOW TO MAKE A FISH EMULSION FERTILIZER. We had been asked this question but I never knew the answer until *Organic Gardening* answered it in their February 1990 issue. It does not make me want to go to my suburban home and try it, but I could see its use on the small farm.



"Place fish scraps in a large container and add water. Cover the top securely with a cloth plus a wire screen to keep out animals and insects. Put the container in a sunny location to ferment for 8 to 12 weeks. You can add a small amount of citrus oil or other scent to mask some of the odor, but be sure to keep the container where your neighbors won't complain. Try to avoid spilling any fish scraps or fishy water on the ground, where they will attract animals. When finished, a layer of mineral-rich oil will float on the water, and fish scales will have sunk to the bottom. Skim off the oil and store in a tight-fitting container. To use, dilute 1 cup of oil with 5 gallons of water. Your homemade fish emulsion will be rich in nitrogen, phosphorous and many trace elements, but generally low in calcium."

PIGEON PEA AND CHICKPEA RELEASE PHOSPHATES. (Based on an article in *International Agricultural Development*, April 1992.) We all know that legumes such as these two plants add nitrogen to the soil. Now scientists at ICRISAT in India have shown that they make available more phosphates. They do not add phosphate to the soil, but rather break up phosphate compounds in such a manner that phosphate that was already present but unusable by plants is now available. If you work where phosphate is one of the most limiting nutrients (a common situation in tropical soils), you might want to work these crops into your rotation.

How do they work? Studies show that the roots of pigeon pea exude acids (piscidic acid) which release phosphorous when it is bound up with iron. Chick peas release another acid (mallic acid) from both roots and shoots. In calcareous soils (alkaline soils with high calcium content), this acid breaks up insoluble calcium phosphate. Normally this release would only occur if the pH of the soil were lowered.

Both plants "are deep rooted, so their ability to release more phosphates means that valuable nutrients are being brought up from the deeper soil layers. Residues from both crops are adding extra phosphates which will benefit the crops which follow in the rotation. It is possible that some varieties ... exude more acid than others. So this trait could be another characteristic for selection [by plant breeders]."

PLANT TISSUE NUTRIENT TESTS AVAILABLE AT OHIO STATE UNIVERSITY. This technique is more sophisticated than most of you will require, but readers do occasionally ask us where they can get leaves of a plant analyzed to see what nutrient is causing a certain symptom. "Are the leaves yellow for lack of nitrogen or iron?" The theory behind this technique is that the ideal place to look for a nutrient deficiency is in the plant itself, rather than the soil. For example, even though a soil test might show that a particular nutrient is present in the soil in adequate amounts, a deficiency of that nutrient could still be causing the deficiency symptoms if for some reason (e.g. high pH) the plant could not take it up. A foliar spray with that nutrient might solve the problem.

I read in a newsletter that the Ohio State University experiment station offers this service at a good price. I wrote asking how one could get soil or plant material into the States for analysis. Professor Maurice Watson said you need to obtain a customs permit number from them, then send samples to them directly for analysis. No doubt many other Land Grant Universities offer similar services.

The standard plant tissue analysis for nitrogen, phosphorus, potassium, calcium, magnesium, manganese, iron, copper, zinc and boron costs $12.00. The standard soil test for pH, lime deficit, available phosphorus, exchangeable potassium, calcium and magnesium, cation exchange capacity and percent base saturation costs $6.00. Many other tests are offered, such as organic matter, available minerals, and heavy metals. Write the Ohio State University; R.E.A.L.; Ohio Agricultural Research and Development Center; Wooster, OH 44691; USA; phone 216/263-3760. Prices quoted were in effect April 1995. Be sure to write them for current prices, detailed instructions on how to take samples, how much to send, etc. before submitting any samples.

"FEEDING AND BALANCING THE SOIL" is a five-day short course taught by Neal Kinsey, author of *Hands-On Agronomy*, about $475 registration fee includes lunches. Offered annually (during July in 1995), at Little Creek Acres, a non-profit demonstration farm for sustainable agriculture. Other courses are offered from time to time. For information write Center for Living in Harmony, 13802 Little Creek Lane, Valley Center, CA 92082, USA; phone 619/749-9634; fax 619/749-0720.

INTERNATIONAL AG-SIEVE is "a sifting of news in regenerative agriculture." This publication changed format in 1995 to 4-page information sheets on specific topics in ecologically sound agriculture. Issue #1 was on vermicomposting (using worms to produce high-quality fertilizer); issue #2 discussed the benefits of soil-improving legumes. Each edition has basic information, contacts, and publications on the theme. Readers are encouraged to follow up specific questions with the professional references listed. An index of available issues is sent periodically to individuals on the mailing list, and readers select the issues they wish to receive (about $4/issue). They hope to publish 12 issues per year. Send your name, address, and a brief description of your work to International Ag-Sieve, Rodale Institute, 611 Siegfriedale Rd., Kutztown, PA 19530, USA; phone 610/683-1400; fax 610/683-8548.