ECHO®

Technical Note #10

Green Manure Crops

What's Inside:

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Lablab bean at ECHO.

Green manure crops are crops that are [often times in North America] 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, including:

- They provide large quantities of nitrogen for the soil.
- 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.
- Green manure crops present no transportation problems, in contrast to compost and chemical fertilizers.
- Green manure crops require absolutely no capital outlay after the initial purchase of a handful of seed. Because they require no chemical inputs, dependency on outside sources of fertilizer, nutrients, and pesticides is reduced.
- 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.
- The cover they provide for the soil protects it from wind and water erosion.
- 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 (inasmuch as fodder at this time of year is the limiting factor in traditional animal raising in much of the Third World).
- Some green manure crops provide human food, including various kinds of edible beans, peas, and pods.
- Green manure crops can provide income, by selling firewood, food or feed (and maybe seed).
- 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.
- Some green manures, when intercropped with basic grains, can control weeds, thereby 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. As petroleum prices increase, prices of chemical fertilizers could easily become too expensive to be economically feasible for use with traditional basic

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grains. Almost overnight, Third World basic grain production could plummet. Widespread use of green manure crops could avert much of this impact.

COMPARISON WITH COMPOST

Since 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.

- 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. Organic matter is often in short supply on villagers' farms (or is already being recycled).
- 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.
- A compost heap takes a tremendous amount of work. Though compost will often benefit 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), it takes nowhere near the labor compost does. 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 bringing a net savings in labor.
- A compost heap requires water. This often means it is made near a water supply but at a fair distance from where it is to be applied. Green manure crops are planted to take advantage of available rain water, and are planted right where they will be used.
- Compost cannot be used as a food source, either for animals or humans.

CROPPING SYSTEMS

It is often difficult for smallholder farmers to adopt green manure crop use. 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 to improve crops grown for subsistence, because they earn no money from them with which to replace what they have spent.

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

- It must be a non-woody annual with vigorous growth.
- It should grow well in the poorest of soils in the area without needing any kind of fertilizer.
- 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.
- The plant must have few enough natural enemies that it will grow vigorously without the use of any pesticides or major labor requirements.
- The legume should either be very shade-resistant (for intercropping) or drought-resistant (for growing into or through the dry season).
- If possible, it should first cover the ground well, then climb any stalks that remain in the field.
- If possible, the green manure crop should be edible by animals and/or humans.

World Neighbors/Central America has found a number of ways to overcome most of the problems associated with green manures to the extent that farmers have accepted them 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. In Central America, our work has used the following four ways to produce green manure without reducing the amount of land used for other crops:

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 the first year, and usually with large 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 the majority of their growth would occur during the dry season, thereby using land that would not ordinarily be under cultivation.
3. Wherever multiple-year fallows and/or shifting agriculture is used, green manures can be planted on land the first year it is to go fallow. Thus the period of fallow can be cut to one year instead of three or more years.
4. Use a green manure crop in conjunction with alley cropping.

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 larger group 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).

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

On flatter land, the green manure should be cut and allowed to dry for a couple of weeks before incorporating it into the soil, if you choose. 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 *Canavalia* 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!

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

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 better C:N pigeon pea leaves. The presence of the pigeon pea (a cash crop) will also prevent burning of residues.

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. This produces less green manure than other systems, but can be implemented where green manure cannot be intercropped among traditional crops.

SOME PLANT SPECIES SUITABLE FOR GREEN MANURES

Although a good deal of research still needs to be done in finding adequate plant species (far too much of the research has been done on fertile experimental stations or with the use of chemical fertilizers, thereby making it virtually useless to small farmers), there are a few species that seem to fit most of the requirements for being a good green manure.

Canavalia ensiformis (jackbean) is an incredibly drought-resistant, hardy legume that grows well in extremely poor, droughty soils (and apparently less well in fairly fertile soils). There are two kinds of jackbean, 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 seedpods 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.

Jackbean cover crop at ECHO.

Jackbeans 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 cornfields, 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.

The jackbean will be eaten by grazing animals, but is preferred less than other green manures. Hence jackbeans 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 anthills to eliminate them. [Ants carry leaves into the mounds as food for the fungi upon which they live and jackbean leaves reportedly kill the fungi. Dr. Warwick Kerr in Brazil writes that planting sesame near the mounds has a similar effect.]

Jackbean should be planted in soil that has been cultivated within three 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 cornfields an important advantage of this and the velvet bean is that use of these plants may entirely eliminate the second weeding). Jackbean 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 or broadcast, 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, jackbean can be used in grain fields, under orchard trees or to shorten fallow periods, but is not as vigorous as the velvet bean; perhaps mixtures of the two would function best.

Mucuna pruriens (velvet bean) is the most promising green manure that we have worked with. It covers the soil completely and then climbs as high as its support allows (well over 6 meters). Velvet bean use has spontaneously spread from village to village throughout Mexico and Central America without outside intervention. In Mexico it is planted to shorten fallows and in Honduras to intercrop with corn.

Velvet bean first covers the ground almost completely, and then climbs vigorously. Where corn stalks are present, it will eventually form a mat of leaves near the top of the stalks, with little more than stems and pods underneath. Stems remain thin and non-woody throughout the plant's life. The plant dies after it has set seed. [Ed: Seeing velvet bean grow to the tops of pine trees at ECHO prompted many to ask if it might not take over like kudzu did in the southeastern USA. This might have happened were it not that the plants die after setting seed. Velvet bean was a major US crop for years before WWII, and such problems were never recorded.]

Velvet bean climbing maize in ECHO's South Africa research. Photo by Tim Motis.

Sometimes velvet bean roots produce solid clusters of dark red nodules up to 4 cm in diameter. This heavy nodulation seems to occur most frequently in infertile or sandy soils. Like jackbean, the velvet bean will volunteer heavily the second year if seed is allowed to mature and fall on the ground. Farmers in Chiapas, Mexico get growth each year in their cornfields without bothering to reseed. 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.

The soils in which velvet bean has not done well are those that are waterlogged or have a pH of 4.5 or less. Like the jackbean, velvet bean needs to be planted in a field that is either sandy or has been cultivated within 3 years. Velvet bean will withstand a cooler climate than jackbean, 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-tolerant as jackbean.

Velvet bean is presently our species of choice for cornfields, 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 dactilon*) and imperata grass (*Imperate cylindrica*). [Ed: 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 a very good, fairly palatable high-protein fodder for most animals, especially ruminants and rabbits. It can be eaten (greens and pods) by most livestock, except pigs and chickens. The seeds carry anti-nutritional factors and will actually retard or slow growth in some nonruminants. 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.

For a time, ECHO promoted the use of velvet bean seeds as a coffee substitute, locally known as "nutri-café" or "nutri-coffee." However, the existence of several anti-nutritional factors and toxic compounds in the seed, principally L-dopa, a drug used in the treatment of Parkinson's disease, caused us to rethink this process. The consumption of velvet bean in "nutri-café" and other recipes caused people to suffer symptoms of nausea, vomiting, anorexia, aggression, paranoia, hallucinations, delirium and severe depression. Now, through the work of an international team of scientists, toxins such as L-dopa can be removed from the bean, making it safe for human and animal consumption.

Like the jackbean, velvet bean is native to Central America. However, there are two kinds. The wild variety (*M. pruriens pruriens*), which is found pan-tropically, contains extremely irritating itchy hairs or trichomes on the mature pod. Villagers who know this plant will not want to plant the non-itchy varieties (*M .pruriens utilis*) until they've been shown that the pods are harmless. Although these "hairs" are useful medicinally, we don't recommend the use of the irritating kind with small farmers.

Slugs may damage velvet bean in warm climates; rabbits, leaf-cutter ants and iguanas are other pests. However, due to the L-dopa content and other toxins, velvet bean has relatively few pests. In some locations, rats use velvet bean stems to climb up and eat the corn. Planting the beans later or cutting it back when it gets too large has helped with this problem. It also must be watched and cut back if planted near trees.

Everything that was said about planting jackbean also applies to velvet bean. However, fine-tuning is needed to determine when to plant velvet bean in local cornfields. 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 velvet bean grows rapidly and may need to be pruned.

Corn crops growing where velvet bean or jackbean have been incorporated can often benefit without initial chemical fertilization, but will often show signs of nitrogen deficiency by tassling time. Farmers in Honduras side dress these crops with urea. 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 indicate much problem with this nutrient. It is possible that the increased organic matter from the velvet bean is increasing the availability of soil phosphorous enough to alleviate this deficiency problem.

In corn velvet bean produces an average of 2.5 to 3.5 kg (6-7 pounds) of above-ground biomass (fresh weight) per square meter (30 T/Ha). The effect on subsequent plantings is roughly equal per kilogram to that of cow manure or half that of chicken manure, although this varies from field to field. When incorporated into the soil, velvet bean often doubles subsequent corn yields, and when used as 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 mulch has many benefits (erosion control, weed control, moisture retention), the greater effect on corn yield after incorporation may lead you to incorporate residues rather than leave them as mulch. All nutrients probably become available in one season when incorporated, whereas they are more slowly released when left as mulch, accounting for greater effect. However, almost surely some or much of the remaining nutrients will benefit subsequent corn crops. Experience at the Rodale Institute has shown that over several years the total amount of nutrients available for plants is about the same whether residues are left as mulch or incorporated. *We recommend the 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 have recently started doing the following. The green manure (velvet bean or jackbean) 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 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 subsequently 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.

In Togo, velvet bean grew well and was incorporated into the soil five months before planting corn. There was virtually no response to the green manure. Our hypothesis is that the green manure was burned or leached out. We are now testing whether under such conditions a green mulch (jackbean 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.

Dolichos lablab or *Lablab purpureus* (lablab bean) 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 jackbean, is very shade-tolerant, and is among the most palatable of legumes for animals (definitely preferred over velvet bean or jackbean). Lablab beans grow well from sea level up to about 1500 meters. They require well-drained soils. In pure stands, lablab beans should be planted at rates of 10 seeds per square meter. We have not found a good system yet for planting in cornfields 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.

Lablab bean plot in the Monsoon demonstration area at ECHO.

Lablab starts flowering after 3 months and will 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. A difference from the velvet or jackbean is that the lablab bean can be cut off nearly at ground level and will grow again, although with somewhat less vigor.

Even with insect damage, lablab growth is so vigorous that it remains comparable to velvet bean. Because animals prefer it to almost anything else, lablab beans cannot be grown where animals run free. Where it grows well, the lablab bean has produced a phenomenal 11 kg per square meter (110 T/Ha) of above ground organic matter (fresh weight).

Lablab beans are traditionally planted toward the end of the agricultural cycle in come 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.

Clitoria ternatea (Butterfly Pea) is even more drought-resistant then the *Canavalia*, although being small-leafed, it does not cover the soil well. We really do not have much experience with this plant yet. It grows well at sea level.

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 that took over so much land in the southeastern USA. They then cut circles perhaps 2 meters wide and plant fruit trees, coffee, etc. in the middle.

Crotalaria juncea (Sunnhemp) is reported to be receiving widespread acceptance as a versatile green manure in East Africa (according to Fr. Gerold Rupper in Tanzania). Jackbean, velvet bean and lablab bean are all vines. Sunnhemp is a vigorous upright legume growing 2 meters tall. When planted in narrow rows, mature plants tend to fall over. When planted in the field, plants tend to hold each other up. While sunnhemp has a different growth habit than most of the green manures we have featured, the uses are much the same, including weed control, livestock feed, and erosion control.

Sunnhemp planting at ECHO.

Sunnhemp is especially suited for weed control in fruit groves because, unlike vining ground covers, continual vigilance to keep it from covering

the trees is not necessary. It is being used 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. Fr. Rupper stresses that no less than 10 kilograms of seed per acre must be planted.

Fr. Rupper wrote, “In Hanendi, sunnhemp 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 sunnhemp. When the sunnhemp 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 sunnhemp, ate the roots and are perishing.”

Crotalaria is known to contain toxins, but this species is free of toxin, except perhaps the seed. It is cut about 3 months after planting. Later in the season, cattle can be allowed to graze in the sunnhemp field. One farmer noted that after first spending an hour in a grass field, his cows even ate the dry stems.

Sunnhemp seeds are used to keep weevils from stored rice and maize. Seeds are also spread over the ground with bags of grain put on top. This procedure is continued, layering sunnhemp 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. Fr. Rupper tells farmers, “If you have no chemical fertilizer when the season starts, plant sunnhemp between your food crops. If fertilizer arrives you may still be able to use it. If not, use sunnhemp and you will at least get a modest crop.” According to Fr. Rupper, sunnhemp will completely kill striga. A simple alley cropping system has been developed for controlling this important weed. When a field is ploughed and sown to corn or sorghum, sunnhemp is sown along with the grain at a rate of 10 kilograms (mixed with 20 kilograms of sand) per acre. At weeding time, sunnhemp is left standing in every third row, knowing that it will kill the crop. After seven or eight months sunnhemp seeds are harvested and the dry stems are placed in the furrows. If this is practiced each year, you can have a sustainable system free of striga. Other uses for sunnhemp include 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. Sunnhemp is fairly drought resistant, recovering well when rains return. Plants bare 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 sunnhemp is interplanted with maize. Some species of *Crotalaria* are also useful in suppressing nematodes, but we do not know if this is one of them.

Unless otherwise noted, all photos are by Cody Kiefer.