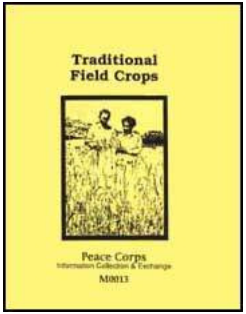

Traditional Field Crops (Peace Corps, 1981, 283 p.)

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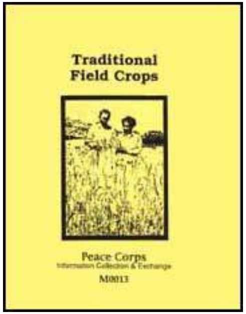

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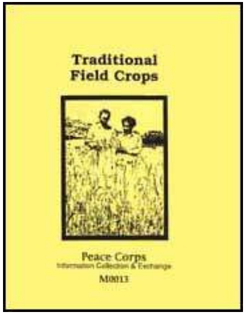


Traditional Field Crops (Peace Corps, 1981, 283 p.)

Pest and disease control

Weed control

How Weeds Lower Crop Yields

Numerous trials in the U.S. have shown maize yield losses ranging from 41-86 percent when weeds were not controlled. One trial in Kenya yielded only 370 kg/ha of maize with no weed control compared to 3000 kg/ha for clean, weeded plots. A CIAT trial with beans in Colombia showed a yield drop of 83 percent with no weeding.

Of course, all farmers weed their fields to some extent, but most of them could significantly increase their crop yields if they did a more thorough and timely job. A University of Illinois (U.S.) trial showed that just one pigweed every meter along the row reduced maize yields by 440 kg/ha. By the time weeds are only a few inches tall, they have already affected crop yields. Weeds lower crop yields in several ways:

- **They compete with the crop for water, sunlight, and nutrients.**
- **They harbor insects, and some weeds are hosts for crop disease. (especially viruses).**
- **Heavy infestations can seriously interfere with machine harvesting.**
- **A few weeds like Striga (witchweed) are parasitic and cause yellowing, wilting, and loss of crop vigor.**

Relative competitive ability of the reference crops: Slow starters like peanuts, millet, and sorghum compete poorly with weeds during the first few weeks of growth. Low growing

crops like peanuts, bush beans, and bush cowpeas, however, are fairly effective at suppressing further weed growth once they are big enough to fully shade the inter-row spaces. However, tall-growing weeds that were not adequately controlled earlier can easily overtake thse "short" crops if allowed to continue growing.

Some Important Facts on Weeds

Broadleaf versus Grassy Weeds

Broadleaf weeds have wide (broad or oval-shaped) leaves with veins that form a feather-like pattern. Grassy weeds are true grasses and have long, narrow leaves with veins that run up and down in a parallel pattern. A few weeds like nutsedge (nutgrass) belong to neither category, but are sedges, all of which have triangular stems. Some chemical herbicides are more effective on broadleaf weeds, while others give better control of grassy types.

How Weeds Reproduce and Spread: Annual versus Perennials

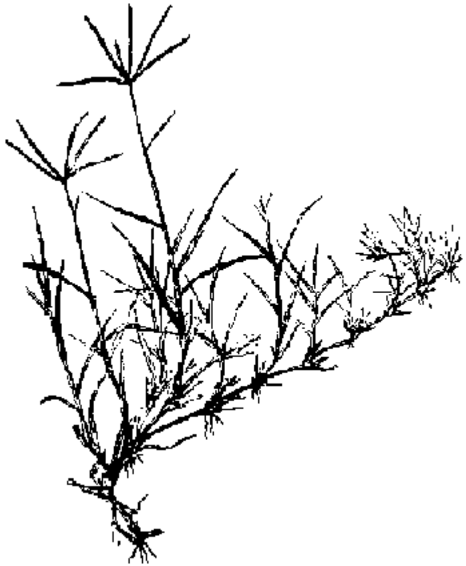
Annual weeds live only a year or so and reproduce by seed; they are the most common weeds in many fields. In the tropics, annuals may live more than a year if rainfall is sufficient. Most annuals produce tremendous amounts of seed, some of which may not germinate for years.

Rough Pigweed, Redroot (Amaranthus retroflexus)

An example of an annual broadleaf weed; reproduction is by seed.

Yellow Nutgrass (Cyperus esculentus)

An example of a sedge-type weed. The main stems of sedges are triangular in shape. This particular type reproduces by seed as well as producing underground "nuts," which sprout into new plants.



Bermuda Grass, Devilgrass (Cynodon dactylon)
An example of a perennial grassy weed; reproduction is by above-ground runners called stolons as well as by seeds.

When the soil is stirred with a hoe, harrow, or cultivator to kill weeds, one crop of them is destroyed, but more weed seeds are brought closer to the surface where they can sprout.

Annual weeds should be controlled before they produce seed. Even so, permanent eradication of annual weeds is not possible because most fields contain millions of weed seeds waiting to germinate, and the supply is continually replenished with more seeds brought in by wind, water, animals, animal manure, and contaminated crop seeds.

Perennial weeds live more than two years. Most produce seed, but many also propogate by means of creeping, aboveground stems (stolons), and creeping underground stems (rhizomes). Hoeing or mechanical cultivation may actually aid in spreading them around the field.

Many herbicides will kill only the topgrowth, and there is usually enough food in the underground parts to continue propagation.

Identifying Weeds

Where weeds are being controlled by hoeing or mechanical cultivation, their specific identification is usually not important. Where chemical weed control is used, however, the farmer and extension worker should have a good idea of which specific weeds are present since herbicides do not give broad-spectrum control. (See bibliography for sources of further information on weed identification.)

Weed Control Methods

Burning

When land is cleared by burning, standing annual weeds are killed along with weed seeds very near the soil surface. However, burning will not kill weed seeds or reproductive underground parts of perennial weeds if they are deeper than 4-5 cm. Furthermore, as the brush is often placed in windrows or piles before burning, much of the soil may not be affected by the fire. Some perennial tropical grasses such as Guinea (Panicum maximum) and speargrass (Imperata cylindrica) are actually stimulated into dense regrowth by burning. On the other hand, weeds may be less of a problem under slash and burn farming, because the soil is usually not turned by plowing or cultivation which brings more weed seeds to the soil surface.

Mulching

Mulching the soil surface with a 5-10 cm layer of crop residues, dead weeds or grass can give very effective weed control and provide a number of other benefits:

- **Erosion is greatly reduced on sloping soils.**
- **Soil water loss by evaporation amd runoff is greatly reduced.**
- **In very hot areas, soil temperatures are reduced to a more beneficial level for crop growth.**
- **Organic matter is eventually added to the soil. In trials conducted by IITA in**

Nigeria, mulching increased maize yields by 23-45 percent and greatly reduced the heavy labor requirement for hand weeding which accounts for 50-70 percent of the hours needed to grow maize in that area.

Shading (The Row Crop Principle)

Arranging crops in rows facilitates hand weeding, but also makes possible mechanical cultivation (weeding) with tractor or animaldrawn equipment. In addition, the rows permit the crop to exert better shade competition against the weeds.

Hoe and Machete Cultivation

Weeding with hand tools is an effective method if sufficient labor is available. It is common, however, for small farmers who rely on this method to fall behind in weeding and crop yields often suffer.

Animal and Tractor-drawn Cultivation

Disk harrows, field cultivators, and spike-tooth harrows can provide excellent preplanting

weed control. The spike-tooth harrow can also be used to control emerging weeds until the crop is about 7.5-10 cm tall. without serious damage.

Animal-and tractor-drawn row cultivators can be used from the time the crop is a few centimeters tall.. They are faster than weeding by hand, and a one-row animal-drawn model can easily cover 3-4 ha/day unless the rows are very narrow. They can also be adjusted to throw soil into the row itself to kill small weeds by burying them. If operated too deeply or too close to the row, however, serious root pruning (cutting off crop roots during cultivation between rows) may result.

Herbicides

Herbicides can greatly reduce labor requirements and permit a farmer to grow a larger acreage. They also avoid root pruning, soil compaction, and stand reduction which are caused by hand tools or mechanical equipment. In a number of cases, herbicides like atrazine have proven competitive with hand labor in maize production in developing countries. Improved methods for small farmer application of herbicides such as granular forms and ultra low volume sprayers are being developed by IITA. Herbicides do have some very definite disadvantages that must be considered when working with small farmers:

- **They are less reliable than hand tool or mechanical weeding and most require careful and accurate application. This can be achieved by small farmers using backpack sprayers, but it requires some training.**

- **Weed control is seldom complete. Most herbicides are not broadspectrum, and it is important to analyze the type of local weeds species present before choosing a product.**

- **Most soil applied herbicides require a certain amount of rain within a week after**

application in order to move the chemical into the zone of weed seed germination. Others need immediate incorporation into the soil with a disk harrow or rototiller.

- **Improper application may damage the crop.**

- **Nearly all herbicides are unsuited for use in intercropping involving cereals and legumes due to the danger of crop injury. These products are crop-specific as well as weed-specific.**

- **Without proper training and care, farmers may subject themselves and the environment to serious risks through the misapplication or mishandling of these toxic chemicals.**

Guidelines for Non-Chemical Weed Control in the Reference Crops

Pre-planting Weed Control

Successful weed control begins with planting the crop in a seedbed free of standing or emerging weeds. This means that when planting on tilled ground (as opposed to pure slash and burn agriculture), the field should undergo some form of cultivation (i.e. plowing, harrowing, hoeing, etc.) as close as possible to planting. This will give the young seedlings a "head start" on future weeds which is especially important under two conditions:

- **Slow starters like sorghum, millet, and peanuts: They are very vulnerable to early season weed competition.**

- **Reliance on tractor or animal-drawn row cultivation: The only way these cultivators can control weeds in the crop row is by throwing in soil to bury them. This means waiting until the crop is tall enough (usually over 5 cm) so that it will**

not be buried too. The problem is that weeds already present or about to emerge in the row at planting may be able to grow tall enough to escape burial by the time cultivators can be used.

Frequent pre-plant harrowings do little to reduce the field's potential weed population and they can increase soil compaction and destroy good filth by speeding up the loss of organic matter.

How to Use a Spike-Tooth Harrow on Young or Emerging Seedlings

If large numbers of weeds emerge at the same time as the crop, a shallow working of the entire soil surface (including the rows themselves) with a spike-tooth (pegtooth) harrow may be the best solution if hand weeding labor is inadequate or too expensive. This method is best suited to crops planted at least 40-50 cm deep and can be used any time from two to three days after planting until the crop is 7.5-10 cm tall.

Peanuts and beans, with their brittle stems, are more likely to be injured than maize and sorghum, unless certain precautions are taken (see below). Millet is usually planted too shallowly to tolerate this method well.

Guidelines for using the spiketooth harrow for this type of weeding:

- **The weeds should be either just emerging from the soil or still very small.**
- **If the soil is very wet and the weather is cloudy, the weeds may be transplanted instead of killed.**
- **The harrow should be run only deep enough to uproot the tiny weed seedlings.**
- **Beans and peanuts are more easily injured when they first emerge and still have**

the crook (bend) in the stem.

- **Less injury is likely if the harrow is used in the afternoon when the plants are less turgid (hard) and brittle.**

- **Care must be taken to ensure that the draft animal or the tractor tires do not run over the row itself.**

Using the spike-tooth harrow in this manner once or twice can often eliminate future, more laborious weeding. Use of this harrow prior to plant emergence is also useful for breaking up any soil crusting that might hinder emergence. (For more information on the spike-tooth harrow, see the PC/ICE Animal Traction manual.)

Guidelines for Animal-and TractorDrawn Row Cultivators

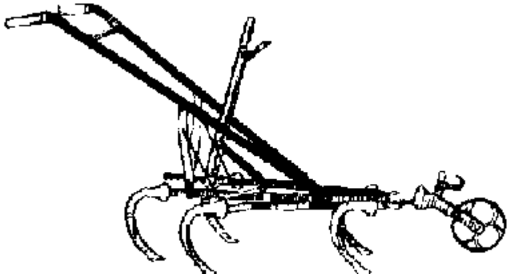
Animal-drawn cultivators are widely manufactured in one-row models and cost about $100-$200 in U.S. currency. They are well worth the investment since they permit more timely and rapid weeding than is possible with hand tools. A onerow cultivator can easily weed 2-3 hectares per day of wide row crops such as maize, millet, and sorghum. Animal-drawn models are available either as single-purpose units or as multi-purpose toolbar frames with attachments for plowing, ridging, and cultivating.

Tractor-drawn cultivators usually consist of a toolbar to which cultivating shanks are attached. Tworow, four-row, six-row, and eight-row arrangements are most common. It is important to remember that such multirow arrangements require uniform spacing of the planting rows to avoid crop injury.

Cultivator Shovels and Sweeps: Both animal- and tractor-drawn cultivators use sweeps and/or shovels attached to the cultivator shanks to do the actual weeding. Some important considerations:

- **Shovels require deeper soil penetration for good weed control and throw more soil than most sweeps. This means that in the case of tractor usage, shovels cannot be operated as close to the crop rows as fast as most sweeps.**

- **Sweeps are available in widths up to about 50 am. However the farmer is usually better off using two or more sweeps of smaller widths or a combination of sweeps and shovels to cover one inter-row space. This permits more effective weeding and more accurate adjustment than is usually possible with just one wide sweep. Wide sweeps are also more prone to breakage.**



An animal-drawn cultivator which can be adjusted for width by moving the upright level.

Some General Guidelines for Weeding with Row Cultivators

1. A sure sign of root pruning is the accumulation of crop roots on the cultivator shanks. To avoid serious root pruning, shovels and sweeps should be operated as shallowly and as far from the crop row as practical. The ideal depth and distance will vary with crop size and row width. For example, when maize is 20 cm tall, it can be cultivated up to 10-15 cm from the stalks. However, once the crop is 75 cm tall, such deep cultivation would prune off much of the root systems. Maximum depth should be about 5.0-7.5 cm at this stage. Sweeps can be run shallower and

closer to the row than shovels and do a good job of weeding without root damage.

2. Sweeps should be set to operate almost flat with the tips angled just slightly downward. When the point rests on a floor or the ground, the outside tips of the wings should rest about 30-60 cm off the surface.

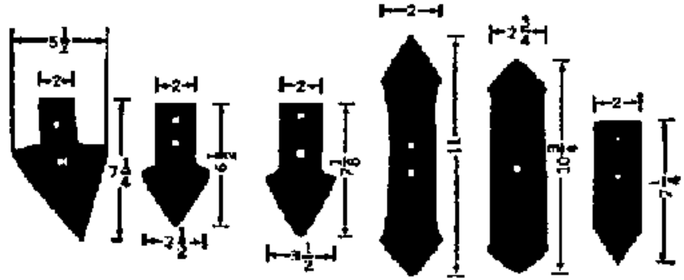
3. Weeds should be killed early to avoid yield losses and to permit more effective control, especially of weeds right in the row.

4. The nitrogen sidedressing is best applied right before a cultivation, then the fertilizer can be worked into the ground a bit to prevent losses through water runoff or through conversion into ammonia gas (a problem with urea).

5. Cultivation is most effective when the soil surface is dry; wet soil keeps partially uprooted weeds alive.

6. The cultivator should be adjusted so that it throws sufficient soil into the crop row to bury small weeds without smothering the crop. DO NOT THROW SOIL INTO PEANUT ROWS (see page 248)

7. Unnecessary cultivation can harm the crop. The main purpose of cultivation is to control weeds, although it is sometimes used to break up a hard soil crust that is interfering with water absorption. Excessive cultivation damages plants and roots, wastes time and labor, and increases soil compaction and loss of humus.



Different types of cultivator shovel; note that some have reversible points.

Different types of sweep. They come in many widths. The height of the sweep's crown determines how much soil it throws. The halfsweeps are used next to the crop row to help avoid damage.

Guidelines for Cultivating Reference Crops

MAIZE AND SORGHUM: In many regions, these two crops are commonly "hilled up" during successive cultivations to provide better drainage and to help prevent lodging.

BEANS: Throwing soil into the plant row not only controls small weeds and provides better drainage (good for root rot control), but also helps promote the growth of secondary roots. This is especially beneficial in cases where the primary root system has been damaged by root rot. Do not cultivate beans while the leaves are wet since this increases the spread of foliar diseases like bacterial blight and anthracnose.

PEANUTS: Soil should not be thrown into the crop row, especially when the peanut plants are young. This practice injures the stems and buries some of the young branches which greatly increases the plants' susceptibility to Southern stem rot (Sclerotium rolfsii) and also interferes with normal branch development. There is no need to throw soil into the row if early season weed control is adequate.

"Flat" cultivation will avoid throwing soil into the row. The secret of flat cultivation is good early-season weed control to prevent weeds in the row from overtaking the crop. Most farmers in the U.S. use herbicides to provide initial control for the first six to eight weeks. If using tractor cultivators, farmers should use "high speed" sweeps which have a low crown and do not throw as much soil. Wide sweeps enable the cultivator shanks to be kept well away from the row since they, too, throw a lot of soil.

Cultivation should cease once the pegs begin to elongate, around eight weeks after plant emergence. Cultivation at this stage can damage the pegs and help spread rosette virus, a serious problem in Africa. By this stage, the plants should be big enough to provide good competition with any emerging weeds.

A Special Note on Striga

Striga (witchweed) is a parasitic annual weed which invades the roots of grass family plants (sorghum, maize, millet) and can cause serious losses. There are several species found in Africa, India, Southeast Asia, Australia, and the Southeastern U.S. In West Africa, improved varieties of sorghum are sometimes heavily attacked. Improved maize varieties are somewhat less susceptible but native varieties have better resistance. Gero type millet usually escapes injury since it is harvested during the wet season when striga seeds are dormant. Maiwa millets, which mature later, are more prone to attack. Striga seeds are stimulated to germinate by moisture and plant juices (root excretions) from the roots or grass family host plants and emerge above ground in about one to two months. Flowering

occurs three to four weeks later, and the seeds mature in another 30 days. A single plant can produce half a million seeds which are easily spread by wind, water, and tools. Crops are often injured before the weed emerges, and severe attacks cause stunting, yellowing, and wilting.

Striga Control Recommendations

- **Hand weeding provides partial control; some herbicides give good control, and one foliar product has been developed that can be applied with an inexpensive water pistol.**

- **High fertility helps plants resist attacks, and plant breeders are working on varietal resistance.**

- **An effort should be made to prevent movement of striga seed from infested to noninfected fields.**

- **All crops should be kept free of grassy weeds which are hosts for striga.**

- **"Trap" crops of cereals or grasses can be planted to stimulate striga germination and then plowed under before the weeds have produced seeds.**

Guidelines for The Use of Herbicides in the Reference Crops

In some parts of the developing world, there is a critical labor shortage at weeding time. Herbicides can be economically feasible for small farmers under these conditions. In Central America, herbicide use by small farmers has become common in many districts. Chemical weed control is a sophisticated management practice, however, and most farmers using herbicides need more instruction in proper application procedures.

How Herbicides Kill Weeds

Some herbicides like glyphosate will kill weeds only if sprayed on their leaves. Others like simazine will not control emerged weeds, but must be applied to the soil itself where weeds are killed as they germinate by absorbing the chemical through their roots. Some herbicides like atrazine are effective either way.

Choosing a Herbicide

The choice of a suitable herbicide depends on the type of weeds present and the crop's tolerance to the chemical. Weed Selectivity: Some herbicides control grassy weeds better, some are more effective on broadleaf types, and still others will control some of each. Nearly all herbicides are much more effective on annual weeds than perennial weeds. It is important to remember that individual herbicides seldom provide a full range of weed control and that the specific weed species must be considered when choosing a product to control it.

Crop Tolerance: Each crop may tolerate certain herbicides, but at the same time, be severely injured or killed by others. For example, atrazine will kill most annual grassy and broadleaf weeds on maize, sorghum, and millet without injury to the crop. The herbicide 2, 4D can also be sprayed directly on maize, sorghum, millet, and other grass family crops to control broadleaf weeds without injury to these crops (unless applied too heavily or at the wrong stage of growth). On the other hand, glyphosate has no selectivity and will kill all foliage that it touches.

Some Important Herbicide Terminology

Contact herbicides kill only those plant parts the spray actually touches. There is little, if any, translocation (movement) to other parts of the plant. Contact herbicides can be either selective or non-selective.

Glysophate is a non-selective contact product that kills the green topgrowth of all weeds and crops. Propanil is a selective contact herbicide that controls many grassy and broadleaf weeds in rice without injury to the crop (it can be freely sprayed on the rice plants).

Systemic herbicides are absorbed through the leaves (less so through the roots) and then translocated throughout the plant. Systematics are especially useful for killing perennial weeds, although several applications may be needed. Many other herbicides like atrazine have a partial systemic action.

Timing and Method of Herbicide Applications

The herbicide label will state that the particular product can be applied in one or more of three ways:

- **Pre-plant: Before the crop is planted. Most pre-plant herbicides require incorporation into the top 2.5-10 cm of soil with a disk harrow or rototiller.**

- **Pre-emergence: After the crop is planted, but before it or the weeds have emerged.**

- **Post-emergence: After the crop and the weeds have emerged, usually before the weeds are 2.5-5.0 cm tall.**

Broadcast applications are applied over the entire field. Band applications are applied in a narrow strip (about 30-40 cm wide) centered over the crop row. These save the farmer money since less herbicide is used, but he or she will still have to cultivate the untreated inter-row area.

How Herbicide Dosages are Given

Herbicide recommendations are usually given in terms of lbs./acre or kg/ha of active ingredient* which refers to pure 100 percent chemical. However, each herbicide is usually available in several different formulations (i.e. wettable powders, liquids, granules) that vary in strength. It is up to the farmer or extension agent to figure out how much of a particular product is needed to satisfy the recommendation. This is much the same as figuring fertilizer requirements. For example 3.75 kg/ha of Gesaprim 80 percent wettable powder would be needed to supply 3 kg of active ingredient per hectare (80 percent x=3 kg; x=3.75 kg).

Herbicide Safety

Fortunately, most herbicides are relatively safe, but there are a few exceptions:

- **Paraquat has an unusally high oral toxicity and even a small amount of diluted mixture can be fatal. Paraquat is inactivated by clay or activated charcoal which should be administered orally (mixed with water) if oral ingestion occurs.**

- **Dinitrophenols (DNBP, Dinoseb, Basanite) have high oral toxicity and can also be absorbed dermally (through the skin) .**

- **Suspected birth defects caused by 2, 4-D type herbicides have been linked with faulty manufacture which produces dioxins (rarely present under current production methods).**

For these reasons, it is not recommended that these herbicides be used without first receiving instructions in handling from a knowledgeable professional.

The same general safety guidelines in section B. On insecticides apply to herbicides. Except for those mentioned above, nearly all herbicides are Class 4 in their relative toxicity (least dangerous).

Factors Affecting Herbicide Performance

- **Choice of product: The product must be suited to the crop and the weed species present.**

- **Soil organic matter and clay content: The rates of most soil-applied herbicides are very dependent on soil clay and especially organic matter content. The higher these levels, the higher the rate of herbicide needed. Some soil-applied herbicides may cause crop damage on sandy soils.**

- **Rainfall: Most pre-emergence herbicides require moderate rainfall within a few days following application in order to move the chemical into the weed seed germination zone. Otherwise, a very shallow cultivation may be needed to work the chemical into the soil.**

- **Weed size: Post-emergence applications of many herbicides will not kill weeds much taller than 2.5 cm while others will effectively control larger weeds.**

- **Accuracy of application: Most herbicides need to be applied at fairly precise dosages. This requires calibrating the sprayer in order to determine how much water it will take to cover the field and how much herbicide should be added to each tankful. When spot spraying, the farmer can get by using a tablespoon per gallon or cc per liter dosage, but this is the exception. Application also needs to be uniform to avoid crop injury or patches of surviving weeds.**

General Guidelines For Applying Herbicides

- **READ AND UNDERSTAND THE LABEL!**

- **Do not spray on windy days. Spray drift or vapors may damage nearby**

susceptible crops.

- **Avoid spraying when the temperature is above 32 High temperatures increase volatility (vaporization) and may also reduce herbicide effectiveness.**

- **When using wettable powder formulations, be sure to agitate the sprayer tank to keep the powder in suspension during application.**

- **Never use a herbicide on a crop for which it is not recommended.**

- **Do not burn herbicide containers. Fumes may be released which can injure susceptible crops.**

Herbicide Carryover

Some herbicides take a long time to break down in the soil and may injure succeeding crops. It is likely that residues may cause problems with those crops for which the product is not recommended. Fortunately, residues are less of a problem in the tropics where higher temperatures favor a more rapid breakdown of the chemicals. Atrazine takes two to eight months for its residues to disappear, and most broadleaf crops may be injured if planted within this period. Simazine, diuron, and diphenamid may take even longer. Most others take a few weeks to a couple of months. The label should show carryover information.

Applying Herbicides with Backpack (Knapsack) Sprayers

A few herbicides do not require much dosage accuracy and can be easily applied with backpack sprayers. However, most herbicides require a level of precision, which is difficult to achieve with these sprayers unless extra care is taken.

In order to avoid applying too much herbicide, which wastes money and might injure the crop, or too little, which might make the spraying ineffective, the sprayer should be calibrated (see Appendix K).

Once the sprayer has been calibrated, the farmer must maintain the same constant spraying pressure and walking speed that was used in the calibration process.

Nozzle selection is important. Fan nozzles (see page 225) should be used to make pre-emergence and postemergence applications over the soil and small weeds. Cone nozzles are best for spraying herbicides on larger weeds, since they provide more complete coverage than fan nozzles when used on foliage. They should not be used for broadcast applications of herbicides over the soil and small weeds since the circular spray patterns will not overlap properly. If two or more cone nozzles are mounted on a spray boom, overlapping spray patterns will distort each other. As for water volume, 250-300 1/ha is adequate as long as weeds are small or only the soil surface is being sprayed. Larger weeds require up to 500-600 1/ha when uniform coverage is needed. The sprayer should be shaken periodically to keep wettable powder formulations in solution.

Improvements in Hand Sprayers

- **Low-volume hand-held sprayers: A very effective hand-carried sprayer that runs on flashlight batteries has been developed by IITA. It is known as a controlled droplet applicator sprayer and is specifically designed for applying herbicides. Its special nozzle produces extremely fine droplets which permit adequate coverage to be achieved with only 20 liters of water per hectare. The single nozzle covers a meter-wide swath which enables a hectare to be sprayed in about eight hours at a walking speed of 0.5 meters/ second. This is a big improvement over backpack sprayers in terms of water volume and time requirements. The controlled droplet applicator sprayer is very light and holds just 2.5 liters of spray solution.**

Calibration is also simplified, because the sprayer's output is constant and only walking speed need be considered. The sprayer is currently being manufactured by two companies:

- **The "HERBIE" by Micron Sprayers Ltd., Bromyard, Herfordshire, ENGLAND HR7 4HU. This model uses eight flashlight batteries (good for up to five hectares of spraying).**

- **The "HANDY" by Ciba-Geigy AG, CH 4000, Basle 7, SWITZERLAND. Uses five flashlight batteries.**

The price of the controlled droplet applicator is about half that of a backpack sprayer. However, it is not suitable for applying most insecticides and fungicides.

A spray boom for backpack sprayers: To reduce labor requirements for backpack spraying, a simple but effective spray boom can be constructed so that two to five nozzles can be used at once. If only two nozzles are used, special "T" extensions are commercially available for many sprayer models. Larger booms can be made by arranging nozzles along a length of narrow diameter pipe and connecting them with high-pressure plastic hose. If fan nozzles with an 80° angle of spray width are used and spaced 50 cm apart on the boom, uniform ground coverage can be achieved when the boom is carried about 50 cm off the ground. (This provides three to four fingers width of overlap between adjacent spray patterns. As shown in the illustration, these large booms are too unwieldy to be carried by the sprayer operator alone.

Applying Herbicides with Tractor Boom Sprayers

Tractor boom sprayers can cover up to six to eight rows at once and have nozzles spaced every 40-50 cm. They may be used on small farms as part of a cooperative venture. Here are some guidelines:

1. Low sprayer pressures (30-40 1bs./ sq. in.) are usually recommended for herbicides. Higher pressures decrease droplet size, distort the spray pattern, and cause drift.

2. For nozzle selection follow the guidelines listed under backpack sprayers. Brass, aluminum, and plastic nozzle tips are cheapest. However, they wear much faster than tips made of harder metals when wettable powders are used.

3. If output per nozzle is too low, switch to a larger nozzle size or drive slower. Increasing pressure is a poor way of increasing spray volume. Pressure must be increased fourfold in order to double the output.

4. When broadcasting herbicides over the soil or on very small weeds, the sprayer boom height should be adjusted to give three to four fingers width of overlap between adjacent spray patterns. Fan nozzles are available with different spray width angles such as 65°, 73°, and 80 . The wider the angle, the closer to the ground the boom can operate and still achieve the necessary overlap. This is a big advantage on windy days.

5. Nozzles of different sizes or spray angles should not be used on the same boom.

6. The manufacturer's tables for output and calibration are not reliable. Nozzle output can be markedly affected by wear, and pressure gauges and tractor speedometers vary in accuracy.

7. Wettable powder formulations need constant agitation to stay in suspension. Mechanical or hydraulic jet agitation is a must for tractor sprayers.

8. The tractor must be driven at a constant speed while spraying or output will be affected. A fluctuation of only 1-2 km/hr can increase or decrease the dosage being

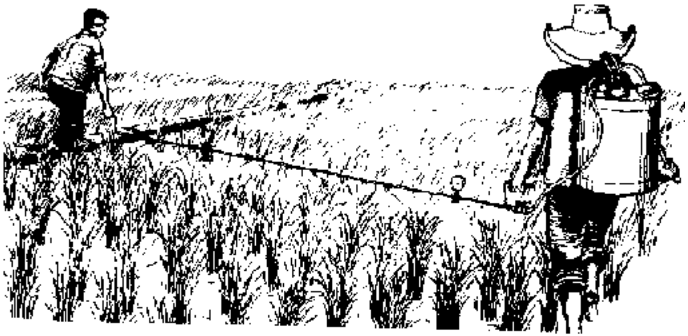
applied by as much as one third.

9. Tractor speed should be adjusted to suit ground conditions. Excessive bouncing of the spray boom will cause uneven coverage. The tractor should not be driven faster than 8 km/hr.

10. It is important to check constantly for blocked nozzles while spraying.

RECOMMENDED HERBICIDES FOR THE REFERENCE CROPS

The number of herbicides available for use on the reference crops and their individual application guidelines are too numerous to be adequately covered in this manual. It is best to rely on locally-derived recommendations based on field trials if possible. Several resources are listed in the bibliography that will provide reliable general guidelines for herbicide selection and dosages.



Boom backpack sprayer

Insect control

Some Important Facts on Insects

Insects can often be identified by the type of damage they cause:

- **Chewing and Boring Insects**

  Caterpillars are the larvae of moths. They damage plants by feeding on leaves and making holes in them or by boring into stalks, pods, and maize ears. The cutworm caterpillar is unusual in that it lives in the soil and emerges at night to cut off plant stems near ground level.

  Bettles feed on plant leaves and chew holes in them. Some beetles of the weevil family bore into pods and seeds and deposit eggs inside. Certain beetles can also transmit bacterial and viral diseases.

  Beetle larvae like white grubs, wireworms, and rootworms live in the soil and damage roots and the underground portion of the stem by chewing or boring.

- **Sucking Insects**

  Aphids, leafhoppers, stinkbugs, harlequin bugs, whiteflies, and mites have piercing and sucking mouthparts and feed on plant sap from leaves, pods, and stems. They transmit a number of plant diseases, especially viruses. Sucking insects do not make holes in the leaves, but usually cause leaf yellowing, curling or crinkling.

Insect Life Cycles

A general understanding of insect life cycles is useful in identifying insect problems in the field. Beetles and moths go through a complete metamorphosis (change in form)

consisting of four stages, while aphids, leafhoppers, whiteflies and other sucking insects go through only three stages.

(Adult stage)

MOTH EGG

(Does no damage.)

CATERPILLAR	PUPA
(Usually feeds on leaves.)	(Dormant stage; turns into a moth.)

(Adult stage)
BEETLE EGG

(Feeds on leaves,pods)

LARVA	PUPA
(Grubs, wireworms, rootworms, etc. Feed on plant roots.)	(Dormant stage turns into a beetle.)

(Adult stage)

APHIDS, LEAFHOPPERS,STINKBUGS, WHITEFLIES, OTHER SUCKING INSECTS

EGG NYMPH

(Looks like a miniature adult; at this stage also sucks sap.)

How to Identify Insects and Their Damage

BE OBSERVANT! Troubleshooting takes practice, and a sharp eye is essential. When walking through a field, closely examine the plants for insects or their damage symptoms. Check both sides of the leaves since many insects prefer the undersides of leaves. A magnifying glass can be very helpful.

Identifying Insect Damage: Often it is possible to identify insects by the damage they cause.

- **Holes in leaves: Caused by caterpillars, beetles, crickets, snails, and slugs. (Snails and slugs are not insects but do attack plant foliage.)**

- **Wilting: Usually caused by soil insects like white grubs and wireworms. If root feeding or tunneling of the underground portion of tile stem has been serious it could be due to stem borers. Remember that wilting can be caused by other factors, too: dry soil, very high temperatures, root rots, bacterial and fungal wilts, and nematodes.**

  To determine if insects are the cause of wilting, dig up the affected plants. Check the root system and underground portion of the stem for insect and disease damage, also look for soil insects. Slit the stem lengthwise with a pocket knife and check for borers or rotted tissue.

- **Leaf curling, crinkling or yellowing: Caused by sucking insects, especially aphids, leafhoppers, and mites. Viruses and some nutrient deficiencies also produce these symptoms. Nematodes and poor drainage cause yellowing too.**

Identifying Insects: Spend time with locally experienced exten ion workers in the field and have them point out the prevalent crop insect pests (and beneficial predator insects) in the work area. Seek out host country or regional insect guides such as extension bulletins. The publications listed in the bibliography are also very useful.

Major pests of the reference crops

This list is not complete but deals with the more prevalent reference crop pests. Full or partial (genus only) scientific names are given in parentheses. More specific control measures will be given at the end of the insect section. Stored grain Pests, some of which attack the crops before harvest, will be covered in Chapter 7.

Major Pests Of Maize

Soil Insects

White grubs (Phyllophaga, others): Brown headed, plump, six-legged, white larvae up to 25 mm long. Many are larvae of May (June) beetles and attack roots of maize and other grass family crops, sometimes causing serious damage. Especially common where maize is planted on recently cleared pasture land. Occasionally attacks legumes. Larval stage lasts one to three years.

Rootworms (Diabrotica, others): Small, slender, whitish larvae with brown heads, measuring up to almost 20 mm. They attack the roots and sometimes bore into the underground portion of the stalk while adult beetles feed on the silks and attack other crops. They are most prevalent in Latin America. Affected plants often become "goosenecked" because of lodging caused by root damage. Ten or more larvae per plant or a brown discoloration of 50 percent of the root system indicates serious damage.

Wireworms (Elateridae): Shiny, brown, hard larvae up to 1.5 - 3.5 mm long with six legs. The larval stage of click beetles attack germination seeds and below ground plant parts. Larval stage lasts two to six years.

Wireworm Larva (top) and Adult (bottom)

Cutworms (Agrotis, Feltia, Spodoptera): These are caterpillars ranging from bright green to black. Most are rather plump and curl up when disturbed. They attack young plants and cut off stems at or slightly above the soil surface, but some will feed on the leaves. Most remain below ground during the day and emerge at night to feed.

Lesser cornstalk borer (Elasmopalpus: Caterpillars, usually light green with faint stripes and distinct vertical bands of brown. They are most common in Latin America. Young larvae feed first on the leaves and then bore into the stalk about 2-5cm above ground. Each builds a tunnel made of soil particles and silk that runs from the soil to the stalk hole. May also attack the root system. Larval stage lasts about three weeks and pupation takes place in the soil in a silken cocoon.

Seed corn maggots (Hylemya): Yellowish gray fly larvae up to 6-7 mm long with a blunt rear end and a sharply-pointed head. They attack germinating seeds, sometimes eating out the entire kernel.

Maize Foliage Insects and Borers

Fall armyworm (Spodoptera frugiperda: Larvae have a green and brown coloring with a prominent, white, inverted "Y" mark on the head and grow to about 40 mm. One of the most serious and prevalent maize insects in the lowland tropics. The caterpillars are

larvae of night-flying moths that lay eggs in clusters of 100 or more on the leaves. Eggs are covered by a coating of body hairs and scales and hatch in two to six days in warm weather. The larvae are cannibalistic and attack each other until only a few are left. They then move to the leaf whorl and feed on the unfolding leaves, but may also damage the growing point in older plants. Larva will sometimes tunnel into older plants. The larval stage lasts about three to four weeks and the pupal stage only 10 days, so maize can be attacked by several generations. Damage is easy to spot by the ragged appearance of the leaves and the large amount of sawdust-like excrement found around the leaf whorl. Diseases and predators may greatly reduce their numbers. Liquid or granular insecticides applied to the leaf whorl are effective and should be applied before the larvae have reached 16-18 mm.

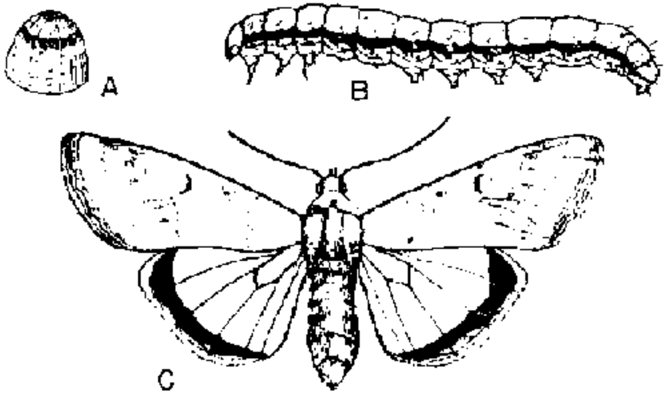
Seedcorn Maggot.

A— Mature larva; B—Adult; C—Injured germinating seed.

Corn earworm (Heliothis zea): A striped yellow, brown or green caterpillar. The moth deposits her eggs individually on the maize silks. Eggs are white, round, and smaller than the period at the end of this sentence, but can be easily seen with a low power magnifying glass. They hatch in three to seven days, and the larvae feed on the young silks and

kernels near the ear tip. Earworms seldom interfere with pollination, since most silks become pollinated the first day they emerge from the ear. Eggs are sometimes laid on the leaves of younger plants, followed by leaf feeding in the whorl as with the armyworm. Ear damage is rarely serious enough to justify using insecticides, which would have to be applied to the silks-a time-consuming process. Varieties with long, tight husks have good resistance.

Leafhopper Adult



Corn Earworm

A—Egg; B—Mature larva; and C—Adult.

Miscellaneous leaf-feeding caterpillars (yellow striped armyworm, true armyworm, measuring worm, etc.): These may occasionally require foliar insecticide sprays.

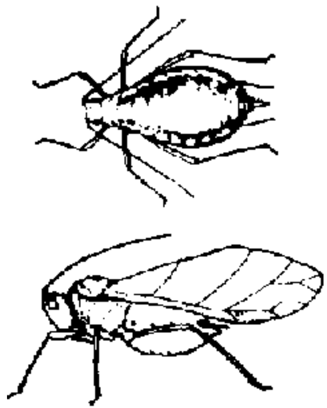
Southern cornstalk borer (Diatraea), Southwestern corn borer (Zeadiatraea): Prevalent in lowland areas of Latin America. Moth larvae are about 25-mm when fully grown and are white with dark spots. Eggs are laid in overlapping rows of 10-12 on the leaves near the central veins. Eggs hatch in three to six days, and young larvae spend two to three days feeding on the leaves, making circular holes, before they bore into the stalk. Larval stage lasts several weeks, and pupation takes place inside the stalk. Control is only partly successful and requires spraying the plants during the short period before the larvae bore into the stalks or the use of systemic insecticides, some of which are very toxic.

Stalk borers (Busseola, Sesamia, Eldana, Chilo): Very common in Africa and parts of Asia

and can cause serious losses. Busseola and Sesamia prefer young plants and can kill them by damaging the growing point. All four types may attack the ears on older plants in addition to the stalks. Busseola moths mate soon after emergence from the pupal stage and deposit their eggs in groups of 30-100 on the inner leaf sheath near the whorl. The larvae feed on the whorl and then tunnel into the young plant. Systemic insecticides applied to the soil or to the leaf whorl give fair to good control. Eradication of wild grasses that serve as borer hosts helps reduce numbers.

Leafhoppers (Cicadulina Dalbulus: Small, light-green, wedge-shaped insects with piercing-sucking mouthparts. Cicadulina transmits maize streak virus in Africa, and Dalbulus spreads corn stunt virus ("achaparramiento") in Latin America. Both diseases can cause serious losses. Insecticides are effective.

Grasshoppers: Cause serious losses in parts of Africa. Foliar sprays and baits are effective unless the infestation is severe.



Aphids—Wingless and Winged (USDA)

Maize aphids (Rhopalosiphum): Small, soft-bodied, green or blue, green insects that suck sap from plants and secrete a sweet substance (honeydew) on which a black mold grows. They can stunt and deform the tassels, causing poor pollination. Treatment should be considered if 50 percent of the plants have some aphids and 10-15 percent are heavily infested. Systemic insecticides give longterm control.

Common Storage Insects of Cereal Grains

Maize weevil (Sitophilus zeamais), rice weevil (S. oryzae), and granary weevil (S. granarius): All have long snouts and are about 8.3mm long. Only the maise and rice weevils can fly and infest crops in the field. Females live several months and lay 200-400 eggs by boring holes in the kernels and depositing the eggs inside. The white, legless larvae feed on the inside of the kernels, then pupate, and finally emerge as weevils. All three species are more common in humid than dry regions.

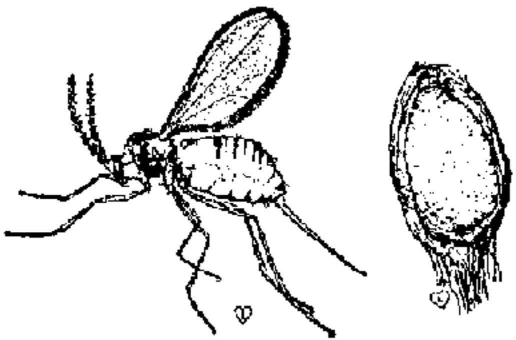
Angoumis grain moth (Sitotroga cerealella): A small cream- or tancolored moth with a wingspan of about 12.7 mm that is often the major stored grain pest in drier regions. Adult moths have a black fringe on the tip of each forewing. They can infest grain both in the field and during storage, but can penetrate only about the top 4-inch layer in stored, threshed grain. Maize stored as ears can be completely infested, however. Each female lays about 40-400 eggs on the outside of the kernels, and the tiny larvae burrow inside to feed. Pupation takes place inside the kernel, and the young moths emerge to begin a new cycle. The moths themselves do no feeding. Unlike most other storage insects, the angoumis grain moth can be controlled by spraying or dusting only the surface layer of stored, threshed grain with an approved insecticide like Malathion or pyrethrin.

Major Sorghum Pests

Sorghum is attacked by many of the same insects that attack maize, but two other insects can also cause serious damage.

Sorghum midge (Contarinia sorghigola: A small orange fly about 2 This is the most important sorghum pest worldwide. The adult lives only about a day and lays eggs on sorghum grain heads during flowering. Larvae hatch in two to four days and spend 9-11 days feeding on the juices of the developing seeds, preventing them from developing. The pupal stage lasts two to six days for a total life cycle of just 15-20 days.

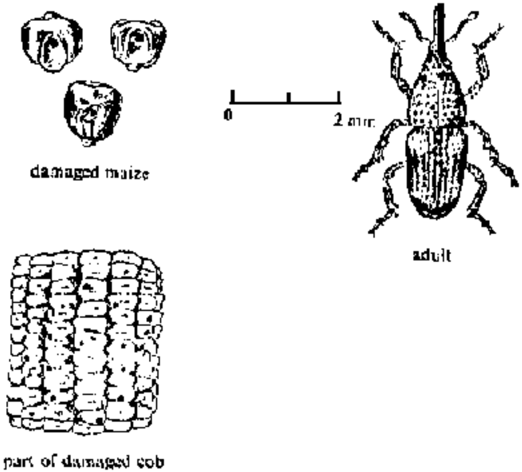
Some local varieties show fair resistance to this pest. Sorghum heads can be sprayed with an insecticide three to five days after they emerge from the boot. Sorghum should not be planted near young sorghum or Johnsongrass, and out of season sorghum heads should be removed from fields. In cooler areas, the larvae pupate in a silken cocoon, but may also do this in very hot, dry weather. Plowing under residues may help control the pest in these cases.



The sorghum midge, Contarinia sorghicola (Coq.). Adult female and larva in its cocoon.

Sorghum shoot fly (Atherigona soccata): A major pest in Africa and Asia. Adults look like small houseflies and lay eggs on the leaves of young plants. Larvae move down into the leaf whori and then bore into the young stem, often killing the growing point. The youngest leaf then turns brown and withers-this condition is called "deadheart". Some

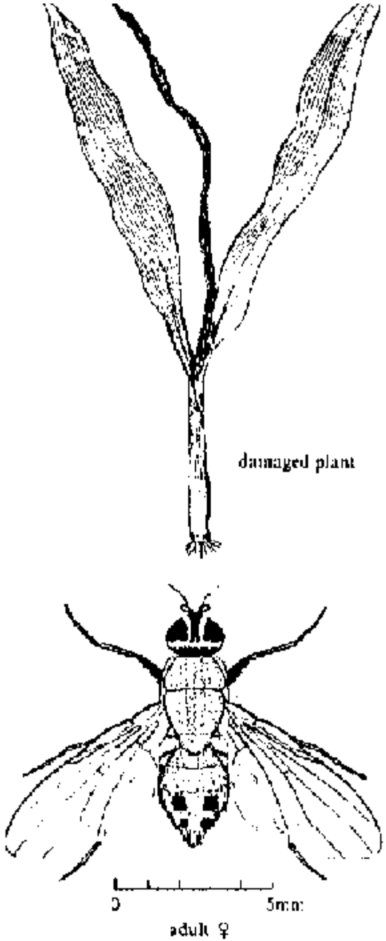
sorghum varieties show shoot fly resistance. Insecticides applied to the whorl are not as effective as preplant applications of systemic insecticides to the soil.



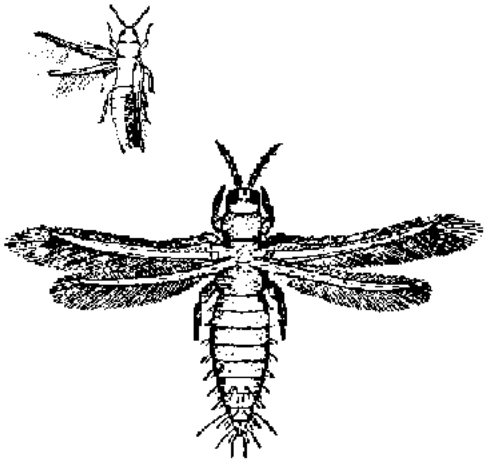
Maize Weevil (Sitophilus zeamais). The rice weevil (S. oryzee) looks identical.

Millet Pests

Millet is attacked by many of the same inects as sorghum, including the shoot fly, midge, and stem borer, but damage is usually less serious. The millet grain midge (Geromyia pennisetti) is common in the savanna region of Africa. A caterpillar (Masalia spp.) has increased in numbers in the northern savanna and Sahel during the 1970's and can cause serious head damage.


damaged plant
0
5mm
adult ♀

Sorghum Shoot Fly



The flower thrips, Frankliniella tritici

Peanut Pests

White grubs, wireworms, and rootworms attack peanut roots, and the latter two also attack the pods.

Termites can severely attack the pods, but damage is usually patchy. Treating planting seed with an insecticde, destroying the nests with Chlordane or other insecticides, or applying insecticides broadcast or banded along the crop row are effective on termites.

The lesser cornstalk borer may bore into stems and pods. In Senegal, about a dozen types of millipedes damage pods. Any pod damage increases the likelihood of aflatoxin (a

harmful toxin and carcinogen produced by Aspergillus fungus; see section on diseases).

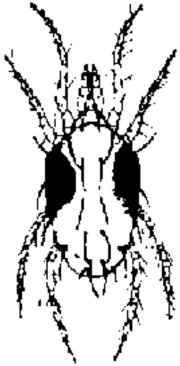
Thrips: These tiny(1 mm) yellow to black insects have two sets of fragile wings which are fringed with hairs along the rear edge. Immature thrips (nymphs) are light yellow to orange and smaller than the adults. If disturbed, thrips will jump or hop. They can cause serious damage by feeding in the buds or folded leaflets. They have rasping-sucking mouthparts which cause the leaves to be scarred and distorted as they unfold. Thrips can also spread spotted wilt virus.

Leafhoppers: Can be another major pest. Adults are around 3 mm long, pale green, and wedge-shaped. Immature leafhoppers (nymphs) are similar in appearance to adults, but smaller and without wings. Both stages have piercing-sucking mouthparts. The first signs of leafhopper damage are yellow "V" formations at the leaf tips, and severe cases can cause stunting and leaf drop.

Spider mites (Tetranychus and other species: Common in hot, dry conditions. They are sucking insects, and feeding damage may appear as translucent dots on the leaves. Some insecticides will not control mites, while Kelthane is effective only against mites.

Corn earworms (Heliothis spp.), armyworms (Spodopters, Pseudaetia), and other caterpillars feed on the leaves. Blister beetles (Epicauta spp.) are brightly colored with alternate bands of black and red or yellow-they feed on the flowers. Aphids occasionally attack peanuts. One species (Aphis croccivora) spreads rosette virus, a serious problem in Africa.

Peanuts are very susceptible to attack by storage insects. The groundnut bruchid (Caryedon spp.) is a serious pest in West Africa. This weevil lays eggs on the pods after the crop has been lifted from the ground, and the larvae tunnel into the pods and kernels.



A Spider Mite (Univ. of Arizona)

Bean Pests

The following information is based on The International Center for Tropical Agriculture (CIAT) studies on the mayor insect pests of common beans (Phaselous vulgaris) in Latin America.

Seedling Stage Insects

Cutworms and white grubs may cut off the stems of young seedlings. White grubs are usually only serious when beans are planted following pasture. The lesser cornstalk borer may bore into the stem just below the soil surface and move upwards and kill the plant. Clean fallowing for long periods or heavy flooding will control these borers as will granular insecticides applied near the seed row at planting.

Leaf Feeding Insects

Many species of beetles, such as the banded cucumber beetle (Diabrotica balteata), bean

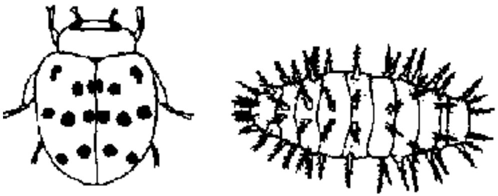
leaf beetle (Cerotoma), flea beetle (Epitrix), and Mexican bean beetle (Epilachna), attack bean leaves. The most serious damage is caused during seedling stage when the insects can defoliate the plant more readily, or during flowering. Both larvae and adults of the Mexican bean beetle feed on the leaves. The larvae of the other beetles feed mainly on the roots of beans, maize, and certain weeds.

Caterpillars usually do not cause economic damage on bean leaves. The bean leafroller (Urbanus or Eudamus), saltmarsh or wooly bear caterpillar (Estigmene), and Hedylepta caterpillar are the most common.

Sucking Insects

The leafhopper species Empoasca Kraemeri is the most serious insect pest of beans in Latin America and is also found in other regions. It does not transmit virus (some other leafhoppers do) but causes severe stunting, yellowing, and leaf curling. Work done by CIAT has shown that yields are reduced about six percent for each leafhopper present per leaf. Eggs hatch in eight to nine days and the nymphs feed on the plants for eight to eleven days before becoming adults. The adult stage lasts about 60 days and is more damaging. Beans grown with maize are less affected than pure stands. Mulching reduces leafhopper populations. Leafhopper problems are generally more severe in hot, dry weather.

Several species of aphids attack beans, although their feeding causes little direct damage, they can transmit bean common mosaic virus.



Mexican Bean Beetle—Adult and Larva

Several species of mites attack beans. The red spider mite is found on the lower leaf surface, and heavy infestations turn the leaves brown. The tarsonemid mite is too tiny to be seen without a magnifying glass, but causes young leaves to curl up-ward. Mites are seldom serious except during the dry season.

Whiteflies (Bemisia spp.) do not usually cause direct damage but can transmit bean golden mosaic virus and bean chlorotic mottle virus. They are often controlled by natural predators, and most insecticides are effective.

Pod Borers

The bean pod weevil (Apion godmani) is a serious problem in Central America. Adults are black and about 3 mm long and they feed on flowers and pods without causing much damage. However, the female chews a small hole in young pods and deposits an egg. The larva feeds on the inner pod and the developing seeds. Pupation takes place in the pods, and the adults emerge near harvest time. Bean types vary in their resistance. A number of insecticides give good control if applied once at a week past flower initiation and again a week later. Carbafuran applied at planting gives excellent control.

Bean bruchids (Acanthoscelides obtectus and Zabrotes subfasciatus) are snout less weevils about 2.5mm long and are the major storage pests of beans. A. obtectus predominates in cooler areas, while Z. subfasciatus prefers warmer regions. Life cycles for both are very similar with eggs being laid on stored beans or in cracks of growing pods in the field. The larvae tunnel into the seeds to feed.

Adult weevils are short-lived and do little feeding. Both types of weevils may be present initially, but A. obtactus is a better competitor at lower temperatures and will eventually predominate under these conditions. These bruchid weevils are estimated to cause

storage losses of up to 35 percent in Mexico and Central America.

Slugs occasionally cause serious leaf damage and are mainly active at night or on wet, cloudy days. Damage is msot likely along field borders but may move inward. Cleaning the field of weeds and plant debris helps control them, but baits are the most effective means of control. Slime trails on the leaves indicate the presence of slugs.

Cowpea Pests

The caterpillar Maruca testulalis is the major cowpea pest in the Savanna region of Africa. It attacks flowers, pods, and leaves, causing yield losses up to 70-80 percent.

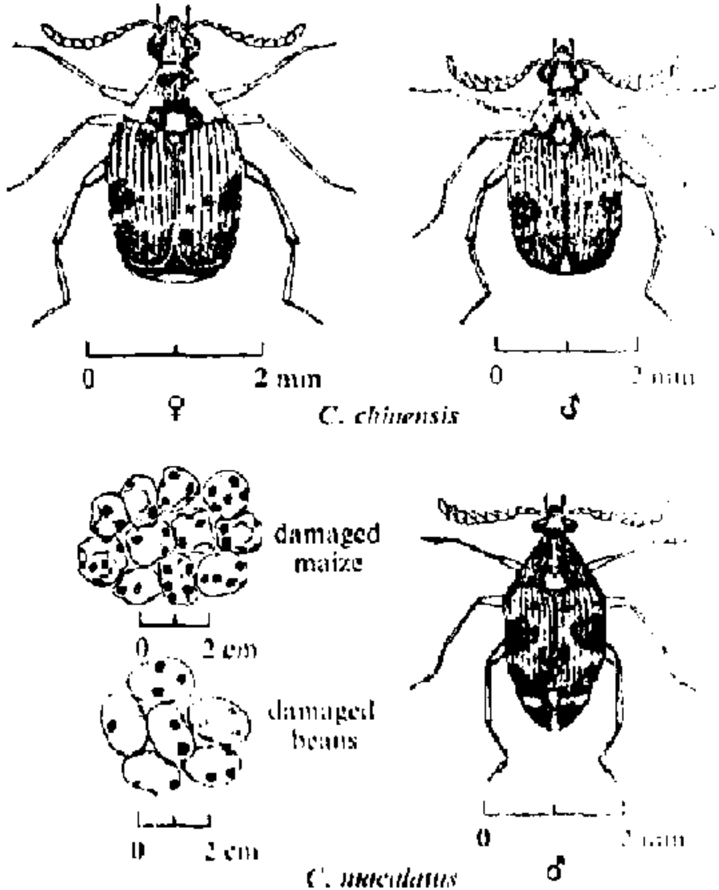
Coreid bugs (plant bugs) are larger sucking insects that feed on green pods and cause them to shrivel and dry prematurely.

The leaf feeding beetle Ootheca mutabilis can cause yield reductions when young plants are heavily attacked. It also carries yellow mosaic virus.

The flower thrip (Megalurothrips sjostedti) is a major cowpea pest in tropical Africa. Thrips have suckingrasping mouthparts and are very small (about 1 mm or less).

The snoutless bruchid weevils (Callosobruchusspp) infest cowpeas both in the field and in storage. The adults can fly up to a kilometer and are most likely to infest crops downwind from strong facilities. The 2.5 mm adults lay eggs on the pods or seeds, and the larvae bore into the grain.

IITA, in Nigeria, estimates that one-third of the cowpea crop in Africa is destroyed by bruchids.



Cowpea bruchids (Callosobruchus spp.)

Methods of insect control

Non-Chemical Methods

Many natural controls act to keep insects in balance:

- **Weather factors like temperature and rainfall can restrict the distribution of an insect species. For example, mites and leafhoppers are usually more prevalent under dry conditions.**

- **Geographic barriers like large bodies of water, mountains, and deserts can also limit insect distribution.**

- **Frogs, toads, lizards, moles, and birds are some of the many animals that feed largely on insects.**

- **Beneficial predator insects like ladybugs feed on aphids, while others like the braconid wasp and tachnid fly lay eggs on or in certain pests which are killed by the developing larvae. Some predator insects like the praying mantis eat beneficial insects as well, however. Insects are also attacked by viruses, fungi, and bacteria which help keep populations down.**

As agricultural activities have increased, many of these natural balances have been upset and can no longer be relied upon to keep harmful insects under control. Monoculture and the existence of vast areas under cropping have led to marked increases in a number of insect pests. Indiscriminate use of pesticides has actually resulted in buildup of harmful insects in some cases. Many of the traditional crop varieties, despite their lower productivity, have better insect resistance than some of the improved varieties.

Biological Control

Biological control is the purposeful introduction of predators, parasites or diseases to combat a harmful insect species. About 120 different insects have been partially or completely controlled by this method in various parts of the world. Microbial insecticides such as Bacillus thuringiensis (effective against a few types of caterpillars) are now commonly used by farmers and gardeners in many areas. Unfortunately, biological control measures are presently effective against a very small portion of harmful insect species.

Cultural controls

Cultural controls such as crop rotation, intercropping, burying crop residues, timing the crop calendar to avoid certain insects, and controlling weeds and natural vegetation that harbor insects are all effective control methods for some insects. In most cases, however, cultural controls need to be supplemented by other methods.

Varietal Resistance

Crop varieties differ considerably in their resistance to certain insects. For example, maize varieties with long, tight husks show good resistance to earworms and weevils. Researchers at CIAT have found that some bean varieties are relatively unaffected by leafhopper damage during the wet season, while others suffer yield losses of up to 40 percent. Screening for insect resistance is an important part of crop breeding programs.

"Organic" Controls

"Organic" control refers to non-chemical methods in general. These include the application of homemade "natural" sprays made from garlic, pepper, onions, soap, salt, etc., and the use of materials like beer to kill slugs and wood ashes to deter cutworms and other insects. Some of these "alternative" insecticides are slightly to fairly effective on small areas like home gardens and where insect populations are relatively low. They are seldom feasible or effective on larger plots, especially under tropical conditions that favor

insect buildup.

Chemical Control

Chemical control refers to the use of commercial insecticides in the form of sprays, dusts, granules, baits, fumigants, and seed treatments. While some of these insecticides like rotenone and pyrethrin, are naturally derived, most are synthetic organic compounds that have been developed through research.

Advantages of Insecticides:

- **They act rapidly.**

- **They are the only practical means of control once an insect population reaches the economic threshold of damage on a commercial-size plot.**

- **They are available with a wide range of properties, species effectiveness, and application methods.**

- **They are relatively inexpensive, and their proper usage can often return $4.00 5.00 for every $1.00 spent.**

Disadvantages of Insecticides:

- **Insect resistance to pesticides: This is a growing problem. By 1961, 60-70 species had developed resistance to certain products, and the number had increased to around 200 by the mid-1970's.**

- **Outbreaks of secondary pests: Few insecticides kill all types of insects, and some actually promote the increase of certain pests. For example, continual use of Sevin (carbaryl) in the same field may increase problems with some types of aphids** which it does not control well.

- Damage to non-target species: These include beneficial predators such as bees and wildlife.

- Residue hazards: Some chlorinated hydrocarbon compounds like DDT, Aldrin, Endrin, Dieldrin, and Heptachlor are highly persistent in the environment and may accumulate in the fatty tissues of wildlife, livestock, and humans. Many other insecticides are broken down into harmless compounds fairly rapidly.

- Immediate toxicity: Some insecticides are extremely toxic in small amounts to humans and animals. Again, it is important to realize that insecticides vary greatly in their toxicity.

Current Status of Insecticide Use in the Reference Crops

At the present time and for the immediate future, insecticide usage will often be an essential part of any package of improved practices for the reference crops. For this reason, all extension workers must learn the basic principles of safe and effective insecticide application. Some extension workers may be personally opposed to the use of these chemicals, but it is a fact that farmers throughout the developing world are using them, often in an unsafe and indiscriminate manner due to the lack of proper instruction. Most developing countries have few, if any, pesticide regulations or restrictions on environmentally harmful products like Aldrin or highly toxic ones like Parathion. By instructing farmers in safety precautions and in the appropriate choice and use of insecticides, the incidence of human poisoning and possible environmental damage can be greatly reduced.

Integrated Pest Control

The disadvantages of total reliance on insecticides have given rise to integrated pest control or pest management which involves the judicious use of these chemicals based on the following guidelines and principles:

- **The development and use of cultural and other nonchemical control methods to avoid or reduce insect problems.**

- **Determining crop tolerance to pest damage based on the principle that complete freedom from pests is seldom necessary for high yields. Nearly all plants can tolerate a surprising amount of leaf loss before yields are seriously affected.**

- **The appropriate timing and frequency of treatments to replace routine, preventative spraying. Treatments are not initiated before the particular insect has reached the economic damage threshold, which will vary considerably with the species. Insect scoutinglooking for related kinds and number of insects and their density and population counts-is an essential part of this system.**

The advent of integrated pest control dates back to the early 1970's, and most of the efforts have been directed at cotton where insecticides frequently account for up to 80 percent of total production costs. Some remarkable successes have been achieved with other crops as well. For the reference crops, integrated pest control is still in the very early stage, especially in developing countries.

USING INSECTICIDES SAFELY

Insecticide safety guidelines, toxicity data, and first aid measures are covered in Appendix J, which should be referred to before working with insecticides.

Some important facts on insecticides

Pesticide Terminology

Pesticide: A general term referring to chemicals that control crop insects, mites, weeds, diseases, nematodes and rats.

Miticide (acaricide): A pesticide that kills mites. Mites are related to spiders and not all insecticides will kill them. Some pesticides like Kelthane control only mites, while others like Diazinon and Malathion kill mites and other insects.

Nematocide: A pesticide that kills nematodes. A few insecticides like carbofuran and Mocap will also control nematodes, but most will not. Some nematocides like Nemagon control only nematodes, while others like VAPAM, Basamid, and methyl bromide are general soil sterilants that kill insects, weeds, fungus, and bacteria as well.

Systemic vs. Non-Systemic Insecticides

Nearly all modern insecticides are contact poisons that kill insects by being absorbed through their bodies. Contact poisons act as stomach poisons if eaten by insects. Most insecticides are non-systemic and are not absorbed into the plant. Systemic insecticides are absorbed into the plant sap, and most are translocated through-out the plant. Most systemic insecticides like Metasystox, Dimethoate (Rogor, Perfecthion), and Lannate are sprayed on plant foliage. Others like carbofuran, Thimet, and Disyston, are applied to the soil in a band along the crop row, where they are absorbed by the plant roots and then translocated to the stems and leaves. Some of these soil-applied systemics will also control certain soil insects.

There are several considerations in choosing between a systemic and nonsystemic insecticide:

- **Systemic insecticides are especially effective against sucking insects like aphids,**

leafhoppers, stinkbugs, and thrips since these feed on the plant sap. However, many non-systemic contact insecticides will also control sucking insects adequately.

- **Most systemics are less effective against caterpillars and beetles, but may give good control of some stem borers.**

- **Foliar-applied systemics may remain in the plant for up to three weeks. Soil-applied systemics may provide control for up to six weeks. However, this also means that they must not be applied close enough to harvest time to cause residue problems.**

- **Most systemics will not harm beneficial insects.**

- **Foliar-applied systemics are not broken down by sunlight or washed off the leaves by rainfall as with non-systemics.**

- **Since they are translocated, systemics do not require uniform spray coverage when they are applied to the leaves. New growth occuring after application is also protected.**

- **Some systemics like Thimet, Di-syston, and Systox are highly toxic both orally and dermally. However, the same is also true with some non-systemics like Parathion and Endrin. (See Appendix J.)**

Types of Pesticide Formulations

Most insecticides are available in several types of formulations:

- **WETTABLE POWDERS SOLUBLE POWDERS: These range in strength from 25-95 percent active ingredient and are meant to be diluted with water and applied with a sprayer. For example, Sevin 50 W is a wettable powder containing 50 percent pure carbaryl by weight. Once mixed with water, wettable powders require periodic agitation (shaking or stirring to keep them from settling to the bottom. Soluble ' powders ("SP") are completely soluble and do not require agitation.**

- **EMULSIFIABLE CONCENTRATES ("EC" or "E"): these are high strength liquid formulations. Like wettable powders, EC's are meant to be diluted with water and applied with a sprayer. They contain 20-75 percent active ingredient. In countries using pounds and gallons, a label that reads "Malathion 5 E" would refer to a liquid formulation of malathion that contains 5 1bs. active ingredient per gallon. Where liters and grams are used, EC's are often labeled in terms of grams of active ingredient per liter. For example, Tamaron 600 is a liquid formulation of Tamaron containing 600 grams of active ingredient per liter.**

- **DUSTS ("D"): Unlike WP's and EC's, dusts are low strength formulations (1-5 percent active ingredient) and are meant to be applied without dilution by a duster. Dusts are usually more expensive than WP's or EC's due to higher transport costs per unit of active ingredient. However, if dusts are blended within the country, they may be competitive cost-wise and are especially suited to situations where a farmer has difficulty transporting water to his field. They do not stick to the leaves as well as sprays and are more easily washed off by rainfall. Retention is improved if they are applied while the leaves have dew on them. Dusts pose more of an inhalation hazard than sprays. They should never be mixed with water.**

- **GRANULES "(G"): Like dusts, granules are low-strength formulations meant to be applied without dilution. They are especially well suited for soil applications and for placement in the leaf whorls of maize and sorghum to control armyworms.**

Granules cannot be effectively applied to leaves, because they roll off. Furadan 3G is a granular formulation that contains 3 percent pure carbofuran.

- **FUMIGANTS: These are available as pellets, granules, liquids, and gasses whose fumes kill pests. They are used to kill insects in stored grain or applied to the soil to kill insects, nematodes, and other pests.**

- **BAITS: These are usually the most effective formulations for controlling cutworms, crickets, slugs, and snails.**

Cutworms are most effectively controlled with baits rather than with sprays. Baits should be scattered near the plants in the late afternoon if rainfall is unlikely. Bait should not be left in clumps which might poison birds or livestock. One kg of bait should cover about 400 sq. meters.

Cutworm bait recipe:

25 kg of carrier (sawdust, rice bran, maize flour, etc.)
3 1 of molasses
1 - 1.25 kg active ingredient of trichlorfon or carbaryl

Water can be added to moisten the bait.

Slugs and snails can be controlled by applying baits in the late afternoon in a band along the field's borders or within problem areas. It should not be applied if rain is expected that night, since rain may wash the insecticide from the bait.

Slug and snail bait recipe:

25 kg maize flour or bran

10 1 molasses
65 g metaldehyde (a stomach poison of lowdermal toxicity) or 0.5 kg active ingredient trichlorofon or 0.5 kg active ingredient carbaryl

Chemical Classes Of Insecticides

Commercial insecticices fall into three main chemical classes or groups:

- **Chlorinated hydrocarbons (organochlorines): Many of the insecticides in this group such as DDT, Aldrin, Endrin, and Dieldrin have very long residual lives and have caused environmental problems such as fish kills. However, other members such as Methoxychlor are readily biodegradable. Toxicity to humans and animals varies greatly within this group (see Appendix K).**

- **Organic Phospates (organophosphates): The insecticides of this group such as Malathion, Dipterex, Diazinon, and Parathion have a much shorter residual life than most of the organochlorines. Their toxicity to animals and humans varies greatly. Some like Parathion, TEPP, Endrin, and Thimet are highly dangerous, while others like Malathion, Gardona, and Actellic are among the safest insecticides available.**

- **Carbamates: Relatively few insecticides belong to this group and they tend to be of moderate to low toxicity. The exceptions are carbofuran and methomyl which have very high oral toxicities. Carbaryl and propoxur are probably the bestknown carbamates. The residual life of this group varies from short to moderate.**

Insecticide Dosage Calculations

For all types of pesticides, there are four basic ways of stating dosages:

1. Amount of active ingredient (pure chemical) needed per hectare or acre.

2. Amount of actual formulation (i.e. Sevin 50 WP or Furadan 3 G, etc.) needed per hectare or acre.

3. Amount of actual formulation needed per liter or gallon of water.

4. As a percentage concentration in the spray water.

Types 1 and 2 dosages are suited more to large plots or to those pesticides (especially herbicides) needing very accurate dosage application. Sprayer calibration is needed in both cases to determine how much water to use and how much pesticide to add to each tankful.

Types 3 and 4 are very general recommendations best suited to smaller plots or where dosage accuracy is not critical.

1. AMOUNT OF ACTIVE INGREDIENT NEEDED PER HECTARE: For example, a dosage might be given as 2 kg active ingredient carbaryl per hectare. This means 2 kg of pure (100%) Sevin. Since actual pesticide formulations vary in strength from l percent up to 95 percent, it takes some math to figure out how much of a given formulation is needed to supply a given amount of active ingredient. If the local agricultural supply store sells carbaryl 50 percent WP, the farmer would need 4 kg for each hectare in order to supply 2 kg active ingredient. Note that nothing is said about how much water the farmer should mix with the pesticide when he sprays it on the plants. This will depend on plant size, plant density, and the degree of coverage desired. The only way to find out how much water is needed is to calibrate the sprayer.

2. AMOUNT OF ACTUAL FORMULATION NEEDED PER HECTARE OR ACRE: A recommendation calling for 4 1 of Malathion 50 percent per hectare, for example, is somewhat simpler than Type l since it is given in terms of actual formulation rather than active ingredient. However, the farmer still needs to know how much formulation he needs

for his field's area and how much water it will take to provide adequate coverage with his sprayer. This requires sprayer calibration.

3. AMOUNT OF ACTUAL FORMULATION NEEDED PER LITER OR GALLON OF WATER: If the recommendation is expressed as for example, 5 cc of Malathion 50 percent EC per 1 of water, no sprayer calibration or dosage calculation is needed. The drawback is that the amount of pesticide the farmer actually applies on his field depends entirely on how fast he or she walks while spraying, how coarse or fine the spray is, and how much pressure is used. However, if proper guidelines are followed, Type 3 recommendations are precise enough for most conditions and are the most feasible for small farmers. They should not be used for most herbicides where accuracy of dosage is critical.

4. AS A PERCENTAGE CONCENTRATION IN THE SPRAY WATER: This is basically the same as Type 3, except that the concentration of pesticide in the spray water is given in terms of percent rather than cc/liter. Such recommendations are usually based on percentage by weight, although sometimes a volume basis is used when dealing with Et's (the actual differences are slight). The percentage figure given may refer to active ingredient or to actual formulation. As with

Type 3 recommendations, no sprayer calibration is needed, and dosage accuracy is not as good as with Types 1 and 2.

Pesticide Math

Converting recommendations from an active ingredient basis to an actual formulation basis.

Once you know how much actual formulation is needed per hectare or acre, you can easily calculate how much is needed for farmers' fields by multiplying the field size in hectares times the dosage per hectare.

Following a percentage strength spray recommendation:

Determine first whether the spray's percentage strength is to be calculated in terms of active ingredient or in terms of actual formulation. For example, one recommendation might be expressed as 2 percent strength spray in terms of pure Malathion.

Another recommendation might call for using a 0.1 percent strength spray of Lebaycid 50 percent EC for controlling thrips on peanuts.

- **For wettable powders When using WP's, a percentage strength spray is based on weight of pesticide to weight of water. Since 1 liter of water weighs 1 kg, these formulas can be used:**

  Active ingredient basis

  Grams of wettable powder needed per liter of water [2% x 1000]/40%= 20/0.4 = 50g

  Actual product basis

  Grams of wettable powder needed per liter of water

  = % strength spray desired x 1000

- **For liquids (EC's)**

  Active ingredient basis

  cc (ml) of EC needed per liter of water

  = [% strength spray desired x 1000] / % active ingredients in the EC

Guidelines for applying insecticides

When is Treatment Necessary?

Farmers should apply insecticides in response to actual insect problems rather than on a routine and indiscriminate basis. Ideally, insecticides should be used only when damage has reached the economic threshold. This level varies with the insect species, the crop, and the type and extent of damage.

General guidelines (see also the unit on major reference crop insects):

- **Soil insects. These pests should be treated preventatively by making pre-planting or atplanting insecticide applications if a known problem exists. Treatments after planting are generally not effective except in the case of cutworm baits.**

- **Leaf-eating insects (beetles, caterpillars): Crops can tolerate considerable defoliation as long as new leaves are being continually produced. Loss of leaf area becomes more serious as the vegetative stage nears its end, although defoliation in the very late stages of grain development will not have a big effect on yield. Stem-borers usually cause more serious damage at much lower populations than most leafeating insects. The sorghum shoot fly, sorghum midge, and one species of bean leafhopper (Empoasca kraemeri) are other examples of insects that reach the economic threshold of damage at relatively low populations.**

- **Sucking insects: Not all species of aphids and leafhoppers spread virus diseases. For example, CIAT found that bean yields were reduced about 6 percent for each Empoasca kraemeri leafhopper present per leaf, even though this species does not transmit any viruses. Bean plants can tolerate aphids well unless they are of a species capable of transmitting common bean mosaic virus.**

Using a Sprayer Effectively

Achieving the Correct Coverage

The extent and uniformity of coverage needed depend on the insects' location and whether or not a systemic insecticide is being used. In some cases such as armyworms feeding in the maize leaf whorl, the insect is very localized, so general coverage is not needed. Other insects are more general feeders and require thorough spray coverage over the whole plant. Since they are translocated, systemic insecticides do not require the uniform coverage nonsystemics do.

The amount of water need for adequate coverage varies with plant size, density, type of product (systemics versus nonsystemic), and insect location, but there are some rough guidelines:

> **Water rates for insecticides: When covering the entire foliage of full size plants, at least 500-550 l of water per hectare will be needed when using conventional sprayers. When spraying is localized or plants are very small, water volume may be only one-quarter of this amount.**
>
> **Too much spray is being applied if there is a visible amount of runoff from the leaves, although this can also be caused by not using enough wetting agent (spreader).**

Using a Spreader And Sticker

A spreader (wetting agent) reduces the surface tension of spray droplets, allowing them to spread out rather than remaining as individual globules on the leaf surface. Spreaders markedly improve the uniformity of spray coverage and also help prevent droplets from rolling off the leaves.

A sticker (adherent) is a gluelike substance that helps the spray stick to the leaf surface and resist being washed off by rainfall or sprinkler irrigation.

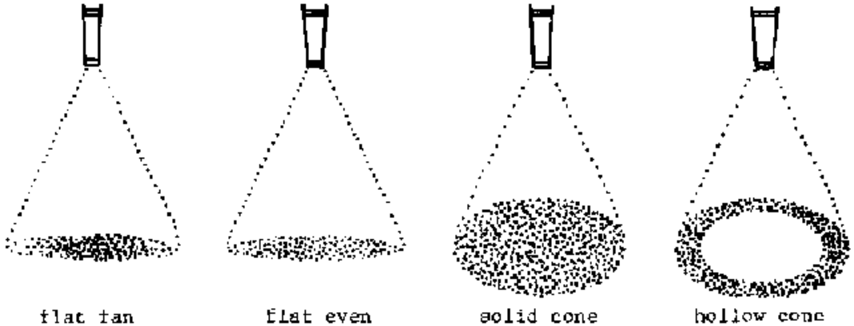
Many commercial stickers and spreaders are available, including combination sticker-spreaders. The pesticide label will indicate if a spreader or a sticker is needed. If spraying the soil, neither a spreader nor a sticker is needed. When spraying the leaf whorl of maize, a spreader is not needed, though a sticker might be helpful. Use of a sticker and spreader is especially important when applying most foliar fungicides.

Commercial stickers and spreaders are relatively cheap. However, if not available commercially, they can be made at home. Egg white, cassava (yuca, manioc) flour, and corn starch can be used as stickers at about 15 cc per 15 liters. Liquid dishwashing detergent makes a satisfactory spreader at about the same rate.

Non-ionic spreaders: Paraquat and diquat post-emergence herbicides are unusual in that they require the use of special non-ionic spreaders in order to avoid deactivation (loss of effectiveness). Ortho-77 is one commonly available non-ionic spreader.

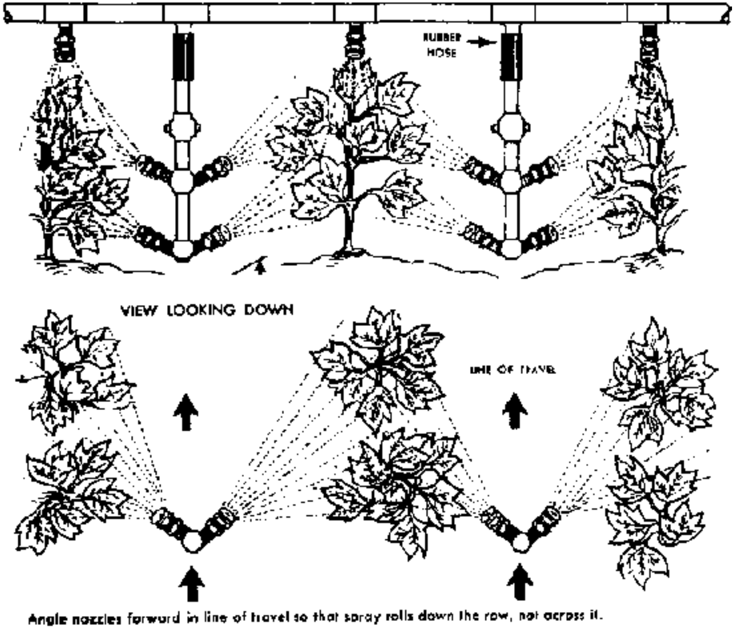
Choosing a Spray Nozzle

Spray nozzles are available in a wide variety differing in output, spray pattern angle, and type of spray pattern. Proper nozzle selection has an important influence on pesticide effectiveness.



Spray Patterns

Nozzle Output: Many backpack (knapsack) sprayers come equipped with adjustable nozzles which allow the farmer to vary the output by making the spray finer or coarser. This would seem to be an advantage, buth such nozzles usually do not maintain their setting well and output can change considerably during application. This is unsatisfactory where accurate dosages are necessary, and it makes sprayer calibration difficult. Fixed orifice nozzles are available in a wide range of outputs and should be used whenever possible.



Tractor boom spray nozzle

Illustration courtesy of Rohm & Hass Co., Philadelphia, Pennsylvania

Ideal tractor spray boom arrangement for applying insecticides and fungicides and achieving uniform coverage. Note that the drop nozzles are angled about 30° upward as well as 30° forward. Only one tier of "drop" nozzles may be needed on small- to medium-size crop plants.

Spray Pattern Angle: See flat spray

Type of Spray Pattern: Care should be taken to choose the right spray pattern for the job.

- **Flat (Fan) Spray Nozzles are ideal for making broadcast (full coverage) applications of insecticides or herbicides over the soil surface (and small weeds). The application rate decreases at both edges, so the spray patterns of adjacent nozzles should be overlapped about three to four fingers width at the soil surface to achieve even distribution. Fan nozzles do not provide as good a coverage as cone nozzles when used to spray crop foliage. Fan nozzles are available in several different angles of spray width. Wider angles allow the spray boom to be carried closer to the ground and this lessens spray drift problems on windy days.**

- **Even Flat (Fan) Spray Nozzles should be used for making band applications of pesticides to the soil. Spray output does not decrease at the edges, so spray patterns should not be overlapped and used for broadcast applications.**

- **Solid Cone Spray Nozzles provide better coverage of plant foliage than fan nozzles but should not be used to apply herbicides and insecticides to the soil.**

- **Hollow Cone Spray Nozzles offer somewhat better foliar coverage than solid cone nozzles due to greater leaf agitation as the spray pattern passes over the plants.**

- **Whirlchamber (nonclog) Spray Nozzles are special wide angle hollow cone nozzles that can be used in place of fan nozzles. Their design reduces clogging, and drift is minimized because of the wide angle pattern (enabling lower boom height) and larger droplet size.**

Nozzle Screens: Nozzles used on tractor boom sprayers usually have mesh or slotted strainers to help prevent clogging. Some backpack sprayers have strainers or can have

them added on. Routine cleaning is required, especially when wettable powders are used.

Tips on Using Backpack Sprayers to Apply Insecticides

- **Use good pressure and a fine spray. Pressure is too high if excessive spray drift (misting) occurs.**

- **Maintain a steady pace through the field. Avoid pausing at each plant unless the crop is very large.**

- **Rotate your wrist while spraying so that the spray hits the foliage from different angles.**

- **Keep the nozzle far enough away from the foliage so that the spray has a chance to spread out before hitting the leaves.**

- **If using a wettable powder, remember to periodically shake the sprayer to keep the pesticide in solution.**

- **Keep a piece of soft wire handy for cleaning out clogged nozzles, but use it gently to avoid damaging the nozzle opening.**

- **Do not spray plants when their leaves are wet or when rain is likely within a few hours afterwards.**
- **Do not add wettable powders or EC's directly to the sprayer tank. First mix them thoroughly in a bucket with several liters of water. Make sure wettable powders are completely dissolved.**

Pesticide Compatibility

Most pesticides are compatible with each other in the spray tank, but check the fable to

make sure. In some crops like peanuts and vegetables, foliar insecticides and fungicides are often applied together. Spray compatibility charts are available from many pesticide companies.

Water with a pH of 8.0 or above (alkaline) causes a rapid breakdown of organic phosphate insecticides. Such high pH water is usually confined to limestone or low rainfall areas. Special buffering agents are available to lower the pH if necessary.

Certain insecticides are phytotoxic (injurious) to certain crops. Always check the label instructions. Wettable powder formulations tend to be less phytotoxic than emulsifiable concentrates, especially in temperatures over 32 C.

Sorghum:	Trichlorfon causes severe injury. Azodrin and methyl parathion cause some injury.
Peanuts:	Minor foliar injury which shows up as reddish brown spots on the earliest leaves is sometimes caused by soil applications of carbofuran, Thimet, and Disyston. The plants usually outgrow the damage with no yield reduction. Runner varieties on sandy soils are the most sensitive, and dosage should be reduced by 25 percent under these conditions.

Insecticide Recommendations For the Reference Crops

Particular pesticides are not recommended for the reference crops in this manual because of the potential misclassification of pest problems and misused pesticides. Rather than rely on this manual for pest diagnosis and pesticide selection, it is recommended that you rely on the insecticide recommendations of your country's extension service if they are known to be effective and if they do not involve the use of high-toxicity Class 1 chemicals (see Appendix K). Before using any insecticide, refer to the safety guidelines and toxicity data in Appendix K. Always know the relative toxicity and environmental hazards of the products you use or recommend.

Disease control

Types of Diseases And Their Identification

Parasitic versus Non-parasitic Diseases

Parasitic diseases are caused by certain types of fungi, bacteria, and viruses that invade plants and multiply within their tissues.

Non-parasitic (non-infectious) diseases are caused by unfavorable growing conditions or other nonparasitic factors such as:

- **Excesses, deficiencies or imbalances of soil nutrients**
- **Excessive soil acidity or alkalinity**
- **Temperature extremes**
- **Poor drainage or drought**
- **Mechanical, fertilizer or pesticide injury**
- **Air pollutants like ozone and sulfur dioxide.**

Some of these non-parasitic conditions produce symptoms that can be confused easily with those of parasitic diseases.

Fungal Diseases

Fungi are actually tiny parasitic plants without roots, leaves or chlorophyll which feed on living or decaying organic matter. They reproduce and spread by means of microscopic seeds called spores. Some fungi, such as those that help break down crop residues into humus, are beneficial. Fungi can penetrate directly into seed, leaf or rock tissue or can enter through wounds or natural openings. General types of fungal diseases are leaf spots leading to possible defoliation; rotting of seeds, stems, stalks, roots, grain heads, pods,

and ears; and storage molds and wilts.

Diseases caused by fungi are by far the most common diseases of the reference crops because the spores are highly resistant to unfavorable conditions. They are spread easily by wind, water, soil, and farm implements, and some types can also be carried by the crop seeds themselves. Most fungal diseases develop and spread much more readily under high humidity and moisture. An important and common characteristic of fungal diseases is their ability to mutate to produce new races that are resistant to certain fungicides.

Bacterial Diseases

Bacteria are microscopic single cell organisms that multiply by cell divisor. Like the fungi, some bacteria are beneficial and perform essential functions like converting unavailable organic forms of soil nutrients to available inorganic (mineral) forms. Others invade plants and cause diseases that produce leaf spots, wilts, galls, and fruit and stem rots. For several reasons, bacterial diseases are generally much less prevalent than fungal diseases.

- **Bacteria lack a resistant spore stage and are very dependent on favorable temperature and moisture conditions.**

- **Unlike the fungi, bacteria cannot forcibly penetrate into plant tissue but must enter through natural openings or wounds.**

- **Although bacterial diseases can be spread by wind-driven rain, field equipment, and certain types of insects (mainly some beetles), they are transmitted much less rapidly than fungal diseases.**

Viral Diseases

Viruses are microscopic particles consisting of a core of nucleic acid (genetic material)

surrounded by a protein coat. Viruses can multiply by diverting living host cells into the production of more virus particles and can also mutate to produce different strains. They are largely spread by sucking insects such as aphids, leafhoppers, and thrips. The relationship between these insect vectors (insect that transmit disease) and the viruses is sometimes very specific. For example, peanut rosette virus is transmitted by only one species of Aphid. Weeds are susceptible to certain viruses and serve as alternate hosts for viral diseases which are transmitted by sucking insects to crops.

Viruses usually do not kill plants, but can greatly reduce yields and quality. A wide variety of symptoms are produced such as leaf mottling (blotching), leaf curling, chlorotic (yellow) or necrotic (dead) spots on the leaves, leaf striping, and excessive branching.

How to Identify Plant Diseases

Some plant diseases can be identified readily by nonprofessionals right in the field. In other cases, however, accurate diagnosis requires a good deal of field experience or even the expertise of a trained plant pathologist and lab facilities. For more information on identifying plant diseases, see Appendix I, "Troubleshooting Common Crop Problems." Resources that give detailed descriptions of diseases of the reference crops can be found in the bibliography.

Methods of Disease Control and Effectiveness

Prevention versus Cure

Most diseases such as viruses and the bacterial and fungal rots of seeds, seedlings, roots, stalks, and stems cannot be controlled once they enter plant tissue. Fair to good control of fungal leafspots can be achieved with foliar fungicides but this is usually uneconomical with low value crops like maize, millet, and sorghum. Disease control methods are therefore geared much more toward prevention rather than cure.

Non-Chemical Disease Control Methods

- **Resistant varieties: Disease resistance is a top priority among plant breeders. Breeders have located genetic sources of resistance to some of the more serious diseases, especially viruses and other types that lack effective or economical chemical control measures. However, resistance does not mean 100 percent immunity, and the ability of viruses and fungi to mutate into new races has posed some problems.**

- **Disease-free seed: Some diseases like bacterial blight and common mosaic virus of beans can be carried by the seeds. The use of certified seed that is disease-free is an important management practice in many bean-growing areas.**

- **Controlling host plants and insect vectors: This is especially important for controlling certain viral diseases and involves the removal of host weeds and other natural vegetation that serve as sources of infection. In some cases, non-susceptible barrier crops are planted around a field in a 15-20 m wide strip to "decontaminate" sucking insects before they reach the susceptible crop. (Usually not practical for the small farmer). Also included is the roguing (removal) of diseased crop plants attacked by viruses. However, roguing is not effective for most fungal and bacterial diseases.**

- **Crop residue management: The burning or plowing under of crop residues is an effective prevention method for a few diseases like Southern stem rot of peanuts.**

- **Other management practices: Several of these may help minimize certain disease problems: not cultivating plants while they are wet; avoiding crop injury at or before harvest; irrigating in the morning when sprinklers or hand watering are used so that crop leaves are dry at night; using raised beds to improve drainage and disinfecting tools.**

- **Crop rotation: This can reduce the incidence of many fungal and bacterial diseases, especially those that are soil~ borne, but will have little effect on viruses. There is nothing wrong with monoculture from a disease standpoint as long as resistant varieties are being continually developed and introduced in response to new problems. However, this is unlikely in the developing countries.**

- **Intercropping: This practice may reduce or intensify disease problems, depending on the crop mixtures involved and whether they share some diseases in common.**

Chemical Disease Control Methods

- **Fungicides can be applied to seeds, the soil, and crop leaves and will provide fair to good control of certain fungal diseases. They are mainly applied as protectants.**

Seed treatment with a fungicide dust or liquid will effectively prevent seed rots (pre-emergence "damping off") caused by soil fungi. This method will also kill any fungal diseases borne on the seedcoat surface such as loose smut and covered smut which attack adult sorghum plants.

Since seed treatments mainly protect the seed, they are not as effective at preventing seedling blights (rots) and seedling root rots. A systematic seed treatment fungicide called Vitavax (Carboxin) gives somewhat better control.

Seed treatments will not control any soil-borne or airborne fungal diseases that attack older plants such as leaf spots, stalk rots, stem rots, and root rots.

Fungicide applications to the soil are sometimes helpful. Some fungicides like PCNB (Terrachlor), Vitavax (Carboxin), and Benlate (benomyl) can be

applied as sprays or dusts to the seed furrow or to the row during crop growth to control certain fungal stem and root rots.

Such soil applications are seldom necessary or economical for maize, sorghum, and millet, but can be profitable on high~yielding peanut and bean crops where disease problems exist.

Foliar fungicides can be applied as dusts or sprays to crop foliage to control fungal leaf spot diseases. Most foliar fungicides act as protectants to help prevent the occurence or spread of leaf spots. Some of the recently developed systemic fungicides like Benlate (benomyl) and Mertect (Thiabendazole) also have erradicant properties.

Most foliar fungicides have little or no effect on bacterial leaf spots, but copper base fungicides provide fair to good control.

Foliar fungicides are usually-not economical for maize, sorghum, and millet,but are often essential for control of Cercospora leaf spot in peanuts and can be very profitable in this case. Their use on beans may be justified where yields are in the medium to high range and fungal leaf spots become serious.

- **Soil sterilants like methyl bromide, formaldehyde, Basamid, and Vapam will control soil fungi, bacteria, insects, weeds, and nematodes. They are applied in advance of planting and allowed to disperse before the seeds are sown. Soil sterilants are frequently used on seedbeds for growing tobacco and vegetable transplants, but are too expensive for use with the reference crops.**
- **Antibiotics like Streptomycin and Terramycin are bactericides used as foliar sprays or transplant dips to control certain bacterial diseases. Other antibiotics like Kamusin (Kasugamycin) and Blasticidin are effective against certain fungal**

diseases such as rice blast, and are widely used in Japan. Their high cost makes them uneconomical for use on the reference crops. There are several problems associated with antibiotics, namely residues, the development of resistant races of fungi and bacteria, and occasional phytotoxicity.

- **Use of insecticides to control insect vectors: Is seldom completely effective since 100 percent control is impossible.**

Integrated Disease Control

Integrated disease control involves the combined use of nonchemical and chemical methods. Except for the mercury base fungicides sometimes used as seed dressings, the fungicides pose few toxic or environmental threats, unlike some insecticides. The incentive for integrated disease control is based on economics and the fact that many diseases cannot be controlled adequately with chemicals.

Major diseases of the reference crops

Maize

Maize Fungal Diseases

Seed Rots and Seedling Blights

These are often referred to as pre-emergence and post-emergence "damping off" and are caused by soilor seed-borne fungi. Seeds may be killed before germination or seedlings may be destroyed before or after they emerge from the ground. Damping off is most prevalent in cold, poorly-drained soils and with damaged seed (cracked seedcoat, etc.). Problems are less likely where conditions favor rapid germination and emergence (i.e. warm weather, adequate soil moisture). Symptoms: Above-ground signs are yellowing, wilting, and death of the seedling leaves, but this can be confused easily with injury by

wind, wind-blown sand, fertilizers, herbicides, and insects. Examine the below-ground portion of the plants and look for rotted seeds, soft rot of the stems near the soil surface, and rotted, discolored roots. Control: Use good quality seed, free of molds and damage, that has been treated with a fungicide like Captan or Arasan (thiram) for protection during germination. Seed treatment is mainly effective against seed rot.

Helminthosporium Leaf Blights

Several species of Helminthosporium fungi attack maize leaves, but the two most important are H. Maydis (Southern leaf blight) and H. turcicum (Northern leaf blight). Helminthosporium maydis is more prevalent in hot, humid areas, but both species can occur on the same plant. Symptoms of H. Maydis: There are two major races of H. maydis and they have different symptoms. Race "O" leaf spots are small and diamond~shaped when young and then elongate to about 2-3 cm and may grow together, killing large areas of leaf. Race "T" leaf spots are oval and larger than those of race "O" and attack the husks and leaf sheaths, unlike race "O". Maize hybrids utilizing "Texas" male sterile cytoplasm (genetic material) in their production are very susceptible to race "T". This became evident during the severe and unexpected outbreak of H. maydis race "T" in the U.S. Corn Belt in 1970. Most hybrids now utilize "N" male sterile cytoplasm in their production to overcome this problem. Symptoms of H. turcicum: Northern leaf blight prefers high humidity and low temperatures. Small, slightly oval, water-soaked spots first appear on the lower leaves and eventually become rectangular in shape and grow to a length of 2.5-15 cm. These lesions are grayish-green to tan and can cause severe defoliation. Control: Resistant varieties offer the best protection. Seed treatment with a fungicide is of no help. Foliar fungicides give fair to good control but are seldom economical since they must be applied every 7-10 days,

Maize Rusts

Three types of rust attack maize: common rust (Puccinia sorghi), Southern rust (Puccinia polysora), and tropical rust (Physopella zeae).

Common rust occurs more frequently in cool, moist weather and produces small, powdery, cinnamonbrown pustules on both surfaces of the leaves. Southern rust is more common in warm humid regions and produces smaller, lighter-colored pustules than common rust. Tropical rust is confined to the tropical regions of Latin America and the Caribbean. The pustules vary in shape from oval to round and occur beneath the leaf epidermis (outer layer). They are cream colored and very small and are sometimes surrounded by a black area. Control: Resistant varieties are the best protection. Fungicide sprays are seldom economical.

Maize Downy Mildews

At least nine species of Sclerospora (Sclerophthora) fungi attack maize. At present, they are mainly confined to parts of Asia and Africa, but also appear to be spreading throughout the Americas. Symptoms vary with the species, age of plants when infected, and the climate, but usually include chlorotic striping of the leaves and leaf sheaths, stunting, excessive tillering, and deformities of the ears and tassels. A downy growth (mildew) may occur on the undersides of the leaves in later stages. Some of these symptoms may be confused with viruses.

Some of the more common downy dildews are listed below with their control measures: Crazy Top (S. macrospora): Rare in the true tropics but of world-wide distribution in temperate and warm-temperate climates. Crazy top causes the tassel to mutate into a mass of leafy bunches and is provoked by one or more days of flooding before seedlings have reached the four to five leaf stage. Adequate soil drainage is the only control.

Sorghum Downy Mildew (S. Sorghi): Widespread. Controls: Using resistant varieties, removing and destroying infected plants, and avoiding maizesorghum rotations in infected

fields. Green Ear Disease or Graminicola Downy Mildew (S. graminicola): Occurs on various grasses but is usually not important in maize. Sugarcane Downy Mildew (S. sacchari): Mainly confined to Asia and the South Pacific. Controls: Eliminating the disease by using healthy planting material, growing maize in areas free of the disease and where sugarcane is not grown extensively, removing and destroying infected plants, and using resistant varieties. Fungicide sprays are used in some areas. Philippine Downy Mildew (S. philippinensis): This is the most important maize disease in the Philippines and also occurs in Nepal, India, and Indonesia. Controls: Removing and destroying infected plants, using resistant varieties and fungicide sprays where economical.

Common Smut and Head Smut

Common smut (Ustilago maydis): A fungus that causes galls (swollen areas on plant tissue) 1520 cm in size which form on any above-ground part of the plant. When young, the galls are shiny and whitish with soft interiors, but later turn into a mass of black, powdery spores. Early infection can kill young plants, but common smut is seldom a serious problem. Controls: Using resistant varieties and avoiding mechanical injury to plants. Good soil fertility is helpful. Galls should be removed from plants and burned before they rupture.

Head smut (Sphacelotheca) reiliana): Can seriously affect yields in dry, hot regions. This is a systemic fungus that enters seedlings without showing symptoms until the tasseling stage. Tassels and ears become deformed and develop masses of black, powdery spores. Head smut is mainly a soil-borne disease. Controls: Most varieties are resistant. Crop rotation and general sanitation also provide some control. Soil applied fungicides in the seed row give fair to good control, but are usually not economical. Seed treatment with a fungicide is ineffective.

Fungal Stalk Rots

Five of the more common fungal stalk rots are discussed below. They attack plants between tasseling and maturity, although Pythium stalk rot may also infect younger plants. Diplodia stalk rot: Most likely to occur several weeks after pollination. The leaves suddenly wilt and die, turning a dull grayish-green, and the stalk dies 7-10 days later. Numerous small,raised,black dots can be seen on the lower internodes of the stalk. Infected portions break readily and can be easily crushed. Diplodia infected stalks usually break between the joints (nodes). Controls: Using resistant varieties, avoiding high rates of N fertilizer without adequate K, and lower plant populations. Gibberella stalk rot: Similar to Diplodia except that the stalks tend to break at the joints, and the inside of the stalk is pinkish-red. The small black dots found on the lower portion of the stalk can be scraped off with a fingernail, unlike those of Diplodia, Controls: See Diplodia, Fusarium stalk rot: Similar to Gibberella and difficult to distinguish from it. Controls: See Diplodia.

Pythium stalk rot: Most likely to occur during long periods of hot, humid weather. Usually attacks a single internode near the soil surface and causes a brown, soft, water-soaked rot that collapses the stem. Stems do not break off but fall over,and plants may remain green for several weeks afterwards. Pythium usually occurs around tasseling time but may also affect younger plants. It is easily confused with Erwinia bacterial stalk rot. Controls: Using resistant varieties.

Charcoal rot (Macrophomina phaseoli) Attacks maize, sorghum, soybeans, beans, cotton, and others, It is most prevalent under very hot, dry conditions and first attacks seedling roots where it produces brown, water-soaked lesions which eventually turn black. The fungus usually does not invade the stalk until well after pollination when it causes the lower internodes to ripen prematurely and shred, causing breakage at the base of the plant, The inner stalk has a charred appearance due to the presence of numerous black dots (sclerotia). Controls: Charcoal rot can be reduced in irrigated fields by maintaining a good soil moisture content during dry spells after tasseling; see also Diplodia.

Fungal Ear and Kernel Rots

Maize can be attacked by a number of ear and kernel rots, especially when very wet weather occurs from silking to harvest. Insect and bird damage of stalks and ears also increases susceptibility.

Diplodia ear rot: Causes early-infected ears to have bleached husks, while normal husks are still green. Ears are shrunken, and the husks seem to be glued together due to the fungus growing in-between. Ears infected later in the season seem normal from the outside but have a white mold that usually starts at the base of the kernels. In severe cases, black fruiting bodies can be seen on the husks and on the sides of the kernels.

Controls: Ears that mature with the tips pointed downward are less susceptible. Good husk covering is also helpful as is an early harvest and proper storage at a safe moisture content. Gibberella ear rot (G. zeae): More prevalent in cool, humid areas and causes a pink to bright red rot starting at the ear tips. G. fujikuroi is the most common ear rot worldwide and is similar in appearance. Both types also produce a cotton-like pink growth over the kernels, and infected grain is toxic to humans, pigs, and birds. Controls: See Diplodia. Fusarium ear rot: Favored by dry, warm weather end similar to Gibberella. Nigrospora ear rot: Causes the cob to be discolored and easily shredded. The interior is gray instead of white. Kernels are poorly filled and can be easily pushed into the partially rotted cob. Spore masses in the form of black spots are found at the base of the kernels. Controls: Balanced soil fertility; see Diplodia.

Maize Bacterial Diseases

Erwinia stalk rot: Causes symptoms similar to Pythium (see fungal stalk rots). Controls: Using resistant varieties and good drainage. Bacterial leaf blight (Stewart's wilt): Transmitted by certain types of maize beetles and by the seed. Sweet maize is more susceptible. Symptoms are pale green to yellow streaks on the leaves, usually appearing

after tasseling. The streaks die and may kill the leaf. The stem may also become infected, leading to wilting of the plant. Controls: Using resistant varieties, early use of insecticides to control insect vectors.

Maize Viral Diseases

Maize is attacked by some 25 virus or virus-like diseases which are transmitted mainly by aphids and leafhoppers. Alternate host plants like Johnsongrass, sorghum, and sugarcane play an important role in the spread of most of them, Symptoms can be confusing and may often be caused by other problems such as nutrient deficiencies. Some of the more prevalent viruses are dealt with below:

Maize streak virus: A major problem in many areas of Africa and transmitted by several species of leafhopper (Cicadullina spp.). Early signs are tiny round scattered spots on the youngest leaves which enlarge parallel to the leaf veins. Broken yellow streaks later appear and run along the veins. Controls: Resistant varieties; leafhopper control. Maize dwarf mosaic: Spread by several types of aphids and a wide range of alternate hosts, including Johnson-grass (a sorghum relative) and sorghum. Leaves of infected plants develop a yellowgreen mosaic pattern, mainly on the bases of the younger leaves. Foliage becomes purple or purple-red as plants mature, severe stunting may occur, and few plants produce normal ears. Controls: Using resistant varieties. Destruction of alternate hosts and insect control. Maize stunt virus: Spread by several types of leafhopper (Dalbulus, Baldulus, Graminella) and known as "achaparramiento" in Latin America. Now thought to be a viruslike organism. The Mesa Central strain causes yellowing of the young leaves which later turn red. The Rio Grand e strain produces spots at the bases of young leaves, followed by a yellow striping. Controls: Resistant varieties; insect control. Sugarcane mosaic: Occurs where maize is grown next to sugarcane and causes yellow spots and streaks. Controls: Using resistant varieties of sugarcane.

Sorghum

Fungal Diseases

Seed rots and seedling blights: See maize.

Downy mildews: Sorghum is attacked by three species of downy mildew (S. macrospora, S sorghi, S. graminicola). (Refer to maize for details). Controls: Using resistant varieties and rotation with broad-leaf crops. Many forage-type sorghums are very susceptible to sorghum downy mildew (S. sorghi) and should not be planted on ground where grain sorghum will be sown if the disease is present. Covered kernel smut (Sphacelotheca sorghi): Carried by the seed and penetrates the young seedlings. Plants appear normal until heading time when the kernels are replaced by light-gray or brown, cone-shaped smut galls full of black spores. Controls: Seed treatment with a fungicide is very effective since the spores are carried on the surface. Resistant varieties have been developed.

Loose kernel smut (S cruenta):

Very common in Asia and Africa. As with covered smut, the spores are carried on the planting seed and invade young seedlings. Long, pointed smut galls are formed on the grain heads, and infected plants may be stunted and show increased tillering Unlike covered smut, loose smut spores may cause infections of late emerging grain heads on otherwise healthy plants. Controls: Same as for covered smut. Head smut (S. reiliana): The most damaging of the smuts. Destroys the entire head and replaces it with a mass of dark brown, powdery spores A large gall covered with a whitish membrane bulges out of the boot at heading time. The gall ruptures and spores are scattered by wind and rain over the soil where they survive to infect the next crop. Controls: Seed treatment will prevent the spread from field to field, but will not stop infection from spores already in the field. Resistant varieties should be used and infected plants removed and burned.

Grain (Head) Molds

These are caused by several species of fungi that are most prevalent when sorghum matures during wet weather. Seed becomes heavily molded and will germinate poorly if planted. Controls: Photo-sensitive varieties escape head mold by maturing during drier weather. Other types can be sown to mature during drier weather. Open-headed varieties are somewhat less susceptible than those with compact heads. Work in India has shown that head molds can be reduced by spraying the heads with Captan or Benlate (benomyl) plus a sticker immediately after a heavy rain, but this may not be cost effective. Sorghum Rust

This is caused by the fungus Puccinia purpurea which produces raised brownish pustules on both sides of the leaves. This disease is most common under high humidity but is usually confined to the older, mature leaves. Controls: Using resistant varieties. Fungicides are not usually economical.

Anthracnose

This disease is caused by the fungus Collectotrichum graminicola which attacks the leaves, producing tan to reddish lesions that are round to oval and have soft, sunken centers. It may also cause a stalk rot called red rot. Controls: Using resistant varieties. Other Fungal Leaf Spots

Sooty stripe (Ramulispora sorghi), zonate leaf spot (Gloesocercospora sorghi), and oval leaf spot (Ramulispora sorghicola) are the main fungal leaf spots in West Africa, along with anthracnose. Controls: Resistant varieties offer the best means of control. Removal of host plants like Guinea-grass, Bermudagrass, and Paragrass helps.

Fungal Stalk Rots

Charcoal rot (Macrophomina phaseoli see maize): A serious disease of dryland sorghum. Losses are increasing in India, Ethiopia, Tanzania, and Upper Volta. It is the most serious sorghum disease in Nicaragua and also causes serious losses in Mexico and Colombia. Charcoal rot is especially severe when grain filling takes place during high soil temperatures and drought. Controls: See maize. Milo disease (Periconia circinata): Presently confined to the U.S. and attacks the roots as well as the stalks. Even young plants may be affected. The first symptoms are stunting and slight leaf rolling. The tips and margins of older leaves turn light yellow, and all the leaves eventually become affected. Splitting the base of the stalk lengthwise reveals a dark red discoloration in the center. Roots are also dark red. Controls: Resistant varieties. Red stalk rot (Collectotrichum graminicola): The stalk rot phase of anthracnose. The outside basal portion of the stalk becomes red or purple. If the stalk is split lengthwise, the inner pith shows a reddish discoloration which may be continuous or blotchy. The flower stem may be similarly affected. Controls: See anthracnose.

Bacterial Diseases

Several bacterial leaf diseases attack sorghum and are favored by warm, humid weather. Yield losses usually are not serious. Seed treatment with a fungicide, crop rotation, and resistant varieties are the best controls. Sorghum Viral Diseases Maize dwarf mosaic and sugarcane mosaic produce very similar symptoms on sorghum. The mottled light and dark green mosaic pattern is usually most prevalent on the upper two to three leaves and often includes longitudinal white or yellow streaks. Varieties with a red pigment may show a "red leaf" symptom consisting of red stripes with dead centers. Controls: see maize. Yellow sorghum stunt: A virus-like organism that is spread by leafhoppers. Plants become dwarfed with leaves bunched together at the top. Leaves develop a yellow cream color. Controls: Resistant varieties; insect control.

Millet

Downy mildew (Sclerospora graminicola): Can attack millet as early as the seedling stage. The systemic fungus causes the leaves to become yellowish and under wet conditions a downy white mildew may occur on the undersides of the leaves. Affected seedlings may die within a month without producing any tillers. The symptoms may first appear on the upper leaves of the main stem or on the tillers. The first leaf affected normally shows damage only on the lower portion, but subsequent leaves suffer increasing infection. Heads may be partially or totally deformed. Control: Many local varieties have good resistance. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) achieved excellent control of downy mildew by treating planting seed with a newly developed systemic fungicide from Ciba Geigy known as GCA 48/988.

Grain smut (Tolypossporium penicilliriae): Fungi infect the young millet florets on the seed head and replace them with plumb galls ful of black powdery spores. Controls: Use resistant varieties and general sanitation. Seed treatment with a fungicide is probably not very effective. Ergot (Claviceps fusiformis): Common,but generally not serious. The airborne fungal spores infect the young florets before grain development and produce a sweet sticky liquid called honeydew, which is pink or red. The grain head later takes on a bottle-brush appearance due to the formation of dark-colored hard structures called sclerotia Controls:

Burn infected heads. Rust (Puccinia penniseti): Sometimes serious on late millet but usually not with early millet. Leaf spots: Several fungal leaf spots attack millet but are usually not serious.

Peanuts

Foliar Fungal Diseases

Foliar fungal diseases can seriously reduce yields of both nuts and hay, and the decaying fallen leaves provide organic matter for incubating soil-borne diseases like Southern stem

rot. Cercospora Leafspot: Attacks peanuts worldwide, but Virginia types (see Chapter 3) are somewhat less susceptible than the Spanish-Valencia types. It is encouraged by wet conditions. Symptoms: Two species of Cercospora fungi are involved. Early leafspot (C. arachidicola) is usually the first to appear and produces round, brownish-red spots surrounded by a yellow halo. Late leafspot (C. personata) occurs later in the season and produces darker spots that may or may not have halos. Both leafspots may also occur on the stems and leaf petioles (leaf stems) as the disease progresses. Severe defoliation can result, which affects yields as well as the performance of mechanical pullers, which require bulky bushes for satisfactory operation. Controls: Crop rotation helps reduce early infections. Even though Virginia types show some resistance, foliar fungicides are usually essential in most cases and are applied as preventatives. Peanuts are a relatively high value crop, which makes use of foliar fungicides very economical. Specific recommendations are given in the next unit. Peanut Rust (Puccinia arachis): This disease is presently confined to Latin America and the Caribbean. It causes small orange to brown raised pustules on the leaves, mainly on the undersides. It can spread rapidly under hot, humid conditions, and leaf drop can be severe. The stems, petioles and pegs can also be affected. Controls: As with leafspot, fungicide sprays or dusts are the only effective control.

Ground Diseases

Ground diseases caused by fungi are sometimes hard to detect and identify and can drastically reduce yields. Southern Stem Rot: Also known as Southern Blight, wilt and white mold, it is the most serious and widespread ground disease attacking peanuts and also affects beans, soybeans, other legumes, potatoes, tomatoes, and other crops. It is favored by warm, wet conditions. Symptoms: In the early stages, some of the leaves on a few branches usually turn yellowish. Under wet conditions, a white cotton-like mold occurs on the lower stem near the soil surface and on any decaying organic debris on the soil. Fungal bodies called sclerotia appear on the affected areas and are light brown to

brownish red and about the size of mustard seeds. The leaves begin a gradual wilt, but at first seem to recover at night. Eventually, the entire plant can die. The pegs are destroyed, leaving many pods imbedded in the ground. The disease can also cause pod rot. Controls: There is no way to control this disease once plants are affected, but it can be effectively suppressed through a combination of chemical and cultural controls given below:

- **Crop rotations with maize, sorghum, and other grass family plants.**

- **Deep burial of all crop residues using a moldboard plow. Coarse trash like maize and sorghum stalks need to be chopped up manually or with a disk harrow before plowing. Residues left on the surface serve as a breeding ground for the fungus.**

- **Planting peanuts on a flat field or on a ridge. Seed furrows should not have depressions which cause poor drainage.**

- **Avoiding cultivation which throws soil into the crop row, especially when plants are young. This can cause stem injury and burial of young plants, which greatly increases susceptibility to stem rot and crown rot.**

- **Control of Cercospora leafspot and other foliar diseases with fungicides to minimize defoliation, since fallen leaves also serve as breeding grounds for the fungus.**

- **Applications of soil fungicides like PCNB (Terrachlor) and Vitavax (Carboxin) in a band over the row at planting or at early pegging stage. These give fair to good protection where stem rot problems are serious. (See the next unit for specific recommendations.)**

Seed Rot and Seedling Blight (Preand Post-Emergence "Damping Off")

Pre-emergence rot: It is not unusual to find germinating peanut seeds rotting in the ground. Affected seeds break down rapidly, but early examination will show them to be covered with a growth caused by various species of fungus. Seedling blight is often referred to as Aspergillus crown rot and is caused by Aspergillus niger, a black sooty fungus. True crown rot is more accurately used to describe the disease when it attacks older plants past the seedling stage. The stem tissue just below ground level is attacked on young seedlings shortly after they emerge, and the fungus quickly spreads up the stem, covering it with a mass of black spores. The stem will then suffer a total collapse. Contributing factors: Soils that have been continually cropped to peanuts for long periods have more problems with seed rots and seedling blights. Excessively deep planting weakens the stem and increases susceptibility. Seeds may also be damaged as they are being deshelled. Controls: Seed treatment with fungicides gives good control; usually a combination of two fungicides is needed to provide control of all species. Recommendations are given in the next unit. Attention should also be given to planting depth and crop rotation.

Sclerotinia Blight

This is somewhat similar but less common. Affected plants have a white fungal growth attached to rotted areas of the stem which may extend from below the soil surface up into some or all of the individual runners. Infected stem tissue is very shredded and contains many black fungal bodies. Pegs and nuts are also attacked. Control is usually not needed,but a fungicide called Botran (dicloran) is sometimes applied as a spray in the U.S.

Peg and Pod Rots

Several types of fungi including Sclerotium and Sclerotinia attack the pegs and pods. Soil sterilants are sometimes applied before planting in the U.S., but this would seldom be economical or feasible for small farmers. Crop rotation is helpful. Aspergillus flavus is a

fungal mold that attacks stored seed but is sometimes found in the field. Under certain conditions, some strains of A. flavus produce aflatoxin, a potent carcinogen (cancer-causing agent) and toxin that can affect birds, humans, and other mammals. Harvested pods are free of aflatoxin except where they have been broken or damaged by termites, hoeing, threshing or rough handling. The development of Aspergillus and other storage molds largely can be prevented by timely harvest, separation of damaged kernels, and rapid drying of moist pods. Viral Diseases Rosette virus: The most serious disease of peanuts in Africa, especially in the wetter areas. It is spread by one species of aphid (Aphis craccivora) and has several alternate host plants, including Euphorbia hirta, a weed. Plants become severely stunted, and the younger leaves turn yellow and mottled. Emerging leaves remain small and become curled and yellow. Early planting and close spacing appear to reduce the incidence of rosette virus. Affected plants should be removed and destroyed, and aphid control should be considered.

Destruction of alternate host plants is helpful. Resistant varieties have been developed in Senegal. Spotted wilt virus: Caused by tomato wilt virus and spread by several types of thrips. Affected plants have leaves with light green and yellow patterns, often in large patches or in the form of ring spots. Leaves are usually misshapen and puckered, and the plants take on a bunched appearance. Tomatoes, potatoes, lettuce, peppers, ornamental plants, and several types of weed serve as alternate hosts. It is usually not serious.

Beans

Seed-Borne Diseases

Beans suffer heavy disease losses worldwide, and one of the major reasons is the high prevalence of seed-borne diseases. According to CIAT, more than half of the major bean diseases can be transmitted by the seed; these include anthracnose, damping off, root and stem rots, bacterial wilt, bacterial blight, and several viruses. Disease-free certified seed

is very difficult to obtain in Latin America and presently makes up less than 3 percent of the bean seed planted there.

Control of seed-borne fungi: Many fungi are carried on or in the seed coat, and seed treatment with conventional fungicides like Arasan (thiram) and Captan (Orthocide) will control them. Others like anthracnose are carried deeper in the seed and are usually unaffected by seed treatment. Systemic fungicides like Benlate (benomyl) have shown some promise in these cases. Foliar applications of systemic fungicides during the latter half of the growing season have significantly reduced the incidence of seed-borne anthracnose in the harvested seed, but are expensive. Delayed harvesting and pod contact with the soil surface during growth can increase seed-borne disease problems.

Control of seed-borne bacteria: Seed treatments will not control internally-borne bacterial diseases on beans. Seed produced in drier areas using strict sanitary and cultural practices such as crop rotation and inspection is less likely to be contaminated.

Control of seed-borne viruses: Current seed treatments are ineffective against seed-borne viruses. Control involves the production of disease-free seed in areas where vectors and hosts can be controlled.

Fungal Diseases

PreEmergence Rot: Seed treatment with fungicides is very effective. (See maize and peanuts.) Root Rots: Beans are very susceptible to root rots caused by Rhizoctonia, Fusarium, Sclerotium, and other fungi. Symptoms include reddish or brown lesions on the hypocotyls (belowground portion of the stem) and rotting of the lateral roots from one to several weeks after emergence. Wilting and leaf yellowing may or may not occur.

Controls:

- **In temperate areas, planting only after soils have warmed up**
- **Good drainage**
- **Crop rotation**
- **Avoiding contamination of virgin ground with unclean tools, animal or green manure containing bean residue or dirty irrigation water.**
- **Treating seed with Arasan (thiram), Zineb, Demosan, PCNB, Vitavax (carboxin) or Benlate at 1-3 active ingredient per kg to give partial control.**
- **Applying Benlate or PCNB over the seed furrow after planting to give good control.**

Anthracnose (Colleotrichum lindemuthianum): Anthracnose is of worldwide importance in cool to moderate temperatures and wet conditions and is spread by seed, soil, crop debris, rain, and tools. It produces elongated reddish-brown to purple cankers on stems and leaf veins. Pods have sunken spots with pink centers and darker borders. Infected seeds mav be discolored and have dark brown to black cankers. Anthracnose is seldom a problem in hot, dry areas.

Controls:

- **Use disease-free seed.**
- **Do not grow beans more than once every two or three years on the same field (includes cowpeas, lima beans).**
- **Avoid working in fields when the plants are wet.**

- **Plow under bean residues.**

Seed treatment with fungicides is only partially effective. Preventative applications of foliar fungicides have variable results. Rust (Uromyces phaseoli): Rust is of worldwide distribution and also attacks cowpeas and lima beans. Losses are heaviest when plants are infected at or before flowering. The disease is favored by damp weather and cool nights and can infect both the leaves and the pods. First symptoms usually appear on the lower leaf surface as whitish, slightly raised spots. The spots grow into reddish-brown pustules which may reach 1-2 mm in diameter within a week. The entire leaf begins to yellow, then turns brown and dies. Rust is not carried on the seed, but the spores persist in bean residues. There are many races of rust, and bean varieties vary in their resistance to them.

Controls:

- **Crop rotation.**
- **Sulfur dust or fungicide sprays (see next section).**

Angular Leafspot (Isariopsis griseola): This disease causes gray or brown angular lesions on the leaves which eventually lead to premature defoliation. Pods may be affected with oval to round spots with reddish-brown centers and seeds may be shrivelled. The disease is carried by the seed, but contaminated plant debris is a much more common source of infection. Control: Using disease-free seed, crop rotation, and removing previously infected crop debris from the field before planting. Seed treatment with a fungicide (Benlate has given good results) and fungicide sprays may help. Sclerotinia Blight (white mold): Causes water-soaked lesions and a white mold on leaves and pods (see also peanuts). It can be controlled by crop rotation and foliar sprays of Benlate, Dichlone, Dicloran, PCNB or Thiabendazole around early to mid-bloom. Irrigation intensifies this disease.

Web Blight (Thanatephorus cucumeris) This disease can be a major limiting factor to bean

production under high temperature and humidity. Many other crops are also affected. The fungus causes small round water-soaked spots on the leaves which are much lighter than the surrounding healthy tissue and look like they have been scalded. Young pods show light tan spots that are irregular in shape but become darker and sunken with age--they can be confused with anthracnose. The stems, pods and leaves become covered with a spider web-type growth that is imbedded with brown fungal bodies. Web blight can be carried by the seed but is more commonly transmitted by wind, rain, tools, and the movement of humans and draft animals through the field.

Controls:

- **Disease-free seed.**
- **Crop rotation with maize, grasses, tobacco, and other non-hosts.**
- **Planting beans in rows, not by broadcasting, to maximize air circulation.**
- **Fungicide sprays give fair to good control. Systemics like Benlate are recommended under high rainfall.**

Bacterial Diseases

Common Blight (Xanthomonas phaseoli) and Fuscous Blight (Xanthomonas phaseoli var. fuscans): Both diseases produce the same symptoms on leaves, stems, pods and seeds. The first leaf symptoms are water-soaked spots on the undersides which grow irregularly and are surrounded by a narrow zone of lemon yellow tissue. These spots eventually become brown and dead. The stem may become girdled near the soil and break. Water-soaked spots form on the pods, gradually enlarge and become dark, red and somewhat sunken. Infected seed may rot and shrivel.

Controls:

- **Disease-free seed.**
- **Crop rotation and deep plowing.**
- **Copper-base fungicides have controlled leaf symptoms well, but have not given good yield increases. Antibiotics should not be used due to the danger of causing mutations.**
- **Seed treatment is not very effective.**
- **Some varietal resistance is available.**

Halo Blight (Pseudomonas phaseoli-cola): This bacterial disease prefers cooler temperatures than common and fuscous blights. The initial symptoms are small,water-soaked spots on the undersides of the leaves, which eventually become infected with greasy spots if the attack is severe. Stem girdle or joint rot occurs at the nodes above the seed leaves when the disease results from contaminated seed. However, leaf yellowing and malformation may occur without many other external signs.

Controls:

- **Deep plowing and crop rotation**
- **Removing infected plant debris from the field**
- **Avoiding work in the fields when the foliage is wet**
- **Disease-free seed**

- **Varieties that have some resistance**

- **Seed treatment with Streptomycin (2.5 g active ingredient per kilogram of seed) or Kasugamycin (0.25 g active ingredient per kilogram), using the slurry (liquid) method.**

- **Copper-base fungicides applied to the leaves gives poor to fair control.**

Viral Diseases

Beans are attacked by a number of viruses, many of which also attack cowpeas. Bean common mosaic, bean yellow mosaic and cucumber mosaic viruses are spread by aphids. Bean rugose mosaic and several others are spread by beetles. Bean golden mosaic and chlorotic mottle viruses are spread by white-flies, and curly top virus by the beet leafhopper. Symptoms include one or more of the following: green-yellow leaf mottling, leaf malformation, puckering, curling, plant stunting, and yellowing. Control consists largely of using resistant varieties and disease-free seed, and controlling insects.

Non-Parasitic Diseases

Seed injury: Bean seed is very susceptible to seedcoat damage and internal injury by improper threshing and mechanical harvesting or by rough handling. Damage may be invisible or produce cracks in the seedcoat, both of which can cause the following seed abnormalities:

- **Reduced germination and seedling vigor: This can also be caused by bacteria, fungi, insects, fertilizer burn, and herbicide injury.**

- **"Baldhead": The seedling lacks a growing point. There is only a bare stump above the cotyledons, so no further leaf growth can occur.**

- **Detached cotyledons: Young bean seedlings need at least one complete cotyledon or two broken ones with more than half attached to provide adequate nutrition for emergence and early growth.**

Dry bean seed (14 percent moisture or below) is the most easily damaged. Bagged seed should not be dropped or thrown onto hard surfaces.

Sunscald: Intense sunlight, especially following cloudy and humid weather, can produce small water-soaked spots on the exposed sides of leaves, stems, branches and pods. These spots turn reddish or brown and may grow together into large necrotic lesions. Air pollutants and tropical spider mites can produce similar symptoms.

Heat Injury: High daytime temperatures may cause lesions that form a constriction around the stem at the soil line, especially on light-colored sandy soils. Temperatures above 35.5°C cause blossom drop if they occur during flowering.

Chemical disease control recommendations

Seed Treatment With a Fungicide

Effectiveness

- **Seed rots (pre-emergence damping off): Very good.**

- **Seedling blights (maize, sorghum, millet, peanuts): Fair.**

- **Seedling root rots: Poor to fair.**

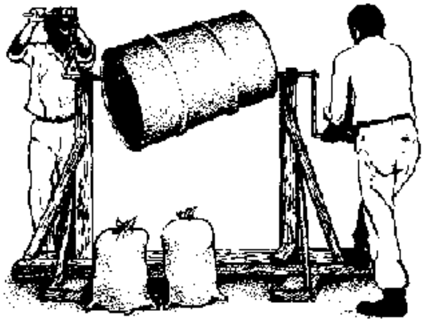
- **Seed-borne fungal diseases: Very good if the spores are carried on or close to the seedcoat surface as with loose smut and covered smut of sorghum. Poor if the disease is deeper inside the seed as with bean anthracnose.**

- **Seed-borne bacterial diseases: Poor.**
- **Seed-borne viruses: Ineffective.**

Seed treatments are very economical and are recommended for all the reference crops, especially for peanuts and the other pulses. They are most beneficial under wet conditions, particularly in cool weather where germination is slowed.

How to Treat Seed

Seed from commercial or government sources may come pretreated with a fungicide or fungicide/insecticide combination. Check the label and look for a red, purple or green dust on the seed. Farmers can treat seed by mixing it with the correct amount of fungicide dust. Large quantities of seed can easily be treated using an oil drum set up to rotate on its longitudinal axis in an offset manner, but bean and peanut seed must be treated gently. Some treatments are applied as slurries (liquids); farmers should always follow label instructions.



A mixing drum for applying insecticide and/or fungicides to seeds prior to planting.

Precautions: With the exception of mercury compounds like Ceresan, Semesan, and Agallol, seed treatment fungicides are relatively non-toxic, although some can cause skin and eye irritation. Avoid using mercury compounds. NEVER use any treated seed for human or animal consumption. Combination fungicide/ insecticide treatments containing Dieldrin or other Class 1 and 2 compounds should be handled with rubber gloves.

Table 10 Recommendations for Seed Treatment

The following recommendations are based on current information from North Carolina State University and CIAT

CROP	TREATMENT	Grams/kg	Oz/100 lbs of seed
Maize	Arasan (thiram) 50% dust	1.5	2.5
&	Captan (Orthocide) 75% dust	0.75	1.25
Sorghum	Dichlone (Phygon) 50% dust	0.6	1.0
Peanuts	Arasan (thiram) 50% dust	2.0-2.5	3.0-4.0
	Captan + Maneb (30-30 dust)	2.0-3.0	3.0-5.0
	Botran + Captan (30-30 dust)	2.0-3.0	3.0-5.0
	Difolatan + Captan (30-30 dust)	2.0-3.0	3.0-5.0
	Vitavax (carboxin) 75% W	2.0-3.0	3.0-5.0

	Vitavax + Arasan or Captan	1.25-2.0	2.0-3.0
Beans Arasan, Captan, Zined, Busan or Vitavax		.0-3.0	-

NOTE: Increase dosage on sorghum by about 25-50%, since it has more surface area per kg.

NOTE: The combinations are recommended where Aspergillus seedling blight is prevalent. Vitavax is a systemic fungicide. Innoculated peanut seed should be treated immediately before planting.

NOTE: Seed coat infections of anthracnose have been effectively controlled with Arasan 75% dust applied at 5g/kg of seed.

Recommendations for Soil Fungicides

Vitavax (carboxin) and PCNB (Terrachlor) are sometimes applied to the seed furrow at planting or to the row soil during crop growth to control soil-borne diseases like Southern stem rot and root rot. They are rarely necessary or economical for maize, sorghum, and millet and are usually not justified on peanuts an-i beans unless potential yields are high and disease problems are serious.

Peanuts

Southern stem rot control: Apply PCNB preplan" at active ingredient 11kg/ ha in a band 20-30 cm wide centered over the row or at early pegging stage in a band 30-40 cm wide. Preplant applications should be incorporated 5.0-7.5 cm deep. When applying PCNB at early pegging, direct the spray so that it reaches the soil at the base of the plants. If granules are used, don't apply them when the plants are wet. Drag bags over the plants to settle the granules to the soil. Vitavax can be applied in the same manner at early pegging

using 1.1-2.25 kg/ha active ingredient (Recommendations from North Carolina State University and Clemson University.)

Beans

Root and stem rot caused by Sclerosium rolfsii: Application of PCNB at 3.4-4.4 kg/ha of active ingredient to the seed and surrounding soil at planting has proven effective in Brazil (CIAT data). Root rot caused by Rhizoctonia solani: North Carolina State University recommends PCNB at 100-150 grams active ingredient per 1000 meters of row length applied at planting time to the seed and surrounding furrow soil.

Recommendations for Foliar Fungicides

Protectant versus Erradicant Fungicides

Most fungicides like Maneb, Zineb, Difolatan, and Manzate act as protectants by remaining on the leaf surface to prevent fungal spores from germinating and penetrating the plant. They have little or no erradicant ability to stop the progress of an existing infection. However, a few fungicides like Benlate (benomyl) and Thiabendazole (Mertect) are actually absorbed into the leaf tissue and translocated outwards toward the margins. These systemic fungicides act as erradicants as well as protectants and also have other advantages:

- **They are not vulnerable to being washed off the foliage by rainfall or sprinkler irrigation.**
- **Since they are translocated within the leaf, uniform foliage coverage is not as important as with the nonsystemic protectant fungicides.**

The main disadvantage of the systemic fungicides is that they are effective against a

narrower range of fungal diseases than most of the protectant fungicides, so more care must be taken to match the product to the disease. Vitavax (carboxin) and Plantvax (oxycarboxin) are two other systemic fungicides mainly used for seed treatments and soil application.

Guidelines for Applying Foliar Fungcides

Type of Crop: Foliar fungicides are seldom economical for maize, sorghum, and millet. They will give the best benefit/cost ratio when used on wellmanaged peanuts and beans under conditions where fungal leaf diseases are a limiting factor. When to Apply: Ideally, applications should start slightly before the onset of infection or at least before the disease signs have become very evident. This is especially important when non-systemic protectant fungicides are used. In most growing areas, the major fungal leaf diseases are somewhat predictable as to their date of first appearance. Fungicides are too expensive to be used on a routine basis from the time the plants emerge. Besides, most fungal diseases do not infect plants until around flowering time or after. Frequency of Application: This depends on disease severity, rainfall, and type of fungicide. The non- systemic protectant fungicides can be washed off the foliage by rainfall (or sprinker irrigation), but the systemics remain safely within the plant once they have been absorbed. Under frequent rainfall, the protectants may have to be applied as often as every four to seven days. Under drier conditions, intervals of 10-14 days are normal. Systemics are usually applied once every 12-14 days regardless of rainfall frequency. Disease severity also affects application frequency but is usually closely related to rainfall and humidity (as well as varietal resistance).

Uniform and thorough coverage of crop foliage is very important when applying fungicides. This is especially true for the protectant products which are effective only on those portions of the leaf surface they actually cover. An attempt should be made to cover both sides of the leaves when using protectants. Stickers and spreaders are recommended

for nearly all fungicide sprays to enhance coverage and adhesion.

Duter is one exception, since these additives increase the likelihood of crop injury from that particular product. Some fungicides already contain stickers and spreaders, so be sure to read the label. Amount of water needed for adequate foliage coverage: This varies with plant size, crop density, and type of sprayer. When using backpack sprayers on full-size plants, at least 700 1/ha of water is needed.

Dosage Recommendations

Label instructions and extension service recommendations are the specific quidelines to follow. The following recommendations are meant to serve as general guidelines. Peanut Cercospora Leafspot: Benlate and Duter have generally proved the most effective, although most other products, such as Dithane M-45, Antracol, Bravo (Daconil), Difolatan, copper-sulfur dusts, and copper-base sprays, also give satisfactory control. The following recommendations come from North Carolina State University (U.S.A.) and Australia.

> **Duter 47% WP, 425 g actual formulation per hectare. Do not use a sticker or a spreader.**
>
> **Benlate 50% WP, 425 g actual formulation per hectare plus stickerspreader.**

Control is enhanced by combining 285 g Benlate plus 1.7 kg Dithane M-45 or Manzate 200 plus 2.3 non-phytotoxic crop oil per hectare. The oil improves penetration.

> **Daconil (Bravo), 875-1200 g active ingredient per hectare.**
>
> **Copper-base products like copper oxychloride, copper hydroxide, and basic copper sulfate can be used at 1.85 kg active ingredient per hectare.**

Antracol 70% WP can be used at 1.7 kg/ha.

Copper-sulfur dust: Follow manufacturer's recommendation.

Note: Do not feed treated hay to livestock unless only copper or copper-sulfur products are used. Duter helps retard spider mite buildup. Plant injury may result if a sticker-spreader is used with Duter.

Bean Leaf Diseases: Potential bean yields must be high to warrant the use of foliar fungicides. Systemics should be considered where rainfall is high if they are effective against the disease involved.

Anthracnose: Literature from CIAT recommends Maneb 80% W or Zineb 75% W at 3.5 g/l of water, Benlate at 0.55 g/l, Difolatan 80 W at 3.5 kg/ha, and Duter 47 W at 1.2 g/l.

Rust: Suggestions from CIAT are for Dithane M-45 or Mancozeb at 3-4 kg/ha; Manzate D 80 W or Maneb 80 W (Dithane M-22) at 4 kg/ 1000 1/ha; sulfur dust at 25-30 kg/ha. Plantvax (oxycarboxin), a systemic, has been found effective when sprayed at a rate of 1.8-2.5 kg/ha of the 75% WP at 20 days and 40 days after planting or every two weeks until the end of flowering.

White mold (Sclerotinia): North Carolina State University recommends Benlate 50 W at 1.72.25 kg/930 1/ha on Botran (dichloran) 75 W at 4.5 kg/9301/ha.

Web blight: Recommendations from CIAT are for Benlate 50 W at 0.5 kg/ha (0.5 g/l at 1000 1/ ha) or Brestan 60 at 0.8 kg/ha or Maneb (DIthane M-22) at 0.5 g/liter. (Note: The Maneb dosage seems unusually low.)

Angular leafspot: Literature from CIAT suggests Benlate 50 W at 0.5 g/l, Zineb,

Mancozeb, Ferbam-sulfur-adherent (no dosages given).

Bacterial blights: Use copperbase sprays and follow label directions.

Nematodes

Nematodes are tiny, colorless, thread-like roundworms 0.2-0.4 mm long. There are many kinds of plantfeeding nematodes. Most live in the soil and feed on or within plant roots using needle-like mouthparts for piercing and sucking. They dissolve the roots' cell contents by injecting an enzyme with produces various reactions depending on the type of nematode. The root-knot nematode causes portions of the roots to swell into galls or knots, while root lesion nematodes produce produce dark-colored lesions on the roots. Sting nematodes and stubby-root nematodes prune the root system and make it appear stubby. Root growth is often stopped and becomes very susceptible to attack from bacteria and fungi.

Nematodes are most prevalent and active where soil temperatures are warm. They seem to prefer sandier soils or those portions of the soil where fertility or moisture are low. However, clayey soils can have serious nematode problems, too.

Since they are so tiny, nematodes seldom move more than a few inches a year. Unfortunately, they are spread easily by soil carried on tools and equipment or by water runoff from a field.

Maize, sorghum and millet are fairly resistant to most kinds of nematodes, and yield losses seldom exceed 10-15 percent. The pulses are most vulnerable to root lesion and sting nematodes which feed on roots, pegs, and pods. Beans and cowpeas are attacked by root knot, root lesion, and sting nematodes plus several other types. In Kenya, heavy infestations of root knot nematodes have reduced bean yields by up to 60 percent in some cases.

Diagnosing Nematode Damage

Above-ground symptoms are seldom distinctive enough to make a conclusive diagnosis without examining the root system, but the following are possible indications of nematode damage:

- **Stunting, yellowing, lack of plant vigor. However, these can be caused by many other problems--low fertility, diseases, excessive soil acidity or moisture, for example.**

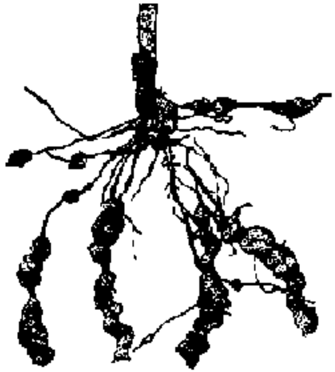
- **Wilting, even when moisture seems to be adequate and heat is not excessive. This can also be caused by soil insects, borers, and diseases.**

- **Damage almost always occurs in scattered patches in the field and is rarely uniform. This is an important characteristic of nematode problems.**

Root symptoms, as described below, may be observed if the roots are carefully dug up and examined:

- **Galls or knots are a sure sign of root knot nematode damage. These should not be confused with the Rhizobia bacteria nodules attached to the roots of legumes. The galls or knots caused by root knot nematodes are actually swollen portions of root.**

- **Other types of nematodes cause tiny, dark-colored lesions, stubby roots or loss of feeder roots. This damage should not be confused with that caused by rootworms, white grubs or other insects.**



Nematodes

Root knot nematode galls on bean roots. Note how they differ from nodules by actually being part of the root.

Laboratory diagnosis is usually needed to confirm nematode damage, although root knot nematode injury is often readily apparent. Plant pathology labs in most countries can test soil and root samples for nematodes. It will be necessary to take 10 random subsamples within the field right next to the plants using a shovel for testing. Sample the soil by digging down about 2025 cm and discarding the soil from the top 5 cm and from the sides of the shovel. The remaining soil should be placed in a pail, making sure some roots are included. The sub-samples should be mixed together and a half-liter of the soil placed in a plastic bag. The sample should be protected from sunlight or excessive heat, preferably by refrigerating it until mailing time. A lab diagnosis is also valuable for planning a suitable crop rotation program to reduce nematode numbers, since different types vary in their crop preferences.

Nematode Control

Complete eradication is impossible, but chemical and nonchemical controls can reduce populations to tolerable levels. Non-Chemical Controls Crop rotation: This is sometimes difficult or impractical, since most types of nematodes have many crop hosts as shown below:

- **Root crop nematodes (Meloidogyne spp.): Beans, cowpeas, cucumber, squash, watermelon, cantaloupes, tomatoes, tobacco, okra, cotton, carrots, lettuce, peas and strawberries are very susceptible, but peanuts can be attacked also. Grass family crops tend to be less vulnerable. Cotton and peanuts can also be included in the same rotation, since they do not share the same root knot species. However, planting cotton immediately prior to peanuts will cause a buildup of peanut soil diseases.**

- **Root lesion nematodes (Pratylenchus spp.): Beans, cowpeas, peanuts, soybeans, tobacco, okra, pepper, potatoes, sweet potatoes, tomatoes, sugar cane and strawberries are among the most susceptible. Maize is less so, and sorghum and millet have better resistance.**

- **Sting nematodes (Bolonolaimus spp.): Beans, cowpeas, cotton, soybeans, maize, millet, sorghum, sweet potatoes, tomatoes, squash and pasture grasses are among the hosts. Tobacco and watermelons are resistant.**

Some types of tropical legume tree such as Prosapis spp. harbor nematodes. Host country extension services sometimes have a nematode specialist who should be consulted concerning crop rotations and other controls.

Resistant varieties: Varieties differ somewhat in their resistance to nematodes.

Exposure: Plowing up roots of susceptible crops right after harvest will expose them to sunlight and drying, which will kill many of the nematodes.

Flooding: One month of flooding followed by a month of drying and a further month of flooding will greatly reduce nematode problems, but is not often feasible.

Antagonistic plants: Many garden books recommend inter-planting marigolds among susceptible crops to control nematodes. Unfortunately, research has shown that marigold species vary in their effectiveness, which is limited mainly to one type of nematode, the root lesion nematode. Furthermore, marigolds do not kill nematodes, but starve them out. This means that interplanting is not effective, since the nematodes will still have a food source. Marigolds would have to be planted exclusively and then followed by a crop susceptible to root lesion nematodes in order to provide some control.

Two legume green manure or cover crops, Crotalaria spectabilis (showy crotalaria or rattlebox) and Indigo fera hirsute (hairy indigo) can reduce populations of most type of nematodes.

Soil: Good soil fertility and high soil organic matter levels help somewhat.

Chemical Controls

Soil fumigants: Some of these, like methyl bromide, Vapam, Basamid and EDB are often used on vegetables or transplant beds, but are either too expensive or require specialized application equipment. Some are very dangerous.

Non-fumigant nematocides: These include Mocap (ethoprop), Furadan and Dasanit, and can be applied as granules to the crop row and are effective against some insects. Under small farmer conditions, their use on maize and other cereals for nematodes only would be uneconomical except in cases of heavy infestations and high potential yields. There may be some cases where their use is justified on the pulses, especially peanuts. Product use guidelines for some of the more common nematocides:

NEMAGON (DBCP, Frumazone): Comes as a liquid or granules but has been virtually banned in the U.S. as a possible carcinogen. Prolonged exposure over the years has caused testicular atrophy in males. Stay away from this one.

FURADAN (Carbofuran): See description under Section B. Has a very low dermal, but very high oral toxicity. Nematode application guidelines are:

> **Peanuts: Apply a band 30-35 cm wide over the row before planting; use 2.2-4.5 kg of active ingredient per hectare. Needs to be worked into the soil 5.5-15 cm deep.**
>
> **Maize: Apply in a band 18-36 cm wide over the row before planting and work into the top 5-10 cm of soil. Use 1.7-2.25 kg of active ingredient per hectare.**

MOCAP (Ethroprop, Prophos): Kills nematodes and soil insects but is very toxic both orally and dermally. Applied like Duradan at the rate of 1.7-2.25 kg active ingredient per hectare. Not recommended for most small farmers. Non-systemic.

TEMIK (Aldicarb): A systemic insecticide/nematocide with extremely high oral and dermal toxicity. Avoid it.

DASANIT (Terracur, fensulfothion): A non-systemic product for soil insects and nematodes. Very high oral and dermal toxicity. Avoid using.

NEMACUR (Phenamiphos, Fenamiphos): A systemic product for nematodes, soil insects, and above-ground sucking insects. Class 2 toxicity. Applied to peanuts like Furadan at 1.7-2.85 hectare. Handle with care. Use Furadan instead if possible due to its much lower dermal toxicity.

Bird and rodent control

Birds

Seed-Eating Birds

In parts of Africa and in other areas, birds like the bush fowl dig up and eat freshly-planted seeds, They often uproot young seedlings of maize and other cereals during the first several weeks of growth as well. Controls: Scarecrows are relatively ineffective, although noise-making devices may offer some control. It is often necessary to frighten away the birds from planted fields during their usual early morning and late afternoon feeding times for the first two or three weeks after planting. Farmers sometimes soak their seeds in highly toxic insecticides like Endrin and Dieldrin and plant them or use them as scattered bait. This is not only dangerous, but can lead to indiscriminate killing of wildlife. Some safer repellents are available such as Mesural 50 percent dust, which is mixed with maize before planting at the rate of 9-10 g/kg to repel blackbirds. Mesurol may injure maize seed under cool, wet conditions. Dusting seeds with Captan fungicide or soaking them in turpentine may provide a fair repellent effect.

Perhaps the most effective control method is continuous string flagging which uses cloth or plastic streamers 5-6 cm wide and 50-60 cm long. The streamers are attached at 1.5 m intervals to strong twine which is strung along heavy stakes at least 1.2 m tall spaced about 15 m apart.

Quelea Birds

The Quelea bird (Black-Faced Dioch) is a sparrow-sized weaver that may be the world's most destructive grain-eating bird. It is confined to the Sahel and savanna regions of Africa in a band running from Senegal to Mauritania to Ethiopia and Somalia and then south through East and South Africa and across into Angola.

The birds congregate in vast nomadic colonies that feed on the seeds of both natural

grasses and crops like millet, sorghum, rice, and wheat, mainly in the unripe stage. (Maize is less affected.) Queleas begin breeding a few weeks after the rainy season begins and build their nests in thorn trees or swamp grasses. Studies in Senegal have shown that even small trees can hold up to 500 nests and taller ones up to 5000-6000. Each pair of Queleas can produce two young. Controls: In areas prone to attack, the villagers build high platforms in the fields and maintain noise-making vigils, sometimes for many weeks, while the grain is ripening. Governments frequently undertake mass Quelea extermination campaigns which center around the destruction of nesting and roosting sites with explosives, flamethrowers, etc. South African authorities killed 400 million with aerial sprays in one four-year campaign. However, the birds usually return in undiminished numbers within a year or two, since they are highly nomadic and have extensive breeding grounds estimated to cover two million square miles. At the present time, bird-resistant crop varieties are not very successful against the Quelea, and the same seems to be true of repellents like Avitrol and Morkit.

Other Grain-Eating Birds

Blackbirds (grackles, starlings, etc.), sparrows, cockatoos, parrots, galahs and pigeons also feed on grain crops, though usually in less awesome numbers than Queleas. Bird-resistant varieties of sorghum (see Chapter 3) are fairly effective at repelling them while the grain is ripening, but lose this ability when maturity nears. Repellants like Avitol (aminopyridine) are often used successfully in the U.S. The usual result of using repellents in one field, however, is that the birds move on to attack other fields that are unprotected.

Rodents

The cane rat (Thronomya sp.) can cause considerable losses of cereal crops during the latter stages of growth, especially if lodging has been heavy due to high winds or diseases. Controls:

- **Rodents can be discouraged from entering fields by maintaining a 2.0-3.0 m wide cleared swath around the field borders from planting until harvest. Fences made from oil palm fronds or split bamboo are also effective, especially if traps or wire snares are set in the gaps.**

- **Good weed control in the field is helpful.**

- **Leaning or fallen plants should propped up and the dry lower leaves stripped off to help deter climbing.**

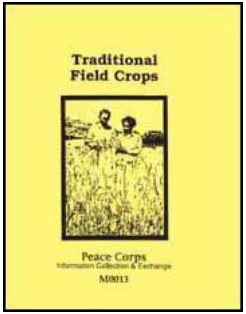
- **Many villages carry out organized killing campaigns. The best time for such campaigns is during the dry season when the rats congregate in the few remaining pockets of green vegetation.**

- **Repellants like Nocotox 20 may be partly effective.**

- **Rats should be prevented from gaining access to stored grains and other food that can cause a buildup in populations during the dry season. (See Chapter 7.)**

- **Poison baits can be used.**

NOTE: Killing rats in the field with poisons, traps, and other methods is usually not a very effective longterm solution. The best approach is to prevent a rat population buildup; this requires area-wide coordination. The PC/ICE Small Farm Grain Storage manual contains a very useful section on rat control.



Traditional Field Crops (Peace Corps, 1981, 283 p.)

Harvesting, drying, and storage

For the farmer, the challenges of agriculture do not end when a successful crop reaches maturity in the field. Losses between maturity and consumption or sale are frequently serious, especially for the small farmer, and are also a major contributing factor to the world food problem. This chapter focuses on specific practices that will keep these losses at a minimum.

From maturity to harvest

Maize, Sorghum And Millet

When these cereal crops reach physiologic maturity, the grain is still too wet and soft for damage-free threshing (separation from the stalk or ear) or for mold-free storage. Most small farmers let the crop dry naturally in the field for several weeks prior to harvest, unless immediate land preparation is needed for the next crop. During this "dry-down" period, the crop is vulnerable to losses caused by several factors:

- **Rodents: Losses are especially high where lodging or stalk breakage is severe.**

- **Lodging and stalk breakage: These may occur during the drydown period and are encouraged by overly-high plant densities, low soil potassium levels, high winds, and stalk rots. They promote rodent damage and grain rots, especially when the ears or seedheads touch the soil.**

- **Grain rots: Wet weather during dry-down may provoke fungal grain rots (head molds, ear rots) or accelerate those that may have begun during grain filling. Some small farmers bend the maize ears downward near maturity to prevent water from entering through the tips.**

- **Weevils and other storage insects: Some storage insects like the rice weevil (Sitophilus oryzee) and the Angoumis grain moth (Sitotroga sp.) can fly to the fields and infest crops from the soft dough stage onward. Maize varieties with long, tight husks have good resistance, but high-yielding varieties tend to be inadequate in this respect.**

- **Birds: Most species prefer younger, softer grain but can still cause problems after maturity. Bird-resistant sorghum varieties lose their repellent ability by the time maturity is reached.**

- **Theft: Farmers should be encour encouraged to harvest their crops as soon after maturity as is practical to prevent losses from theft.**

Beans and Cowpeas

Losses between maturity and harvest of beans and cowpeas are caused by:

- **Pod shattering: Spillage of seeds from drying pods that split can be a problem,**

but losses are not usually serious unless harvest is delayed.

- **Bruchid weevils: (See section on storage.) These are not only serious storage pests of pulse crops but also can fly to the fields to infest beans and cowpeas by laying eggs in cracks or cuts in the pods.**

- **Seed deterioration: This can be a serious problem in beans and cowpeas and can occur soon after maturity if rainfall continues. Studies by IITA have found that cowpea seed quality and germination decline rapidly when harvest is delayed. In tests under wet conditions, seed germination fell to 50 percent or lower within three weeks after maturity, and preharvest fungicide sprays were of little benefit in preventing this.**

- **Delayed maturity: Literature from CIAT mentions that bean plants may put out new growth and flowers during maturation under high rainfall. The new foliage can interfere with the proper drying of the maturing pods and may lead to rotting.**

Peanuts

Peanuts pose a special problem since the nuts do not mature simultaneously. Those that ripen first may become detached from the pegs before the rest mature. The timing of the harvest is critical and will be covered in the next section.

Harvesting and threshing

Nearly all small farmers in the developing countries harvest their cereal crops and beans by hand and thresh them later. In the case of peanuts, harvesting involves lifting the plants and attached pods from the ground, then allowing them to cure (dry) in the field for a period of from several days to four to six weeks before threshing.

Threshing consists of separating the seeds from the seedheads, cobs or pods by beating, trampling or other means. With peanuts, threshing separates the pods from the pegs that hold them to the plant and does not include actual shelling. (With maize, the term "shelling" is usually used in place of "threshing".)

With cereal crops and beans, the small farmer has several options as to when to thresh the crop. If the matured crop has stood in the field for some time during dry weather, the seeds may be low enough in moisture content to be threshed without damage right after harvest. However, the farmer may still prefer to delay threshing for two reasons:

- **The grain may still be too high in moisture content to escape spoilage if stored as loose seed. Grain stored in unthreshed form on the cob, on the seedhead or in the pod can be safely stored at a much higher moisture content since there is much more air space for ventilation and further drying.**

- **Maize stored as unhusked ears and pulses stored in their pods are more resistant to storage insects.**

Winnowing follows threshing and consists of separating chaff and other light trash from the grain using wind, fan-driven air or screens Winnowing may need to be repeated several times before consumption or marketing and is usually supplemented by manual removal of stones, clods, and other heavy trash.

Guidelines for Harvesting and Shelling Maize

Determining Maturity

In the 0-1000 m zone in the tropics, most maize varieties reach physiologic maturity within 90-130 days after seeding emergence or 50-58 days after 75 percent of the plants have produced silks. As maturity nears, the lower leaves begin to yellow and die off. In

healthy, wellnourished plants, this should not occur until the ears are nearly mature. Ideally, most of the leaves should still be green when the husks begin to turn brown. Unfortunately, such high-yielding plants are not often seen in small farmer fields because of stress factors like low fertility, insects, diseases, and inadequate weeding. More typically, most of the leaves are dead by the time the plant matures.

The "black layer" method: When a maize kernel reaches physiologic maturity (maximum dry weight), the outside layer of cells at its base where it connects with the cob will die and turn black, thus preventing any further cob-to-kernel nutrient transfer. This "black layer" provides an indication of maturity. The layer can be seen by detaching kernels from the cob and examining their bases. Newly-matured kernels may have to be slit lengthwise with a pocketknife to expose the black layer. However, with older kernels, the layer can be readily seen by scraping the base with the fingernail.

Keep in mind that physiologic maturity is not reached until all the kernel's milky starch has solidified. This process begins at the tip of the kernel and moves downward toward the base. The kernels at the ear tip are the first to mature, followed by those in the middle and finally the ones at the lower end (the difference is no more than a few days).

With healthy plants, kernel moisture at physiologic maturity will vary from about 28-36 percent. This is usually too high for damagefree threshing or for mold-free storage except in the form of husked ears placed in very narrow cribs. The black layer may form much earlier in the maize plant's growth cycle if growing conditions are adverse. Such kernels will be small and shrunken and have much higher moisture contents when the black layer forms. The drydown rate of maize: When maize plants are left standing in the field after maturity, the kernels lose about 0.25 0.5 percent moisture per day, but this can range from 0.1 - 1.0 percent depending on weather conditions and whether the ears are pointing downwards to prevent water entry.

Methods of Harvesting Maize:

- **By Hand: The ears are removed by hand from the plants with or without husking. Husked ears require a smaller storage area and are more resistant to insects, but may rot more easily if stored at a high moisture content.**

- **Mechanical: Tractor-drawn pickers and picker-shellers can handle one to two rows at once, but self-propelled combines are available which can harvest up to six to eight rows. By changing the front attachment (the "head"), combines can also harvest other cereal crops (if not overly tall) and bush beans, but cannot be used on peanuts. Well-adjusted pickers and combines should have losses of less than 2 percent and 4 percent respectively unless lodging is severe.**

When to Begin Harvesting

Harvest should begin as soon as is practical after maturity, but this depends on the farmer's harvest method and storage and drying facilities.

Hand harvesting: Since husked ears can be safely stored in narrow cribs (see storage section) at up to 30-32 percent kernel moisture, harvest can be started at or soon after maturity if desired. Most small farmers prefer to let the maize dry down further in the field first.

Mechanical harvesting

- **Pickers If narrow cribs (see storage section) are used for storage, mechanical picking can be started once kernel moisture is down to 30-32 percent.**

- **Picker-shellers and combines: In this case, adequate drying facilities and**

kernel damage from shelling are the main concerns. In the tropics, shelled maize above 14 percent moisture will not store more than a week to a few months without spoilage. Rapid drying is essential and usually requires forced air and heated dryers when large volumes are involved. Kernel damage from mechanical shelling may become serious above 28-30 percent or below 15-18 percent moisture.

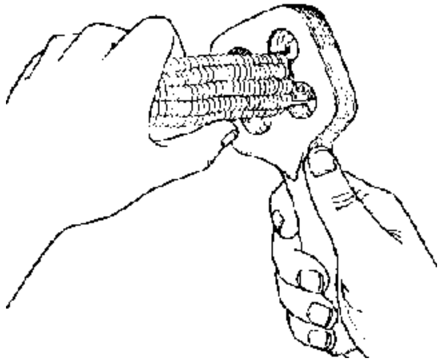
Methods of Shelling Maize

If done too roughly or at too high a moisture content, shelling can cause kernel damage such as tip loss, cracking, stress cracks, and pulverization. Studies have shown that damaged kernels spoil two to five times more rapidly during storage than undamaged ones. Hilysine varieties and other floury types are more susceptible to damage. Shelling methods and guidelines for small farmers include these:

Traditional methods

- **By hand: This method is very tedious and labor-intensive, but causes little damage to the kernels. It is more thorough than other methods and also allows for separation of damaged and insect-infested grain. This method is best suited to small amounts.**

- **Beating: Dry ears are placed in bags and beaten with sticks. This is quicker but less thorough than hand shelling and may cause damage.**



Wooden, hand-held maize sheller

Improved methods

- **Wooden hand-held maize sheller: The model shown in the drawing was developed by the Tropical Products Institute and has an output of roughly 80 kg/hour. (Plans are available from ICE.) Other types of hand-held shellers are available commercially. Cobs must be husked first.**

- **Hand-cranked or pedaloperated shellers Small, hand cranked models have outputs of about 50-130 kg/hour. The Ransomes Cobmaster twin-feed pedal-operated sheller has an hourly output of 750-900 kg. For details write Ransomes Ltd., Ipswich 1P3 9QG, England. Maize at too high or too low a moisture content is likely to be damaged, but this can be checked visually. Ears must be husked first.**

- **Motor-driven shellers have outputs of about 1000-5000 kg/hour. The comments above also apply to this type.**

Winnowing Methods

Reliance on wind is the traditional method, but hand-cranked or pedal-driven fans can be constructed easily. The larger models of the hand-cranked or pedaloperated shellers usually are equipped with blowers.

Guidelines for Harvesting and Threshing Sorghum And Millet

Determining Maturity

When grown under favorable conditions and good management, grain sorghum reaches physiologic maturity while the stalks and most of the leaves are still green. Like maize, sorghum kernels also develop a "black layer" at their base when physiologic maturity is reached. The layer can be checked by pinching off some kernels from the bracts that hold them to the head and examining their bases. If present, the black layer can be seen without splitting the kernel. Sorghum flowers and pollinates from the tip of the seedhead downward, a progression which takes from four to seven days. The kernels mature in the same direction, with those at the bottom lagging about a week behind those at the top. Kernel moisture content is about 30 percent at physiologic maturity.

Methods to Harvest Sorghum

- **By Hand: The seedheads are cut off using a knife or sickle.**
- **Mechanical: Tractor driven or self-propelled combine harvesters can harvest and thresh short (dwarf) and medium varieties.**

When to Harvest Sorghum

In most sorghum-growing regions in developing countries, maturity often coincides with the start of the dry season, and the crop may be left standing in the field to dry for a number of weeks before harvest. Crop losses during this period can be heavy. If dry

conditions prevail, the crop can be harvested at or shortly after maturity and stored on the head with little danger of spoilage. Sorghum can be harvested and threshed with a combine once kernel moisture reaches 25 percent. However, loose grain that is this "wet" must be dried down to around 14 percent within a few days to avoid spoilage. If large amounts of grain are involved, some form of forced air or heated drying would probably be needed.

Methods of Threshing Sorghum

- **Traditional methods: These include pounding, beating, and animal trampling and are very tedious except for small quantities. Kernel damage is possible unless care is taken.**

- **Mechanical methods: Tractoror motor-driven stationary threshers come in many models with outputs of 600-3000 kg/ hour. All but the simplest models will also clean the threshed grain by the use of shaking screens and/or blower fans.**

Plans for a four-person pedalpowered grain thresher/mill for sorghum, millet, and wheat designed by VITA can be obtained from ICE. As of 1979, however, this thresher/mill had not been adequately field tested and is not suited to local village construction.

NOTE: Millet is harvested and threshed much like sorghum.

Guidelines for Harvesting and Threshing Peanuts

Peanuts reach maturity when the veins on the inside of the pods turn dark. However, since the plants produce flowers over a period of from 30-45 days, the nuts do not mature simultaneously. Unfortunately, harvesting cannot be delayed until all the nuts have ripened, because heavy losses may occur for two reasons:

- **By the time the last pods ripen, many of those which matured earlier will have become detached from the plants due to peg rotting. This pod "shedding" can be especially serious when Cercospora leaf spot causes premature leaf loss or when lifting occurs in dry, hard soils.**

- **In Spanish-Valencia varieties, the early-maturing kernels may sprout if kept too long in the ground. The Virginia types have a lengthy seed dormancy period which prevents this.**

Likewise, if harvesting occurs too early, an undesirably high proportion of the kernels will be immature, shrunken, low in weight, and inferior in flavor. The choice of harvesting date can easily make a 400-500 kg/ha difference on a high yielding crop.

How to determine "peak maturity": The farmer should aim for a harvest date that will recover the largest number of mature kernels before excessive pod shedding or sprouting has occured. This is often referred to as "peak maturity", and there are no easy rules for determining it. The pattern of flowering, pod setting, and kernel maturation varies from year to year due to differences in weather and leaf spot incidence. The first 40-60 flowers to bloom are generally the ones that end up as mature kernels at peak maturity. Flowering starts about 30-45 days after plant emergence in warm areas and begins very slowly. In fact, most of these 40-60 flowers usually bloom near the end of the flowering period, although there maybe several "bursts" of flowering.

Peak maturity cannot be determined by looking at the aboveground portion of the plants. The best method is to carefully dig up a few plants every several days beginning near the end of the growing period and examine the pods. With experience, the farmer can learn to estimate quite accurately how many young pods will ripen before the matured pods begin to shed or sprout.

Minimizing crop losses: Pod shedding can be reduced by keeping the plants green and

healthy until maturity. This often requires controlling Cercospora leaf spot with fungicide sprays or dusts. This also increases yields by prolonging the growing season by as much as two to three weeks. Some farmers, however, may object to having leafy green foliage at harvest time, since it may slow down the rate of field curing when the harvested bushes are placed in stacks. In this case, farmers may purposely stop their fungicide applications late in the season to promote defoliations. This also has the effect of making maturity more uniform, although yields are reduced. Such a practice may be justified in some regions, especially where field curing weather is not always dry. On the other hand, farmers can use leafy plants for lifestock feed after harvest.

> **(NOTE: In the U. S., extension service advise against feeding peanut hay to dairy or beef animals if it has received fungicide applications, except in the case of copper or copper-sulfur products.)**

Peanut Harvesting

Whether traditional or modern methods are used, the harvesting process basically consists of four steps:

- **The taproots are cut and the plants are pulled (lifted) from the ground with the attached pods.**

- **Under traditional methods, the plants are cured (dried) in the field for up to 4-6 weeks before threshing. With modern methods, the plants are cured in the field for 214 days, depending on whether artificial drying is available afterwards.**

- **The pods are threshed from the plants.**

- **The threshed pods are placed in bags for storage and possible further drying. In dry areas, the pods are often stored in outdoor piles.**

Note that shelling the nuts from the pods is not normally a part of the harvesting process, since the kernels dry and store better in the pod. Shelling damage can be high unless kernel moisture is at or below 10 percent.

Methods of "Lifting" the Crop:

- **By hand: The plants are pulled from the ground manually after loosening the soil with hand tools. It takes about 30 hours to pull and stack a hectare with this method.**

- **Animal-drawn methods: Special animal-drawn lifters are available and consist of a sharpened, horizontal blade that is run under the plants right below the nuts to cut the taproots, loosen the soil, and partially lift the plants. One hectare can be lifted and stacked in about 15 hours. A carefully operated weeding sweep (see Chapter 5) about 30-40 cm wide can be used, but the blade should be adjusted to slice rather than push through the soil to minimize pod losses. Some farmers use moldboard or lister plows on ridge-planted peanuts.**

- **Tractor-drawn methods: Tractors can be equipped with front mounted cutter bars and rear-mounted pullers that lift the plants. Two to four row setups are common, and some of the pullers will combine two or more rows into one windrow for curing. Peanut inverters are available that flip the bushes over to expose the nuts to the sun.**

Some General Guidelines for Lifting

- **Lifting the crop when the soil is too wet can weaken the pegs. It may cause excessive amounts of soil to adhere to the pods which can also slow down curing.**

- **Lifting losses can be high in very hard, dry soils.**

- **If cutter blades are used, they should be kept sharp and be set at a slight forward pitch to aid in lifting the plants and loosening the soil.**

Methods for Curing and Threshing Peanuts

The method and length of curing prior to threshing varies considerably with weather conditions and the availability of equipment and artificial methods of drying. The most common methods are:

- **The "stackpole" method: This is often used by mechanized and unmechanized farmers alike where curing weather can be wet and no means of artificial drying are available.**

  Poles are placed firmly in the ground, and two slats are nailed at right angles to each other about 50 cm above ground on each pole. After being allowed to wilt, the plants are stacked around the pole with the pods facing inward. The slats hold the bottom layer off the ground and also improve air curculation. The stack is built in a cone shape and the top covered with a few vines to help shed water. In some cases, the plants are kept in the stacks until kernel moisture is down to 8-10 percent. This may take up to four to six weeks in cool, wet weather.

  If harvest takes place at the start of the dry season, the plants may be stacked right on the ground.

- **Row or windrow curing: If artificial methods of drying are available or effective sun drying is possible, the plants may be cured in the field in rows or windrows for two to five days before threshing. Where post-threshing drying is less efficient, the curing period lasts about 7-14 days so the pods will be drier at threshing time.**

  Windrows can be made by hand or through careful operation of a side-delivery rake

(tractordrawn). The main advantage of windrows is that they save time when self-propelled modern threshers are used.

The plants can be placed upside down to expose the nuts to the sun. This will reduce damage in wet weather, hut can lower quality under hot, sunny conditions.

Windrows that are overly compact and dense increase curing time and spoilage under wet conditions. After a heavy rain, it may be necessary to gently turn the windrow to prevent mold. This should be done before it dries out to minimize pod shedding. Avoid placing windrows over depressions in the field.

Methods of Threshing

- **Traditional: Peanuts can be manually threshed by stripping the pods by hand or by striking the base of the plants (above the pods) against the edge of a barrel or wooden box.**

- **Improved: A hand-cranked thresher with an output of 200 kg/hr is being marketed in Senegal.**

Stationary motor-driven threshers are available. Tractor-drawn or self-propelLed threshers are used in modern farming and pick up the plants right from the windrows.

Threshing Guidelines

- **Peanuts can be threshed any time after the plants are lifted as long as adequate natural or artificial drying methods are available (in the case of high-moisture nuts). Further drying will be needed after threshing for peanuts above 10 percent moisture intended for bulk storage and for peanuts above 16 percent intended for**

storage in loosely stacked bags under good ventilation. Peanut moisture content at lifting may be over 35 percent.

- **Tips on mechanized threshing: llull damage and splitting is lowest for peanuts threshed at 25-35 percent moisture. Letting the lifted plants dry down longer in the field reduces post-threshing drying requirements but increases the weather risk. Unless the vines are dry enough to be easily torn apart, rough threshing action may be needed which will increase kernel damage.**

Shelling Peanuts

Peanuts are not usually shelled until shortly before consumption or oil extraction. The shelling percentage is about 68 percent (1000 kg of unshelled peanuts yields about 680 kg of shelled kernels), and the process is most easily accomplished when kernel moisture is below 10 percent. Hand shelling is very tedious and the output is only about 10-20 kg/day Various models of hand-cranked or pedal-operated shellers are commercially available with outputs about 15-90 kg/hour.

Plans developed by VITA for a beltdriven peanut huller made from scrap motor vehicle parts are available from ICE; some simple welding and cement work is needed. Power can be supplied by a water wheel, small motor or animal.

Guidelines for Harvesting and Threshing Beans And Cowpeas

Determining Maturity

The pods begin to turn yellow during the final stages of growth and become brown and rather brittle once maturity is reached. Determinate bush varieties and some indeterminate types have fairly even pod maturity, and the plants have usually lost most of their leave< by the time the pods have ripened. Most indeterminate vining types mature

much less uniformly, and a good number of pods may ripen while most of the leaves are still green. Seed moisture content is around 30-40 paecent at physiologic maturity.

When to Harvest

Indeterminate varieties with an uneven maturity are usually harvested in several pickings, while determinate bush types are harvested all at once when most of the pods are dry.

Method of Harvesting

The following methods apply to bush or semi-vine varieties with uniform maturity:

- **By hand: The mature plants are pulled from the ground and placed in piles for drying. Pulling is best done in the early morning when the pods are moist to prevent shattering.**

- **Mechanized: Two basic methods are used. The plants are cut or "glided" out of the ground using a tractor with frontmounted horizontal blades with blunt cutting edges or rotating disks operated slightly below the soil surface. Several rows are combined into one windrow using a side-delivery rake which can be rear-mounted behind the cutters. The windrows are dried for 5-10 days before threshing with tractor-drawn or selfpropelled threshers.**

Direct harvesting is popular in the U. S. and Canada using grain combines with modifications.

Threshing Methods for Beans

Beans can be threshed manually by beating the plants or bagged pods with sticks once they are dry enough. Whatever the method used, bean seed can be easily injured if

threshed too roughly or when too dry. Injured seed, when planted, will produce weak, stunted plants and other abnormalities (see Chapter 6 on bean diseases).

Winnowing beans: Refer to maize.

Drying and storage

Grain drying and storage are very broad subjects, and adequate coverage is far beyond the scope of this manual. Some of the more important principles and practices are outlined here. More detailed information can be found in the references listed in the bibliography.

Drying

Very moist grain will deteriorate and spoil during storage for two reasons:

- **Since they are alive, the seeds consume oxygen and burn up some of the food stored in the endosperm for energy. This respiration process produces heat, but is too slow to be of concern in dry grain. However, respiration and heat production are rapidly accelerated by moisture, and the moisture and heat promote rapid mold growth and spoilage in wet grain.**

- **Storage insects like weevils become more active and multiply more quickly in warm, moist grain. They also produce heat and add more moisture which further increases mold growth.**

> **NOTE: Some storage molds produce toxins called mycotoxins which are harmful to humans and livestock. Aflatoxin is one example. All cereal and legume grains are susceptible if insufficiently dried or improperly stored, especially peanuts.**

Fortunately, the farmers do not have to dry their grain down to zero percent moisture, since it can tolerate about 12-30 percent depending on the type, the form in which it is stored (ears or seedheads vs. loose grain), how it is stored (bags vs. bins, etc.), and the surrounding temperature and humidity. Most loose grain has about 12-15 percent moisture at marketing or prior to processing for consumption, and crop yields are usually calculated on about a 14 percent moisture basis. In fact, there are several disadvantages to drying grain below this range. Where grain is sold by weight overdrying will reduce the farmer's returns from a sale. It is also costly where artificial drying is used and can lead to cracking, discoloration, and poor germination.

Grain Moisture Guidelines for Safe Storage

Maize, Sorghum, Millet

- **Loose: Threshed grain can be safely stored in silos or bins for up to a year at 25-30°C and 70 percent relative humidity if grain moisture is not above 13.0-13.5 percent for maize and sorghum, and 16 percent for millet. Bagged maize and sorghum can be stored at up to 15 percent moisture, since ventilation is much better.**

- **On the cob or seedhead: Husked maize ears can be safely placed in cribs for storage and further drying at kernel moisture contents up to 30 percent if all the ears are within 30 cm of open air. Sorghum and millet seedheads can also be safely stored and dried down from high moisture contents if kept in small stacks or hung from rafters.**

Peanuts

For safe bulk storage of pods, kernel moisture content should not be above 10 percent. Pods can be safely placed in bags at kernel moisture contents up to 16 percent and will

dry down adequately if loosely stacked, provided ventilation is sufficient. Otherwise, forced air will be needed.

Beans and Cowpeas

Threshed seed stored in bins or silos should not be above 13 percent moisture. Bagged seed can be safely stored at up to 15 percent moisture. Unthreshed pods can be kept at much higher moisture contents and will dry down well if ventilation is adequate.

How to Determine Grain Moisture

Grain moisture should always be calculated on a wet weight basis. In other words, 100 kg of 15 percent moisture maize contains 15 kg of water and 85 kg of dry matter. There are several ways of measuring grain moisture, some of which can be easily done on the farm with very little equipment:

Salt and bottle method: This quick and easy method is accurate to within 0.5% but will only indicate the grain is above or below 15% moisture, the maximum limit for storing maize and sorghum in bags.

- **Thoroughly dry out a bottle of about 100 ml capacity and fill it three-quarters full with maize.**

- **Add 5-10 teaspoons of oven-dry table salt, seal the bottle with a dry lid or cork, and shake for several minutes. If the salt sticks to the inside of the bottle, the grain has over 15% moisture.**

Oven method: A grain sample of known weight should be ovendried for one or two hours at 130°C if ground or 72-96 hours at 100°C if in whole form. After reweighing, moisture content can be calculated as follows (cover the grain to avoid moisture reabsorbtion while

it is cooling off):

% moisture of original sample = [Wet Weight - Dry Weight] / Wet Weight

Biting, pinching, rattling, feel-in": Most farmers will use such methods for estimating grain moisture with varying success, depending on experience. They should not be relied upon where accuracy is important as in the case of grain stored in bulk (bins or silos).

How to estimate the final weight of grain after drying

Final grain weight after drying = [% dry matter before drying / % dry matter after drying] x original weight

Example: A farmer has 2000 kg of shelled maize at 20% moisture. How much will this amount of maize weigh after it has been dried down to 14% moisture?

Solution: To obtain the percent dry matter meeded for the formula, subtract grain moisture content from 100 percent then use the formula.

Final grain weight after drying = 80% / 86% × 2000 kg = 1860 kg of grain after drying to 14%

Some Important Grain Drying Principles

- **Warm, dry, moving air encourages more rapid drying to a lower moisture content than cool, damp, still air. In fact, if the air becomes too damp, grain may actually begin to absorb moisture and become wetter.**

- **Air flow through the grain and air moisture content (relative humidity) have the biggest influence on drying. The lower the air's relative humidity the greater its ability to pick up moisture from the grain and carry it away.**

- **Warm air has a much higher moisture-holding capacity than cool air. This means that warm air is more effective at picking up moisture from wet grain than cool air when the relative humidity is low.**

- **Supplemental heat from either sunlight or fuel can be very effective at improving the drying ability of cool air if it is very damp (high relative humidity). For each 0.55°C rise in temperature, the relative humidity of the heated air is reduced by about 2 percent.**

- **The rate of drying slows down as grain moisture content falls, since the remaining moisture is given up less readily. Unless the air is very hot and dry, a point is eventually reached beyond which no further drying occurs. This is known as the equilibrium moisture content.**

Methods of Drying

- **Traditional sun-drying is the most common method used by small farmers and consists of spreading the grain out in a shallow layer on the ground for sun exposure. Depending on the weather, the thickness of the grain layer, and the amount of stirring, the results range from poor to good. The disadvantages are poor air circulation, contamination with dust and stones, and moisture absorption from the ground. The PC/ICE Small Farm Grain Storage Manual recommends general improvements for this system.**

Enclosed solar drying reduces sun-drying time, requires no fuel, and can be used on other crops like cassava, copra, fruits, and vegetables. However, grain can be damaged or have its germination impaired by the extremely high temperature (65-80°C) that can build up under the plastic or glass sheet. Solar drying may not dry down grain rapidly enough when operated under very cloudy conditions (See

bibliography for references containing plans for solar driers.)

- **Fuel-Heated and/or Forced-Air Drying: For large quantities of grain, fuel-heated and/or forced-air drying is used For the individual small farmer such drying may not be feasible. However, the procedure can be justified on a cooperative basis and can offer several advantages:**

- **Farmers can harvest their crops earlier at a higher moisture content to avoid losses caused by natural field drying. Earlier harvesting also permits earlier land preparation and planting of the next crop.**

- **The grain may end up at a lower, safer moisture content for storage and keep in better condition. Its market value may also be higher.**

On the other hand, construction and fuel costs may outweigh these advantages, so a thorough analysis of the factors should be conducted before deciding to buy or build such dryers.

Temperature Guidelines for Grain Drying

Excessively high drying temperatures can cause cracking, breaking, and discoloration of the kernels and also lower germination and protein quality. Peanuts may become bitter if dried at temperatures above 32-35°C, and overdrying increases splitting and skin slippage during shelling. Beans are also best dried at low temperatures.

The maximum safe drying temperature depends on the crop and its use:

Crop and Use	**Maximum Safe Drying Temperature**
Livestock feed	75°C

Cereal grains for human food except rice	60°C
Milling for flour	60°C
Brewery uses	45°C
For planting seed	45°C
Rice for food	45°C
Beans for food	35°C
Peanuts	35°C

Storage

Storage losses of grain due to molds, insects, and rodents are estimated to be about 30 percent worldwide. Small farmers are especially vulnerable to such losses since their traditional storage methods are often inadequate to protect the crop. In many cases, farmers may be forced to sell much of their grain shortly after harvest at a low price rather than risk spoilage. A few months later, they may end up buying it back at a much higher price. By improving their storage facilities, farmers can ensure more food for their families, more stable prices, and better quality seed for planting. Crop improvement programs should place a higher priority on providing ample safe storage for the expected production increases.

Principles of Safe Storage

- **Grain must be adequately dried before being put into storage, although maize stored on the ear and other crops stored in the form of seedheads or pods can often be stored and dried at the same time using cribs or loose stacks.**

- **Undamaged, winnowed grain has a much longer storage life. Uncleaned grain reduces air movement, and the dirt and chaff hold moisture and encourage molds**

and insects. Damaged grain deteriorates two to five times more rapidly than undamaged grain.

- **Grain should be kept as cool as possible and protected rom fluctuations in outside temperatures that encourage condensation and moisture buildup inside the container.**

- **Grain should be protected from storage insects and rodents.**

- **Containers and buildings must be waterproof and free from groundwater.**

- **New grain should be stored separately from older grain.**

- **The old grain should be used first.**

- **The grain should be checked every two or three weeks for signs of heating and insects.**

Traditional Storage Methods

If a farmer's production is small, it is often stored in the family dwelling. Maize ears and seedheads are commonly hung from rafters in the cooking area, the smoke acting as an insect deterrent. Clay pots, closely-woven baskets, and gourds are also frequently used. While such methods may work well with small amounts of grain, they are not well suited to large quantities.

Improved Storage

The PC/ICE Small Farm Grain Storage manual contains design details and guidelines for many types of improved storage. The major points are summarized briefly here. Storing in sacks made of burlap, local grasses or cotton does not afford much protection against

rodents, insects or moisture. However, sacks are easy to label and move around, and grain can be stored at about 2 percent higher moisture than is needed for airtight storage (i.e. about 15 percent versus 13 percent). For sack storage:

- **The walls and the roof of the storage building should be waterproof.**
- **Sacks should be stacked on platforms (pallets) raised off the floor or on a plastic sheet. They should not lean directly against walls.**
- **The sacks should be stacked in a way that favors good ventilation.**
- **The building should be insectand rodent-proof.**
- **The sacks should be sprayed or fumigated for insects, but only when grain will not be consumed directly by humans or animals (seed grains).**

Silos and bins made from sheet metal, mud bricks, cement blocks or cement with metal staves can be built with capacities ranging from 500-4500 kg of dried, threshed grain. Some of them can be made virtually airtight. However, whenever grain is stored in such large quantities, more care must be taken to ensure that it is well dried. Unless well insulated, the containers should be shaded to prevent large temperature variations which cause moisture migration, condensation, and spoilage of grain at the top and bottom. Airtight storage in sealed gourds, underground pits, plastic bags, drums, and bins provides excellent insect control and also prevents the grain from reabsorbing moisture from humid outside air. The air present in the container when it is sealed is soon used up by grain respiration and any insects already present. For successful airtight storage:

- **The grain should not be above 12-13 percent moisture.**
- **The containers must be made airtight by using metal, plastic, cement (with vapor**

barrier) or a waterproofing material like tar, oil-base paint or pitch.

- **Containers should be filled to the top to exclude as much air as possible before sealing.**
- **Airtight storage should not be used where the containers must be frequently opened, since the added air will make the system ineffective for controlling insects.**
- **Containers, especially metal ones, should be shaded to prevent condensation and moisture migration.**

Crib storage: See drying methods.

Insect Control In Stored Grain

Weevils and grain beetles feed on grain in both the adult and larval stages. In addition, the larvae of several types of moths attack the seeds. Aside from the actual losses due to feeding, storage insects promote mold and spoilage of grain by adding moisture and increasing temperature. A heavy infestation can increase grain moisture content by 5-10 percent within several months. Even if the grain does not spoil, it may be rendered unmarketable by the presence of insects or the physical damage caused by their feeding.

Grain can become infested both in the field and during storage. Some storage insects like the maize weevil, rice weevil, and angoumis grain moth which attack cereal grains and the bruchid beetles that attack pulses, have wings and can infest grain in the field. These and other types can also begin attacking grain during storage. The adults lay eggs on or in the grain, and the developing larvae hollow out the kernels.

Factors Favoring Infestation

- Temperature: This is the most important factor. As temperature increases from 10°C to 26 C, storage insect activity increases, and life cycles are reduced from about eight weeks to three weeks. At optimum temperatures, 50 insects could theoretically multiply to 302 million in just four months' Activity and breeding snows considerably below 10 C and above 35°C, and death occurs below about 5°C or above 59°C.

- Moisture: Storage insects prefer under-dried grain, but can still cause serious problems in grain as dry as 12-13 percent. Grain moisture content has to be 9 percent or below before activity ceases, and this degree of dryness is difficult to achieve and maintain.

- Storage practices: Storing new grain next to old grain or using storage facilities or sacks that have not been disinfected are sure ways of inviting infestations.

Types of Storage Insects and their Identification

It is useful to be able to precisely identify the types of insects attacking a farmer's grain for three reasons:

- Not all insects found in grain are serious pests. On the other hand, lack of visible grain damage does not necessarily indicate that the insects are harmless or minor pests, since it may take some weeks for damage to become apparent.

- Although control measures are fairly similar for most storage insects, there are some differences.

- Some storage insects are known as secondary and tertiary pests since they feed mainly on grain which is cracked or already damaged by primary pests. The presence of these non-primary pests often indicates that more serious pests are at

work.

The Small Farm Grain

Storage manual has a very complete identification guide to cereal grain pests, while the Insect Pests guide mentioned in the bibliography has pictures of both cereal and pulse storage insects.

Checking for Infestations

Early recognition of an infestation is very important for reducing potential grain losses. Stored grain should be closely checked every several weeks for signs of an insect buildup. Exit holes in the kernels, cobweb-like accumulations on sacks and maize ears, and the presence of adult insects are sure signs. When sampling grain, the farmer should examine kernels from various sections of the container or sack, since infestations often develop and spread from very localized areas or "hot spots" where temperature and moisture may be very high.

Controlling Stored Grain Insects

Early recognition of an infestation is very important for reducing potential grain losses. Stored grain should be closely checked every several weeks for signs of an insect buildup. Exit holes in the kernels, cobweb-like accumulations on sacks and maize ears, and the presence of adult insects are sure signs. When sampling grain, the farmer should examine kernels from various sections of the container or sack, since infestations often develop and spread from very localized areas or "hot spots" where temperature and moisture may be very high.

The Small Farm Grain Storage manual contains a detailed section on non-chemical and chemical controls for storage insects. A brief summary is given here plus some additional

information from other sources.

Pre-storage Guidelines

- **Be sure the grain is well dried and cleaned.**

- **Clean out and repair the storage facility. This includes sweeping out old grain and debris and patching all holes and cracks where insects might hide or moisture might enter.**

- **Spray or dust the facility with an approved insecticide (more on this further along).**

- **Disinfect used grain sacks before filling by boiling, spraying with an approved insecticide or placing them on a hot tin roof.**

Non-Chemical Controls for Storage Insects

- **Unhusked: Storing maize in the form of unhusked ears is somewhat effective.**

- **Sunning the grain: Beetles and weevils will leave grain if it is placed in the hot sun in a shallow layer. However, this usually will not kill all the eggs and larvae inside the kernels.**

- **Smoking the grain: By building a smoky fire under a platform or maize crib, many of the insects can be killed by both the smoke and heat.**

- **Mixing materials with the grain: Effectiveness varies with the substance used, but control can be quite good in some cases.**

- **Sand, burned cow dung, wood ashes, and lime give varying results. Sand helps**

exclude air by filling in the spaces. It also scratches the insects' shells which can lead to dehydration and death if the grain is already very dry (9-10 percent moisture). The other materials may have some insecticidal properties. It was discovered by CIAT that adding wood ash to bean seed at the rate of one part to three reduced bruchid weevil infestations by about 80 percent if applied before the insects appeared. Slaked lime (calcium hyroxide) or burned lime (calcium oxide added at 4-8 parts per 100 is also farily effective (both types are caustic).

- **Plants: In some areas, certain plants are known to have insecticidal properties and are mixed with the grain.**

- **Vegetable oil: The oils of peanuts, sesame, coconut, cottonseed, and mustard-seed have given excellent protection from bruchid infestation in beans and cowpeas when added at the rate of 0.5-1.0 percent (5-10 ml per kg of seed). Protection lasts for up to six months and does not affect the physical appearance of the grain since it is absorbed.**

- **Airtight storage: See storage methods.**

Chemical Controls for Storage Insects

Grain that will be stored only a few weeks or even up to two to three months may not warrant the use of insecticides. However, the best time to treat grain is when it is first put into storage, before an infestation becomes serious. CAUTION!: Some insecticides like Malathion, Lindane, Actellic, and Pyrethrins can actually be mixed with food grain without harmful effects or residues if used correctly. Many other insecticides would make the grain very toxic and unsuitable for consumption. Many farmers are not aware of these differences and in fact may refer to all insecticides by one name such as "DDT".

Where to obtain recommendations: The Small Farm Grain Storage manual gives

recommendations for treating both grain and storage areas. However, storage insects vary in their susceptibility to different insecticides and resistance to Lindane and Malathion has become a problem in many areas. Actellic (pirimiphosmethyl) is a newer product that has proven very effective. Two other sources of information on storage insect control are:

> **African Rural Storage Center**
> **IITA**
> **PMB 5320**
> **Ibadan, Nigeria**

> **Tropical Stored Products Institute**
> **London Road**
> **Slough SL3 7HL**
> **Bucks, England**

RODENT CONTROL IN STORED GRAIN

The Small Farm Grain Storage manual contains a very complete section on rodent control.

Lessons of the ''Green Revolution''

The "Green Revolution" of the 1960's and 1970's was really the first organized attempt to develop yield improving practices for staple food crops in the developing world. Most of the efforts of the Green Revolution were directed towards a number of the cereals, namely wheat, rice, and maize.

A major impetus was the development of short-strawed varieties of wheat, rice and maize that would respond well to high rates of fertilizer, especially nitrogen, without lodging.

The term "revolution" is really a misnomer; nearly two decades of plant breeding and local

adaptive research were required before the new wheat and rice varieties were ready for widespread introduction in India and Pakistan. The true origins actually go back to breeding programs for wheat and maize in Mexico in the 1940's and to similar work with rice in the Philippines.

Supported by a "package" of complementary improved practices involving factors like fertilizer use, pest control, and plant spacing, the new varieties were adopted in many developing regions. By 1972-1973, some 33 million hectares in Africa and Asia were were being sown to the high yielding wheat and rice varieties. Average yields were increased about 100 percent for rice compared with traditional varieties.

Despite these increases, the efficacy of the Green Revolution in overcoming hunger and rural poverty in the developing world is a hotly debated issue worthy of a manual in itself. There is no doubt that the Revolution has been the major factor behind the gains in food production in many developing countries during the past 15-20 years and has also laid a solid basis for additional agricultural research in the region. It was conducted in a spirit of humanitarian and largely apolitical international cooperation that should be commended.

On the other hand, it has not proved to be the hoped-for panacea for several reasons:

- **The high yielding variety (HYV) "packages" it developed required relatively high levels of inputs (fertilizers, pesticides, and, in some cases, irrigation pumps) and investment. At least initially, the smaller farmers were often bypassed due to deficiencies in the infrustructure that made it difficult for them to obtain both the credit and the inputs. Unless special provisions were made to provide small farmers credit, lending institutions naturally favored the larger ones. This situation has improved considerably over the past decade in many areas, but is still a serious problem.**

- **The high costs of these inputs, some of which are very petroleum-dependent (i.e.**

nitrogen fertilizer and pumping fuel), raises doubts about their continued practicality, estpecially in view of the current energy crisis. Fertilizer rates are often well above the threshold of diminishing returns in the case of nitrogen and phosphorus; the latter is a non-renewable resource with limited world reserves. Fortunately, there is a growing awareness of the need for an appropriate technology in harmony with both the environment and economics.

- **An important lesson learned is that increased production does not automatically improve rural wellbeing. In some parts of India, for example, the HYV package actually had a negative effect on income distribution, rural employment, and dietary habits. A disturbing number of small landholders and tenant farmers were squeezed off the land by the new production economics, and urban industrialization was insufficient to provide them employment. Cereal cropping was favored over grain legumes, sometimes resulting in actual declines in pulse production and consumption. With a bad case of Western economic ethnocentricity, many "experts" argued that this was the necessary price to pay for modernizing agriculture along "big is better" lines.**

Fortunately, there is a growing realization that the small farmer must be included in agricultural development which should be tied into integrated rural development so that nutrition, health, education and general rural welfare are also considered. In fact, as the small farm family's income and production increases, receptivity to these other programs is usually enhanced.

The Green Revolution is far from over. Rather, its goals are being redefined and extended to other food crops. Future progress will largely depend on how the developing world handles two key issues:

- **The conservation of natural resources and the total environment.**

- **Choosing appropriate scales of production: The Western bias is that "big is better", yet evidence strongly suggests that small, intensively cultivated units are the most efficient. This brings up the issue of agrarian reform, as well as the ultimate goals of agricultural development. The conventional approach of trying to integrate the small farmer into a modern agribusiness system usually fails (as it did in the U.S.). Others feel the goal should be to enable the marginal small farm family to achieve self-sufficiency with a small surplus left over for education and general welfare.**

Agricultural extension workers will have a central role in this effort to extend the benefits of the Green Revolution. By spreading the knowledge gained in trials conducted by the major research institutes to increase production of traditional crops, agricultural extension workers will help ensure that the Green Revolution truly serves to improve the lives of small farmers and their families in the developing world.

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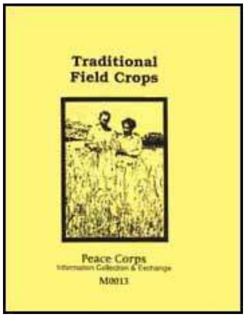


Traditional Field Crops (Peace Corps, 1981, 283 p.)

Appendices

Appendix A - Measurements and conversions

Area

1 HECTARE(ha) = 10,000 sq. meters = 2.47 acres = 1.43 manzanas (Central America)

1 ACRE = 4000 sq. meters = 4840 sq. yards = 43,560 sq. ft. = 0.4 hectares = 0.58 manzanas (Central America)

1 MANZANA (Central America) = 10,000 sq. varas = 7000 sq. meters = 8370 sq. yards = 1.73 acres = 0.7 hectares

Length

1 METER (m) = 100 cm = 1000 mm = 39.37 inches (in.) = 3.28 feet(ft.)

1 CENTIMETER (cm) = 10 mm = 0.4 in.

1 INCH (in.) = 2.54 cm = 25.4 mm

1 VARA (Latin America) = 32.8 in. = 83.7 cm

1 KILOMETER (km) = 1000 m = 0.625 miles

1 MILE = 1.6 km = 1600 m = 5280 ft.

Weight

1 KILOGRAM (kg) = 1000 grams (g) = 2.2 pounds (1bs.) = 35.2 ounces (oz)

1 POUND (lb.) = 16 oz. = 454 g = 0.45 kg

1 OUNCE (oz) = 28.4 g

1 METRIC TON = 1000 kg = 2202 1bs.

1 LONG TON = 2240 1bs; 1 SHORT TON = 2000 1bs.

1 QUINTAL = 100 1bs. (Latin America); 112 1bs. (British); 100 kg (metric)

Volume

1 LITER (1) = 1000 cubic centimeters (cc) = 1000 milliliters (ml) = 1.06 U.S. quarts

1 GALLON (U.S.) = 3.78 liters = 3780 cc (ml)

1 FLUID OUNCE = 30 cc (ml) = 2 level tablespoons (measuring type)

Miscellaneous Conversions

Lbs./acre X 1.12 = kg/ha; lbs/acre X 1.73 = lbs/manzana

Kg/ha X 0.89 = lbs./acre; kg/ha X 1.54 = lbs./manzana

Lbs./manzana X 0.58 = lbs./acre; lbs./manzana X 0165 = kg/ha

Temperature:

C° = (F° - 32) X 0.55
F° = (C° X 1.8) + 32

Appendix B - How to conduct a result test

When is Result Testing Needed?

- **To test responses to an improved practice under actual farming conditions: Research station conditions are often more ideal or at least different from actual on-farm conditions. What works well under the more controlled situation of the station may be less than satisfactory in farmers' fields where soil and management are likely to be much less than optimal.**

- **To test responses in different geographic regions**

- **To measure the profitability of a new practice**

- **To measure the variability of results: Farmers are just as interested in the variability of benefits from a new practice as they are in the average benefit. A practice that produces large benefits on some farms but little or none on others is unlikely to gain wide acceptance.**

The Procedure

- **Clearly describe the practice to be tested**

- **Divide the test region into zones: The work area may have significant variations in soils, rainfall, elevation, farming systems, etc. It is important to divide the testing region into separate zones if they differ enough from each other to warrant separate recommendations. The number of zones will depend on your area's diversity, the complexity of the practice you are testing, and time and budget limitations. In most cases you will be dealing with no more than two to three test zones within a municipality.**

- **Decide on the number of farms to be included per test zone: Naturally, the more tests and farms that are included per test zone, the more representative the results will be and the more specific will be the recommendation that follows. However, costs will be higher and so will time requirements.**

Two factors determine the number of farms that should be included in a test area:

- **If high average benefit is expected from the new practice as opposed to the traditional one, fewer farms need to be included than if the average benefit is lower.**

- **If a large variation is expected in farm to farm results, more farms need to be included than if a smaller variation is expected,**

NUMBER OF FARMS TO INCLUDE IN A RESULT TEST

If you expect an average increase over normal yields of:	And if you expect yield variation between farms within the region to be:	Then you should include this number of farms in your test: (10 maximum)
100 percent	Quite variable	6
	Fairly consistent	4

	Fairly consistent	4
50 percent	Quite variable	9
	Fairly consistent	5
25 percent	Quite variable	10
	Fairly consistent	6

Extension workers ideally should consult an experienced researcher or extension officer in deciding how many farms to include in a result test. If professional advice is not available it may be better to proceed with result tests using less precise sampling methods. The table below is based on a 5001000 farm work area.

- **Decide on how long to run a result test: If the expected benefits of the new practice are likely to be significantly related to weather conditions during the growing period, the test should be repeated over several years. This is often the case with tests involving fertilizer use and changes in plant density and tends to be true with most other practices, at least to some extent. Repeat testing is especially indicated if the first trial takes place during an unusual weather year. Long-term weather records can help determine this, but if not available, local extensionists and farmers can be of help.**

- **Select individual farms: It is important that selected farms be representative rather than "typical". The participating farms should reflect a cross-section of those in the test area so that trial results can be converted into recommendations generally suitable for the entire area. Remember also that you should be just as interested in determining the variation of response among farms as in the average overall response. Farmers do not harvest averages'**

Ideally, the farms should be chosed at random, but this is never completely practical due to the limitations imposed by accessibility and farmer cooperation.

However, the less the choice of farms is confined to a particular class of farms and the more you choose farms on an "as they come" basis, the closer you will be to achieving a valid representation.

This principle is much easier to violate than one might expect. For instance, it is easier to work with farms close to a road, with familiar farmers or with farms where good results can be expected. Such biases can totally discredit the results.

- **Decide what kind of control plot is needed: If the result test is to compare an old practice with a new one, a control or check plot will be necessary. However, if a totally new crop is being introduced rather than a new practice or new variety, no control plot is needed.**

- **Choose the location and size of the plots: Plot location will depend a lot on the feelings of the cooperating farmer. This is no problem, as long as he or she does not purposely select the best piece of ground on the farm. Random choice is the best method here unless parts of the farm have been subjected to very unusual management practices such as ultrahigh fertilizer applications. Both the test plot and the control plot should be in the same field and preferably adjoining each other. This helps ensure that both plots are subjected to the same variables. In fact, it may be best to avoid using farms where the two plots cannot be located in the same field.**

The plots should be large enough so that the usual farming methods can be followed, yet small enough so that the results are clearly visible. The test and the control plot do not have to be the same size. The test plot can be a portion of it serving as the control plot.

- **Conducting and supervising the test: The farmer and his or her usual extra workers should handle all the land preparation, planting, weeding, and other**

operations normally associated with the crop. They-should also apply the new practice themselves under the guidance of the extension worker(s). This assures that the result test is fully representative of actual farming conditions.

Make sure that all variables other than the practice or input being tested are held constant. One common error of both farmers and extensionists is to take better care of the test plot than the control plot. Such preferential treatment can completely invalidate the results.

Documentation is vital. All inputs used should be measured and recorded to the extent possible. Weather data such as rainfall, hail, and unusual temperature extremes should also be recorded if possible along with any visual differences between the test and control plot during growth.

- **Collecting Data: No conclusions can be drawn from the result tests until yields have been measured. The goal is to weigh the harvest from the test plot and an equal area of control plot. The extensionists and the farmer should decide on a harvest date and arrangements should be made to obtain an accurate scale. Gross yields from both plots can be measured at the same time and then converted to a kg/ha, 1bs./ acre or other locally used yield standard.**

However, you should always obtain a Yield sample prior to the actual harvest date just in case the plots are inadvertently harvested without measuring yields before the agreed upon date. A properly collected random yield sample is usually accurate within 5 percent of the actual yield and is a cheap insurance policy.

- **Analysis of the results: Good records are essential to any valid analysis of the results. By far the best way of interpeting the results is to run a standard-statistical analysis of the yield data. You do not need formal training in statistics to do this. Appendix F gives easy to follow instructions for carrying out a statistical analysis**

which will enable you to determine the standard deviation (a measure of the variability of responses from the average).

Calculate the standard deviation, since it serves as basis for giving realistic yield expectations when making recommendations to farmers.

Reducing the Risk To Participating Fanners

- **Subsidizing inputs:**

Result tests: There are two schools of thought here. Some extension specialists feel that all new inputs for the test plots should be provided free to the farmer. They feel this makes it easier to find collaborators and also helps assure control over the plots. Others feel that no compensation should be given unless a completely new or unknown input is involved, Much of the choice depends on the economic condition and receptiveness of the local farmers.

Result demonstrations: Inputs should ordinarily not be subsidized unless there is still some uncertainty about the profitability of the new practice, in which case it probably should not be at the demonstration phase anyway.

> **NOTE: If subsidies are provided, be sure to include the true costs of the inputs when doing a cost/benefit study.**

- **Reducing the number of farm tests :**

Result tests: Reducing the number of tests may make the test results unrepresentative for the area.

Result demos: Reducing their number will not affect the demonstration principle,

but may slow the rate of mass acceptance by farmers.

- **Reducing plot size:**

Result tests: Plot size should be large enough to allow normal growing practices to be followed. Rather than cut plot size below this limit, subsidies should be offered.

Result demos: Let the farmers choose their own plot sizes as long as normal growing practices can be followed.

- **Guaranteeing the price or the yield: The extension agency may guarantee a certain yield or market price to a cooperating farmer, perhaps in the form of a purchase contract. This should only be done with result tests. Demonstrations should stand on their own.**

Appendix C - How to conduct a result demonstration

Examine the Recommendation that Will be Demonstrated

Make sure that the recommendation is:

- **Adapted to local growing conditions.**
- **Within the economic means of most of the local farmers.**
- **Adequately tested under local farming conditions**

Select Demonstration Sites

Since the goal of a result demonstration is to promote acceptance

Since the goal of a result demonstration is to promote acceptance of a new practice on a mass scale, the main concern is maximum effective exposure when selecting sites.

However, if the recommendation involved is suited to several types of soils or other variations commonly found in the local area, be sure to include some farms in each category. Here are some selection guidelines:

- **Choose Key Farmers These are not necessarily the best or the most progressive farmers, since these may be regarded as being too exceptional by other farmers. Do not turn down a "progressive" farmer, but concentrate on seeking out influential farmers.**

- **Chose Conspicuous Sites Sites should be near roads, trails or public gathering places.**

- **Group Demonstrations on Rented or Donated Land These can be very effective, but the group should be a pre-existing one, rather than being specially organized on-the-spot to conduct the demonstration.**

- **Special Factors in Fertilizer Demonstrations Do not use a field that has received unusually heavy rates of fertilizer in the past. Fertilizer demonstrations give the most spectacular visual responses and yield differences on low fertility land, but do not purposely seek out unusually poor land for the demonstration,**

- **The "Spontaneous" Demonstration: Another approach which can be very effective in certain cases is to look for a farmer's field that already demonstrates the value of what you are trying to promote. One disadvantage is that there is usually no control plot for comparison.**

Preparing for The Demonstration

After selecting the sites, the extension worker should discuss the demonstration with the farmer, including the approximate dates of important operations such as planting,

fertilizer application, etc. Make sure the necessary inputs are on hand. The extensionist should thoroughly understand the what, ho´: and why of the procedures involved in preparing and growing the demonstration plot.

Supervision and Management

The extensionist should be present during the application of any new procedure(s) involved with the demonstration plot to assure that the farmer does them correctly. To make the demonstration realistic, the farmer and his or her usual help should do most of the work.

Avoid the strong tendency to favor the "new practice" plot through overly careful tending or protecting it from limiting factors without regard to cost. Visiting farmers can often easily spot these atypical factors, which may seriously affect the demonstration promotional value.

Observation And Records

The main objective of demonstration plots is to promote improved practices, but they can also provide some very useful information in return for the small amount of extra work required to keep records and accurately measure yields. Here are some suggestions:

- **Maintain some kind of chronological record of each demonstration, noting such things as date and amount of input application, weather conditions, visual observations, etc.**

- **Make a yield estimate using the random sample technique explained in Appendix L.**

- **Check these estimates with what the participating farmers claim for their yields.**

Promotion and Followup

Demonstrations are supposed to serve as "living" examples of the benefits of an improved practice (or "package of practices"). Neighboring farmers should be invited to see the demonstration during the crop's growth at any time when the desired results can be clearly seen (such as larger, greener plants resulting from fertilizer use). Final yield results should be discounted conservatively.

Organized sessions for visiting farmers should be arranged if the new practice requires explanation or new skills, both of which are very likely. This is known as a method-result demonstration and such a session should be conducted by a qualified and locally-experienced extension worker fluent in the local language.

The real test of a demonstration is how rapidly farmers begin to adopt the new practice. SOME CAUTIONS:

- **Do not use a result demonstration to test the outcome of a recommendation. That is what a result test is designed to do. Result demonstrations are for promoting practices that have already been largely locally proven. Never undertake a result demonstration unless you are reasonably sure the practice is beneficial.**

- **Do not promise too much in the way of results. Be conservative.**

- **Do not run a demonstration on your own land.**

- **Do not sacrifice quality of work for quantity of work.**

- **Do not favor one demonstration over another.**

Appendix D - How to conduct an elementary statistical analysis

A result test consists of a number of individual trials on representative farms within a local area in order to compare a new practice with an old one. The results of these trials provide the final basis for making specific, locally adapted recommendations to farmers. In order to correctly interpret a result test, the yield results must be given at least an elementary statistical analysis to determine the two most important measures of the new practice's actual benefits:

- **The average benefit: This is the average yield increase of the new practice over the old practice.**

- **The standard deviation: This indicates how much the individual results vary from the overall averages. It is the indicator of the variability of responses around their average. Remember that farmers seldom harvest "averages" and are very interested in knowing the likely variation in benefits.**

The calculations are not difficult if you follow these standard procedures:

1. Arrange the data in column form, as in the table on the next page.

2. Calculate the following averages by adding up the appropriate columns and dividing by the number of individual trials involved. (Refer to table on the next page.)

a. Average (mean) yield for the old (control) practice.
b. Average (mean) yield for the new practice
c. Average benefit: the average yield increase of the new practice compared to the old one.

3. The Square of the Benefit: This is a standard statistical procedure used to calculate the standard deviation. However, the differences between the squares of

the individual benefits have no significance. What is important is the sum of the squares, since it is from this that the standard deviation is determined.

4. Calculate the standard deviation: It is the most important statistic you will derive from the results since it shows the variability of responses from the average. The procedure for calculating the standard deviation is best shown by the following example.

5. Summarize the Data

a. Average yield of the new practice: 23.6 but/acre
b. Average yield of old practice (control or check plot): 17.2 but/acre
c. Average benefit (new over old practice): 6.5 but/acre
d. Standard deviation 2.8 but/acre or 16%

6. Interpret the Data: Once the average benefit and the standard deviation has been calculated, you can answer four key questions which are used to come up with a recommendation based on the test results:

a. What was the average increase in yield from the new practice?

Solution using the data ill Step 5:

[6.5 / 17.2] x 100 38%

b. What is the minimum increase in yield that farmers can expect three out of four times?

Solution: Multiply the standard deviation as a percentage (16%) by 0.7, a mathematical constant used in statistics. Then subtract the result from the

average increase in yield expressed as a percentage (38%).

Solution using above data:

16% x 1.0 = 16%

38% - 16% = 22% increase

Farm	YIELD New Practice	YIELD Control	BENEFIT	SQUARE OF BENEFIT	
	Bushels/acre	Bushels/acre	Bushels/acre		
1	23	16	7	$(7)^2$	49
2	37	26	11	$(11)^2$	121
3	24	17	7	$(7)^2$	49
4	20	14	6	$(6)^2$	36
(5-21)					
22	24	17	7	$(7)^2$	49
23	22	16	6	$(6)^2$	36
24	28	21	7	$(7)^2$	49
25	26	19	7	$(7)^2$	49
SUMS	591	429	162		1236
AVERAGES	23.6	17.2	6.5		

Data from a Maize Variety Test on 25 Farms

How to Calculate the Standard Deviation

a. Sum of the squares of the benefit = 1236 bushels

b. (Sum of the benefits)^2 / number of farms = $(162)^2$ / 25 = 1050 bushels

c. Subract (b) from (a): 1236 - 1050 = 186 bushels

d. The difference (c) / Number of farms - 1 = 186 / 24 = 7.75 bushels

e. Standard deviation = square root of (d) or $(7.75)^{1/2}$ = 2.8 bushels

f. [Standard deviation (e) x 100] / Average yield of the control = [2.8 x 100] / 17.2 = 16%

Therefore: 16% = the standard deviation (variation) as a percentage of the average yield under the old practice (control).

c. What is the minimum increase in yield that farmers can expect three out of four times?

Solution: Multiply the standard deviation as a percentage (16%) by 0.7, a mathematical constant used in statistics. Then subtract the result from the average increase in yield expressed as a percentage (38%).

Solution using above data:

16% x 1.0 = 16%
38% - 16% = 22% increase

d. What percent of the farmers are likely to get no increase in yield from the new practice?

Solution: Divide the average benefit by the standard deviation to obtain a ratio. Then look up the answer according to this ratio in the following table, interpolating if needed.

Solution using above data:

6.5 but / 2.8 but = 2.3 (ratio)

Answer = 1% of farmers

Ratio	Answer (percent)
2.6	Fewer than 0.5%
2.3	1%
2.0	2%
1.6	5%
1.3	10%
1.0	15%
0.8	20%
0.7	25%

7. Interpreting the Results on an Economic Basis

Since most new practices involve increased costs, the real test of their benefits is the increase in net returns over the increase in costs. The same statistical procedures used above can also be applied to the net economic benefit and the cost/benefit ratio tests.

Appendix E - How to convert small plot yields

When dealing with yields from field trials, demonstration plots, and farmers' fields, you will usually want to convert them to a kg/ha, lbs./acre or other standard basis. There are several easy ways to do this, and they are best shown by example.

PROBLEM 1: Pora harvests 300 kg of shelled maize off a field measuring 30 X 40 meters. What is her yield on a kg/ha basis?

SOLUTION

Method 1:

10000 sq. m (1 hectare) / plot area in sq. m × plot yield in kg = yield in kg/ha
10000 sq. m × 1200 sq. m × 300 kg = 2500 kg/ha of maize from Pora's field

Method 2: Make a proportion

$$\frac{\text{Area1}}{\text{Area2}} = \frac{\text{Yield1}}{\text{Yield2}}$$

10000 sq. m / 1200 sq. m = Y_1 / 300 kg

To solve the proportion for Y_1, cross multiply like this:

1200 Y_1 = 300 kg X 10000.

Then solve for Y_1:

Y_1 = [300 kg × 10000] / 1200

Y_1 = 2500 kg/ha of maize from Pora's field

PROBLEM 2: Lam harvests 150 lbs. of dried cowpea seed off a field measuring 45 X 75 feet. What is his yield in terms of lbs. per acre?

SOLUTION

Method 1: 43560 sq. ft. (1 acre) / plot area in sq. ft. × plot yield in lbs. = yield in lbs./acre

43560 sq. ft / 3375 sq. ft. × 150 lbs. = 1936 lbs./acre of cowpeas from Lam's plot

Method 2: Make a proportion

$Area_1$ $Yield_1$
-------- = --------
$Area_2$ $Yield_2$

43560 sq. ft. / 3375 sq. ft. = Y_1 / 150 lbs.

Then cross multiply and solve for

Y_1 like this:

3375 Y_1 = 150 lbs. × 43560

Y_1 = [150 X 43560] / 3375

Y1 = 1936 lbs./acre of cowpeas from Lam's plot

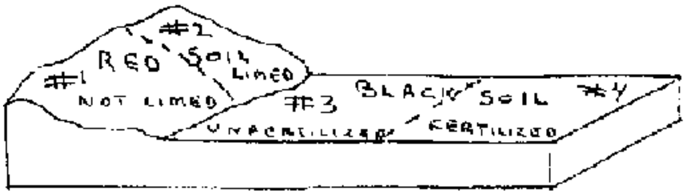
NOTE: You can "mix" units of measure from different systems if you know the

conversions. Examples:
1 Acre = 400 sq. m
1 Manzana (Central America) = 1.73 acres = 0.7 ha = 7000 sq. m

Appendix F - How to take soil samples

1. Divide the Farm into Sampling Units: Each sample sent to the lab is really a composite sample made up of 10-20 sub-samples taken from an area that is uniform in color, texture, topography, past management, and other characteristics that may influence soil fertility. A farm may have several of these distinct areas which are referred to as sampling units.

Begin by drawing a map of the farm land to be sampled, and then divide it into separate sampling units according to the above criteria. Each sampling unit should contain only one type of soil (that is, do not combine red soil with black soil, hill soil with level soil, fertilized soil with unfertilized soil, etc.). It is important to have a good idea of the land's fertilizer and liming history to avoid variations within one sampling unit.



Map

The final map with numbered sampling units might look like this:

Size of sampling units: A sampling unit should usually not exceed 4-6 ha. Of course, small farms will have much smaller sampling units.

2. For each sampling unit, collect sub-samples for making a composite sample representing that unit.

- **If the farm has three sampling units, the farmer will send in three soil samples to the lab. Each sample will consist of 10-20 sub-samples taken at random within the sampling unit.**

- **Depth of sampling: Most labs want topsoil samples only about 15-20 cm deep. When sampling fields to be used for pasture, a 5 cm depth is sometimes requested by the lab. Avoid including any subsoil in a topsoil sample unless the topsoil layer is very thin because of erosion.**

- **To take a sub-sample: A shovel and a machete can be used, although a soil auger is better when the ground is very hard.**

If using a shovel, make a hole with 45° sides to the right depth and then carefully dig out a slice about 3-5 cm thick. The slice should extend to the appropriate vertical sampling depth and be uniform in thickness. Holding the face of the soil slice with your hand will keep it from crumbling apart. Scrape off any surface litter before sampling.

Trim down the width of the soil sample on the shovel with the machete until it is about 4-5 cm wide and then dump it in a pail.

Sampling guidelines: Do not take sub-samples from fertilizer bands, under animal droppings or along a fence line or extreme end of a field. Use a thoroughly clean pail that has not been used to hold fertilizer. Galvanized pails will make zinc tests inaccurate.

- **Preparing a composite sample: After collecting the 10-20 random sub-samples**

within one sampling unit, thoroughly mix them in the pail and then take out enough soil to fill up the soil sample box.

Guidelines: Never mix soil from different sampling units. Do not oven dry wet samples, because this will cause a falsely high potassium reading in the test. Air dry them instead. Clean out the pail completely before moving to another sampling unit.

- **Fill out the informal sheet: The form from the soil laboratory will request information about the soils' slope, drainage, cropping history and yields, past applications of fertilizers and lime, crops to be grown and desired yields.**

When to take soil samples: Send them in at least two months before you need the results. In areas with a concentrated planting season, farmers tend to wait until the last minute to send in samples, and the lab is unable to process all of them on time.

How often is testing needed? Under low to moderate rates of fertilizer use, a field should be sampled about once every three to five years, since the soil's fertility level is unlikely to change significantly on a year-toyear basis. This is fine, since farmers with limited capital should concentrate on feeding the present crop rather than building up the soil's general fertility level.

Appendix G - Hunger signs in the reference crops

Nitrogen

Maize, Sorghum, Millet

Young plants are stunted and spindly with yellowish-green leaves. In older plants, the tips of the lower leaves first show yellowing which progresses up the mid-rib in a "V" shaped

pattern, while the leaf margins remain green. In some cases, a general yellowing of the lower leaves occurs. In severe cases, the lower leaves soon turn brown and die from the tips down. (This "firing" can also be caused by drought which prevents N uptake.) Maize ears are mall and pinched at the tips.

Legumes

The lower leaves begin to turn light green and then yellow with the symptoms progressing gradually upward. Plant growth is stunted.

Phosphorus

Maize, Sorghum, Millet

Hunger signs are most likely during early growth. Mild shortages usually cause stunting without clear leaf symptoms. More severe shortages cause a purplish color starting at the tips of the lower (older) leaves which may begin to turn brown and die. Some varieties of maize and sorghum do not show a purplish color but rather a bronze coloration of the same pattern. Disregard purple stems.

In maize and sorghum, symptoms usually disappear once the plants reach 40-45 cm, but yields will be severely lowered. Maize ears from Pdeficient plants are somewhat twisted, have irregular seed rows, and seedless tips.

Legumes

Phosphorus hunger signs often are not well defined. Plants lack vigor and have few side branches. Upper leaves become dark green, but remain small. Flowering and maturation are retarded.

Potassium

Maize, Sorghum, Millet

The three crops rarely show symptoms the first several weeks of growth. The margins of the lower leaves turn yellow and die, starting at the tip. Potassium-deficient plants have short internodes and weak stalks. Maize stalks sliced lengthwise often reveal nodes that are a darkish brown. Maize ears from potassium-deficient plants are often small and may have pointed, poorly seeded tips.

Legumes

Potassium deficiency is seldom seen in beans, but can occur in highly infertile soils or those high in calcium and magnesium. Symptoms are yellowing and death of leaf tips and margins, beginning on the lower leaves and gradually moving upwards.

Calcium

Beans

Calcium deficiency in beans is uncommon, but most likely to occur in combination with aluminum toxicity in very acid soils. Leaves stay green with a slight yellowing at the margins and tips. Leaves may pucker and curl downwards. Peanuts

Light green plants with a high percentage of "pops" (unfilled pods) show symptoms of calcium deficiency.

Magnesium

Maize, Sorghum, Millet

A general yellowing of the lower leaves is the first sign. Eventually, the area between the veins turns light yellow to almost white while the veins remain fairly green. As the deficiency progresses, the leaves turn reddish-purple along their edges and tips, starting at the lower leaves and working upward. Beans

Most likely in acid soils or those high in Ca and K. Yellowing between the veins appears first on older leaves and then moves upward. Leaf tips show the first effects.

Sulfur

Where to suspect: Sulfur deficiencies may be suspected where there are volcanic or acid, sandy soils, and where low S fertilizers have been used for several years.

Maize, Sorghum, Millet

These crops have relatively low S needs. Stunted growth, delayed maturity, and a general yellowing of the leaves (as distinguished from N deficiency) are the main signs. Sometimes, the veins may stay green which may be mistaken for zinc or iron deficiency. However, iron and zinc hunger are more likely in basic or only slightly acid soils. Beans

Upper leaves become uniformly yellow.

Zinc

Zinc deficiencies occur where soil pH is above 6.8 and high rates of P are used, especially if placed in a band or hole near the seeds.

Maize

Maize shows the most clear-cut zinc hunger signs of all crops. If severe, symptoms appear within two weeks of emergence. A broad band of bleached tissue on each side of the

midribs of the upper leaves, mainly on the lower part of the leaves, is typical. The mid-rib and leaf margin stay green, and the plants are stunted. Mild shortages may cause a striping between the veins similar to manganese or iron deficiency. However, in Fe and Mn shortages, this interveinal striping runs the full length of the leaf.

Sorghum

Similar to maize, but less interveinal striping, and the white band is more defined.

Legumes

Interveinal yellowing of the upper leaves.

Iron

Iron deficiencies can be suspected where soil pH is above 6.8.

Maize, Sorghum, Millet

Sorghum is much more prone to iron deficiency than maize. All three crops show an interveinal yellowing that extends the full length of the leaves and occurs mainly on the upper leaves.

Legumes

Interveinal yellowing of the upper leaves occurs. They eventually may turn uniformly yellow.

Manganese

Where to suspect: Manganese deficiencies are uncommon in maize, millet, or sorghum. It

occurs in soils which have a pH of 6.8 or above and in sandy or heavily leached soils.

Peanuts

Yellowing between the veins of the upper leaves which eventually turn uniformly yellow and then bronze is a symptom.

Beans

Plants are stunted. Upper leaves become yellow between the small veins and eventually take on a bronzed appearance.

Manganese toxicity occurs on very acid soils and is accentuated by poor drainage. Beans are very susceptible. The upper leaves show an interveinal yellowing. Easily confused with Zn or Mg deficiency, but Zn deficiency is very uncommon in highly acid soils.

Boron

Where to suspect: Boron deficiencies can be suspected in acid, sandy soils or high pH soils. Beans and peanuts are the most susceptible of the reference crops.

Peanuts

Foliage may be normal, but kernels often have a hollowed out, brownish area in the meat. This is usually referred to as "internal damage".

Beans

Thick stems and leaves with yellow and dead spots. If less severe, leaves are puckered and curl downward. Easily confused with leafhopper or virus attack. In very severe cases, plants stay stunted and may die shortly after emergence. Boron toxicity can be caused by

applying a fertilizer containing boron too close to the seed row or by applying B non-uniformly. Symptoms are yellowing and dying along the leaf margins of the plants shortly after emergence.

Appendix H - Miscellaneous pulses

Chickpeas

Other names: Garbanzo, gram pea Scientific name: Cicer arietum

Main areas of production: 90% of the world's production occurs in India and Pakistan, but chickpeas are also an important crop in Lebanon, Turkey, Syria, Iran, Bangladesh, Burma, Nepal, Colombia, Argentina, and Chile. Adaptation, Characteristics

Chickpeas prefer cool, semiarid conditions. The seeds have a very permeable coat and lose their viability (germination ability) quickly under high humidity. The crop has a very deep root system and is a very efficient extractor of soil phosphorus. It has good nitrogen fixing ability.

Uses and Nutritive Value

Chickpeas are consumed as immature seeds (and pods) or as mature seeds. Also used as a coffee substitute after roasting. The seeds contain about 70 percent protein.

World chickpea production averaged around 7 million tons/year during the 1975-1977 period and was largely concentrated in India and Pakistan.

Pigeonpeas

Other names: Gandul
Scientific name: Cajanus cajan

Main areas of production: India, the Caribbean (especially the Dominican Republic and Puerto Rico). Colombia, Panama, Venezuela, the Middle East, and parts of Africa.

Adaptation, Characteristics

This is a woody, erect, shortlived perennial which can reach a height of three to four meters. Pods are pea like and flair, with three to seven seeds. Seed color varies from white to red or almost black. Plants can be used as a windbreak. Pigeonpeas are very drought resistant and tolerate a wide variety of soils and rainfall conditions. They are usually treated as an annual or biennial and prunted to encourage branching after each crop. They are often interplanted with maize, sorghum, millet, beans, and squash. Early varieties take 12-14 weeks until pod initiation and a total of five to six months to maturity.

Late varieties take about 9-12 months. Although the plants will grow for three to four years, yields tend to decline. It is often best to treat it as an annual or to slash it back and take ratoon crops using the cut branches and leaves as livestock feed.

Regional figures are not available for pigeonpea production, but worldwide production probably totals about hall that of chickpeas.

Green pod yields range from about 1000-4000 kg/ha with up to 8000 kg/ha possible. Yields of dry seeds average about 600-1100 kg/ha, but up to 2000 kg/ha is possible. The plants are very efficient nitrogen fixers.

Nutritive Value and Uses

Both the dry seeds and the young green ones (sometimes with the pods) are eaten. Mature dry seeds contain about 20 percent. The dried stalks and branches are used for firewood, thatching, and baskets. The crop is also valuable as a forage, windbreak and green manure (organic fertilizer) crop, and for soil erosion control on slopes.

Lima beans

Scientific name:

Main areas of production: One of the most widely grown pulses in both temperate and tropical areas. Lima beans are the main pulse crop in the wet rainforest regions of tropical Africa and Latin America. Extensively grown in Liberia, Burma, and Nigeria.

Types

Most breeding research has focused on the erect, non-vining bushy types with strong stems and a self-standing ability. However, these bush varieties are not well adapted to hot, humid conditions like the vining types of limes.

Adaptation, Characteristics

The vining varieties require a support crop or other form of staking. They tolerate wetter weather during growth than cowpeas or common beans but need dry weather during the late stages when harvested in the mature form. Limas are less drought-tolerant than many other legumes and are very sensitive co soil acidity (the optimum pH is about 6-7). Varieties are either day neutral or short-day in their response to day length. Vining types have been grown up to elevations of 2400 m in the topics.

Nutritive Value and Uses

Lima beans are grown mainly for the dry, shelled beans, but the immature seeds are sometimes cooked as a vegetable along with the pods and leaves. Some varieties have a dangerous level of hydrocyanic acid (HCN) in the leaves, pods, and seeds, but this can be dissipated by boiling and changing the cooking water. Colored seed varieties are higher in HCN than white ones.

The plants also are used as a green manure crop and as a cover crop (to protect the soil from erosion). The seeds contain about 20 percent protein in the mature, dry form.

Mung beans

Other names: Golden gram, green gram

Scientific names: Phaseolus aureus

Mung beans are an important crop in India, China, and the Philippines and have been introduced into other areas. They are fairly drought tolerant but susceptible to poor drainage. They are eaten as boiled mature seeds, green pods or sprouts. The crop is also used for forage, green manure or as a cover crop. Mung beans are efficient nitrogen fixers.

Soybeans

Scientific name: Glycine max

The most extensive areas of soybean production are in the U.S., Brazil, Argentina, China. and other parts of Southeast Asia, although the crop is grown in many other areas worldwide. Its reputation as a high protein crop (35-40 percent protein) has tempted many Volunteers to introduce the soybean to their work areas. However, one should be aware of the following potential problems:

- **Local pulses may be better adapted to the area. Soybeans do not tolerate soil acidity well and prefer a pH between 6.0 and 7.0. High rainfall and humidity encourages diseases and insects.**

  The crop is largely grown for export and for making soybean oil and meal, the latter used in livestock feed.

- **Cooked soybeans often have an unpleasant off-flavor or odor which can make them unpalatable to many people. However, the University of Illinois has developed an inexpensive cooking method that solves this problem. Peanuts have the advantage over soybeans of being both a cash crop and a food crop and are also more droughttolerant.**

- **As with some sorghums and millets, soybeans are highly photosensitive to daylength, and varieties have a very narrow range of adaptation north and south of their origins. U.S. Corn Belt varieties are normal;´ grown under very long summer daylengths and if moved to short day tropical areas, they become dwarfed and reach maturity much too quickly. However, varieties are available for tropics.**

- **While soybeans are an extremely efficient nitrogen fixer, they require a unique type of Rhizobia bacteria unlikely to be present in soils not previously cropped to soybeans. In such cases, the seed needs to be innoculated with a commercial stain of Rhizobium japonicum. Soybean Rhizobia are adversely affected by soil pH's much below 6.0.**

Winged beans

Scientific name: Phophocarpus tetragonalobus

Winged beans are not a row crop, but have received much publicity as a possible "wonder crop." In the interest of clarification, some basic facts are presented here.

The plants are twining vines that grow to over three meters when supported and produce pods with four longitudinal jagged "wings" that contain up to 20 seeds. Winged beans are adapted to the wet tropics and have some valuable characteristics:

- **The dry seeds contain about 34 percent protein and 18 percent oil which makes**

them about equal to soybeans. The young leaves and pods can be eaten too.

- **Some varieties produce edible tubers with a reputed protein content of 20 percent, although some investigators feel that this is considerably overestimated.**

- **They are a very efficient nitrogenfixing legume and produce good yields. Yields of up to 2500 kg/ha of mature dry seed have been reported.**

Now for some of the disadvantages of winged beans:

- **The plants must be staked or they will not flower well, although they can be grown prostrate for their tubers.**

- **The seeds must be cooked using a special technique and soften slowly in water. The cooked, mature seeds have a strong flavor which is disliked by some. However, they do not have potential for the making of curds and tofu as with soybeans. The seeds have some likely metabolic (digestive) inhibitors that have not been adequately investigated.**

Introducing a new crop into an area is usually a task hefter left to professionals associated with a research station that has the money, time, skills, and discipline for such an undertaking. The extension workers' job is to provide the tested recommendations for the crops grown in an area.

Appendix I - Troubleshooting common crop problems

It takes a lot of practice and detective work to accurately troubleshoot crop problems. Some abnormalities like wilting or leaf yellowing can have numerous causes.

First, learn to distinguish normal from abnormal growth when you walk through a farmer's

field. Keep a close watch for telltale trouble signs such as abnormal color, stunting, wilting, leaf spots, and signs of insect feeding. Make a thorough examination of affected plants, including the root system and the inside of the stem, unless the problem is obvious. Obtain deyailed information from the farmer concerning all management practices that might have a bearing on the problem (i.e. fertilizer and pesticide applications, name of crop variety, etc.). Note whether the problem occurs uniformly over the field or in patches. This can provide valuable clues, since some problems like nematodes and poor drainage seldom affect the entire field.

Troubleshooting tools

- **A pocketknife for digging up seeds or slicing plant stems to check for root and stem rots or insect borers.**

- **A shovel or trowel for examining plant roots or checking for soil insects or adequate moisture.**

- **A pocket magnifying glass to facilitate identification of insects and diseases.**

- **A reliable soil pH test kit for checking both topsoil and subsoil pH. Especially useful in areas of high soil acidity. Beware of cheap kits, especially those using litmus paper. The HelligeTruog kit is one of the best and costs about $15 U.S.**

Troubleshooting Guide

CROP APPEARANCE	**PROBABLE CAUSES**
POOR SEEDLING EMERGENCE (Carefully dig up a section of row and look for the seeds)	Low-germination seed

	Planting too deep or too shallow
	Soil crusting or overly cloddy soil
	Lack of moisture
	Clogged planter
	Seeds washed out by heavy rain
	Fertilizer burn
	Pre-emergence damping-off disease
	Birds, rodents
	Seed-eating insects (wireworms, seed corn maggots, seed corn beetle)
WILTING(Pull up a few plants carefully using a shovel or trowel and examine the roots. Check stem for borers or rotted or discolored tissue.)	Actual lack of moisture due to drought or poor irrigation management (watering toc lightly or too infrequently)
	Diseases (bacterial or fungal wilts, certain types of rot and stem rots)
	Very high temperatures,

	especially if combined with dry, windy conditions
	Root pruning by hoe or cultivator
	Nematodes (especially if confined to patches and when plants wilt despite having sufficent water)
	Stem breakage or kinking
LEAF ROLLING OR CURLING	Lack of moisture (maize, sorghum, millet)
	Virus
	Sucking insects feeding on stem or leaves
	Boron, calcium deficiency (beans only)
	Verticillium wilt (peanuts)
LEAF CRINKLING, PUCKERING LEAF "BURNING" OR BROWNING	Aphids, leafhoppers feeding on leaves or stems
	Drought
	Excessive heat
	Fertilizer burn

	Insecticide overdose
	Dipterex, Azodrin (Nuvacron), or methyl parathion injury on sorghum
	Herbicide damage
	Nutrient deficiency
	Aluminum, iron, or manganese toxicity due to excessive acidity (below pH 5.5)
	Salinity or sodium problems (confined largely to low ainfall areas, especially if irrigated)
	Boron toxicity from irrigation water (low rainfall areas) of improper placement of fertilizer boron
LEGGY, SPINDLY PLANTS HOLES IN LEAVES	Lack of sunlight caused by overcrowding or long periods of heavy cloudiness
	Caterpillars

	Beetles
	Earwigs
	Crickets
	Snails, slugs, especially on beans (check for slime trails)
	Breakdown of dead tissue due to fungal or bacterial leaf spots
SPOTS ON LEAVES	Fungal or bacterial leaf spots
	Virus
	Sucking insects
	Spilling of fertilizer on leaves
	Herbicide spray drift, especially paraquat (Gramoxone)
	Sunscald (beans)
LEAF MALFORMATION WITH STEM CURVING & TWISTING (Broadleaf plants only) LEAF MOTTLING, LEAF MALFORMATION, PLANT	2,4-D type herbicide damage due to spray
	drift or a contaminated sprayer (broadleaf
	crops only)
	Virus
MALFORMATION LEAF STRIPING	

	Nutrient deficiency
	Virus
	Genetic
YELLOWING, STUNTING	Nutrient deficiency
	Poor drainage
	Nematodes
	Low pH (excessive acidity)
	Root rot, stem rot
OVERNIGHT DEFOLIATION OF PLANTS	Leaf cutter ants, grazing animals
PLANTS CUT OFF AT OR NEAR GROUND LEVEL TWISTING TUNNELS IN LEAVES YOUNG SEEDLINGS COLLAPSE NEAR GROUND LEVEL AND DIE POOR GROWTH, LACK OF VIGOR	Cutworms
	Mole Crickets
	Leaf miners
	Fungal seedling blights
	Heat girdling of stem (beans)
	Too dry or too wet
	Too hot or too cold
	Insects, diseases
	Weeds

	Unadapted variety
	Low pH
	Salinity-alkalinity problems
	Overcrowding
	Shallow soil
	Soil compaction, hardpan
	Poor drainage
	Nutrient deficiency
	Faulty fertilizer practices
	Nematodes
	Excessive cloudiness
	Herbicide carryover
	Overall poor management
	Damaged seed (beans)
LODGING OR STALK BREAKAGE (Maize, Sorghum, Millet)	Overcrowding
	Stalk rots
	Rootworms
	High wind
	K deficiency
POOR NODULATION ON PEANUTS, COWPEAS, SOYBEANS; OTHER LEGUMES THAT ARE EFFICIENT N FIXERS (Carefully dig up the root system and check for nodulation; clusters of fleshy nodules, especially on	Soil lacks the correct type of Rhizobia-seed innoculation is needed

the taproot, and with reddish interiors are signs of good nodulation. Don't confuse nodules with nematode galls')	
	Improper innoculation: wrong strain, innoculant too old or improperly stored
	Exposure of innoculated seed to excessive sunlight or contact with fertilizer or certain seed treatment fungicides
	Excessive acidity (soybeans are especially sensitive to soil pH's below 6.0)
	Molybdenum deficiency
	Plants are too young (it takes 2-3 weeks after plant emergence for the nodules to become visible)

Appendix J - Guidelines for using pesticides

Pesticides are poisons and are used to kill particular plants and animals that reduce the productivity of a farmer's crop. Fortunately, however, many pesticides have unwanted side effects and may be hazardous to nonpest plants and animals, including man.

Pesticide toxicity to animals may be acute, i.e., having effects resulting in illness or death, or it may be chronic, i.e., having effects that may not be apparent for many years. Chronic toxicity may take the following forms:

oncogenicity - cancercausing
teratogenity - causing deformities in offspring
mutagenicity - causing genetic mutations
reproductive effects effecting an individual's capacity to bear young

It is important that the farmer and extension worker be aware of the level of toxicity of the chemicals with which they are working and the following table lists the relative acute toxicity of some commonly used pesticides. The toxicity classes presented are based upon oral and dermal acute toxicity to rats.

class 1 = most dangerous; requiring a label reading "danger"
class 2 = less dangerous; requiring a label reading "warning"
class 3 = less dangerous; requiring a label reading "caution"

Please note that the toxicity classes only refer to acute toxic effects and the chemical may be a Class 3, least dangerous, and still have serious potential long-term toxicity.

The acute toxicity is rated accordingly to the dose of pesticide that is lethal to 50 percent of the test animals that ingest it (oral LD50) or absorbed through their skin (dermal LD50). The LD50 of a pesticide is measured in milligrams of pure chemical per kiligrams of test animal body weight (mg/kg). The lower the LD50 the less chemical required to kill 50 percent of the test animals and thus, the higher is the pesticide's toxicity. There are several important considerations in using the LD50 ratings.

1. The LD50 ratings are based on the amounts of 100 percent strength from one percent up to 95 percent. After dilution with water for spraying, actual strength

may only be about 0.1-0.2 percent. As a general rule a pesticide which is highly toxic as a concentrate (Class 1) will still be dangerous when diluted to the concentration at which it is useful.

2. The LD50 ratings give little information on the cumulative effect of repeated exposure.

3. If spilled on the skin, liquid insecticides are more readily absorbed than wettable powders or dusts.

4. Note that some insecticides like TEPP and Phosdrin are about as toxic dermally as they are orally.

5. Even Class 3 (least dangerous) insecticides like Malathion can cause severe poisoning if enough is ingested or spilled on the skin, especially in the concentrated form.

Pesticides include insecticides, fungicides, herbicides, nematicides and rodenticides. In general the herlucides and fungicides are not in the highly toxic categories (1 and 2) whereas a fair number of the insecticides and nematicides are very dangerous to use.

Table J-1 gives a partial listing of insecticides, their dermal and oral LD50s and the chemical group to which each insecticide belongs as follows:

CH = chlorinated hydrocarbon,
OP = organic phosphate,
C = carbamate,
M = miscellaneous

The antidote for poisoning varies with the chemical group. Aside from this difference, it's

hard to make meaningful distinctions between these chemical groups. For example, Aldrin, DDT, Endrin, Heptachlor, Lindane. and Kelthane (dicofol) have long residual lives and are all CH's. However, in terms of their immediate toxicity, they vary greatly - DDT is a Class 4 (least dangerous), while Endrin is a Class 1 (most dangerous). Other CH's like Methoxychlor have relatively short residual lives. The OP's and C's break down fairly quickly, but, also vary greatly in toxicity.

Insecticide Names: Note that each insecticide may be marketed under several different trade names. Many extension bulletins refer to insecticides by their non-commercial chemical names (i.e. Sevin is a trade name for carbaryl). This can create much confusion in indentifying insecticides.

The following pesticides have been suspended, canceled or withdrawn United States and their use should not be encouraged in international agriculature projects:

DDT	Mirex	DBCP
Aldrin	Chlordane	2,4,5-T
Dieldrin	Heptachlor BHC	(benzene hexochloride)
Endrin	TOK	Amitroz
	Kepone	Pirimicosb
		gardona
		dimethoate(dusts only)
		galecron*

***Only can be applied under specialized handling conditions on non-food (cathon) crops where mixer/loads exposure can be carefully controlled.**

Category I

Common Name	Other Trade or Chemical Names	LD_{50} Oral	Rating Dermal	Chemical Group
Dasanit 6	Terracur, fensulfothion	2-10	3-30	OP
Disyston 6	Disulfoton, Fruminal, oxydis-ulfoton	7	15	OP
Dyfonate 6	Fonofos	8	25	OP
Endrin 2,5,6	Hexadrin	1	18	CH
Parathion 6	Ethyl parathion, Bladan, Niran, E-605, Polidol E-605, Phoskil, Orthophos, Ekatox, Parathene, Panthion, Thiophos, Alkron	13	21	OP
Phosdrin 6	mevinphos, Phosphene, Menite	6	5	OP
Systox 6	demeton, Solvirex, Systemox, Demox	6	14	OP
Telodrin	isobenzan	5-30	5-30	CH
TEPP 6	Tetron, Vapotone, Kilmite 40	1	2	OP
Thimet 6	phorate, Rampart	2	6	OP
Temik 6	aldicarb	1	below5	C
Aldrin 2,5	Aldrite, Aldrosol, Drinox, Seed-rin, Octalene	39	98	CH
Azodrin 6	Nuvacron, Monocron, monocrotophos	17	126	OP
Bidrin 6	Ekafos, Carbicron	21	43	OP
Birlane 6	chlorfenvinphos, Supona, Sape-cron	10-155	108	OP

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2. Long residue life (3-10 years).

3. Moderately long residue life (1-3 years).

4. High oral, low dermal (skin) toxicity.

5. Now banned or withdrawn from use in the U.S.

6. A restricted pesticide in the U.S. based upon its acute hazard to humans.

7. Chemicals now under EPA's Rebuttable Presumption against Registration (RPAR) process.

Table J-1 Toxicity of Selected Insecticides

Common Name	Other Trade or Chemical Names	LD50 Oral	Rating Dermal	Chemical Group
Dieldrin 2,5	Alvit, Octalox, Dieldrite	46	90	CH
Furadan 4	carbofuran, Curaterr (See below for granules)	11	10,000	C
Guthion 6	Guthion, Carfene, azinphosmethyl	12	220	OP
Methyl Parathion 6	Folidol M, Parathion M, Nitrox, Metron, Parapest, Dalf, Partron, Phospherno	14	67	OP
Lannate 6	Methomyl, Nudrin	17-24	1000	C
Monitor 6	Tamaron, methamidophos	21	118	OP
Mocap 6	Jolt, Prophos, ethoprop	61	26	OP
Thiodan	endosulfan, Cyclodan, Malix, Thimul, Thiodex	43	130	CH
Trithion	carbophenothion, Carrathion	30	54	OP
Nemacur 6	phenamiphos, fenamiphos	8	72	
	Category II			
BHC 2,5	benzene hexachloride, Hexachlor, Benzahex, Benzel, Soprocide, Dol, Dolmix, Hazafor, HCH	600	---	CH
Bux	Bufenkarb, metalkamate	87	400	C
Chlordane	Chlorkill, Orthochlor, Belt, As-	335	840	CH

Ciodrin	crotoxyphos pon	125	385	OP
Diazinon	Basudin, Spectracide, Diazol, Gardentox, Sarolex	180	900	OP
Dibrom	naled, Bromex	250	800	OP
Dimethoate	Cygon, Rogor, Perfekthion, Roxion, De-Feud	215	400	OP
Dursban	chlorpyrifos, Lorsban	97-276	---	OP
Dipterex	Dylox, Klorfon, Danex, Trichlorfon, Neguvon, Anthon, Bovinox, Proxol, Tugon, Trinex	180	2000	OP

Table J-1 Toxicity of Selected Insecticides - continue 1

Common Name	Other Trade or Chemical Names	LD_{50} Oral	Rating Dermal	Chemical Group
Folimat	methoate	50	700	OP
Folithion	Nuval, Agrothion, fenitrothion	500	1300	OP
Hostathion	triazaphos	80	1100	OP
Heptachlor 2,5	Drinox H-34, Heptamul	100	195	CH
Lebaycid	Fenthion	200	1300	OP
Lindane 2	Gamma BHC, Gammexane, Isotox, OKO, Benesan, Lindagam, Lintox, Novigam, Silvanol	88	1000	CH
Metasystox	oxydemetonmethyl	47	173	OP
Mirex 5	dechlorane	300	800	CH
Toxaphene 3,7	Motox, Strobane T, Toxakil, Magnum 44	90	1075	CH
Unden	Baygon, Suncide, Senoran, Blattanex, PHC, propoxur	100	1000	C

Vapona	DDVP, dichlorvos, Nuvan, Phosvit	90	107	OP
	Category III			
DDT 2,5	Anofex, Genitox, Gesarol, Neocid, etc.	113	2510	CH
Galecron	chlordimeform, Fundal	127-372	3000	OP
Gardona 5	Appex, Rabon	4000	5000	OP
Kelthane 3	dicofol, Acarin, Mitigan	1100	1230	CH
Malathion	Cythion, Unithion, Emmatos, Fyfanon, Malaspray, Malamar, Zithiol	1375	4444	OP
Methoxychlor	Marlate	5000	6000	OP
Morestan	Forstan	1800	2000+	
Orthene	Acephate, Ortran	866	---	OP
Sevin	carbaryl, Vetox, Ravyon, Tricarnam	850	4000	C
Tedion	Tetradifon	14,700	10,000	CH
Volaton	phoxim, Valexon	1845	1000+	OP
Actellic	pirimiphos-methyl, Blex, Silosan	2080	2000+	OP

Table J-1 Toxicity of Selected Insecticides - continue 2

Table J-1 Toxicity of Selected Insecticides

Category I				
Common Name	**Other Trade or Chemical Names**	**LD_{50} Oral**	**Rating Dermal**	**Chemical Group**
Dasanit 6	Terracur, fensulfothion	2-10	3-30	OP

Disyston 6	Disulfoton, Fruminal, oxydisulfoton	7	15	OP
Dyfonate 6	Fonofos	8	25	OP
Endrin 2,5,6	Hexadrin	1	18	CH
Parathion 6	Ethyl parathion, Bladan, Niran, E-605, Polidol E-605, Phoskil, Orthophos, Ekatox, Parathene, Panthion, Thiophos, Alkron	13	21	OP
Phosdrin 6	mevinphos, Phosphene, Menite	6	5	OP
Systox 6	demeton, Solvirex, Systemox, Demox	6	14	OP
Telodrin	isobenzan	5-30	5-30	CH
TEPP 6	Tetron, Vapotone, Kilmite 40	1	2	OP
Thimet 6	phorate, Rampart	2	6	OP
Temik 6	aldicarb	1	below5	C
Aldrin 2,5	Aldrite, Aldrosol, Drinox, Seedrin, Octalene	39	98	CH
Azodrin 6	Nuvacron, Monocron, monocrotophos	17	126	OP
Bidrin 6	Ekafos, Carbicron	21	43	OP
Birlane 6	chlorfenvinphos, Supona, Sapecron	10-155	108	OP
Dieldrin 2,5	Alvit, Octalax, Dieldrite	46	90	CH
Furadan 4	carbofuran, Curaterr (See below for granules)	11	10,000	C
Gusathion 6	Guthion, Carfene, azinphosmethyl	12	220	OP
Methyl Parathion 6	Folidol M, Parathion M, Nitrox, Metron, Parapest, Dalf, Partron, Phospherno	14	67	OP
Lannate 6	Methomyl, Nudrin	17-24	1000	C

Monitor 6	Tamaron, methamidophos	21	118	OP
Mocap 6	Jolt, Prophos, ethoprop	61	26	OP
Thiodan	endosulfan; Cyclodan, Malix, Thimul, Thiodex	43	130	CH
Trithion	carbophenothion, Carrathion	30	54	OP
Nemacur 6	phenamiphos, fenamiphos	8	72	
Category II				
BHC 2,5	benzene hexachloride, Hexachlor, Benzahex, Benzel, Soprocide, Dol, Dolmix, Hazafor, HCH	600	---	CH
Bux	Bufenkarb, metalkamate	87	400	C
Chlordane	Chlorkill, Orthochlor, Belt, Ascrotoxyphos pon	335	840	CH
Ciodrin	Basudin, Spectracide, Diazol,	125	385	OP
Diazinon	Gardentox, Sarolex	180	900	OP
Dibrom	naled, Bromex	250	800	OP
Dimethoate	Cygon, Rogor, Perfekthion, Roxon, De-Feud	215	400	OP
Dursban	chlorpyrifos, Lorsban	97-276	---	OP
Dipterex	Dylox, Klorfon, Danex, Trichiorfon, Neguvon, Anthon, Bovinox, Proxol, Tugon, Trinex	180	2000	OP
Folimat	methoate	50	700	OP
Folithion	Nuval, Agrothion, fenitrothion	500	1300	OP
Hostathion	triazaphos	80	1100	OP
Heptachlor 2,5	Drinox H-34, Heptamul	100	195	CH
Lebaycid	Fenthion	200	1300	OP

Lindane 2	Gamma BHC, Gammexane, Isotox, OKO, Benesan, Lindagam, Lintox, Novigam, Silvanol	88	1000	CH
Metasystox	oxydemetonmethyl	47	173	OP
Mirex 5	dechlorane	300	800	CH
Toxaphene 3,7	Motox, Strobane T, Toxakil, Magnum 44	50	1075	CH
Unden	Baygon, Suncide, Senoran, Blattanex, PHC, porpoxur	100	1000	C
Vapona	DDVP, dichlorvos, Nuvah, Phosvit	90	107	OP
Category III				
DDT 2,5	Anofex, Genitox, Gesarol, Neocid, etc.	113	2510	CH
Galecron	chlordimeform, Fundal 127-	372	3000	OP
Gardona 5	Appex, Rabon	4000	5000	OP
Kelthane 3	dicofol, Acarin, Mitigan	1100	1230	CH
Malathion	Cythion, Unithion, Emmatos, Fy- fanon, Malaspray, Malamar, Zithiol	1375	4444	OP
Methoxychlor	Marlate	5000	6000	OP
Morestan	Forstan	1800	2000+	
Orthene	Acephate, Ortran	866	---	OP
Sevin	carbaryl, Vetox, Ravyon, Tricarnam	850	4000	C
Tedion	Tetradifon	14,700	10,000	CH
Volaton	phoxim, Valexon	1845	1000+	OP
Actellic	pirimiphos-methyl, Blex, Silosan	2080	2000+	OP

The following pesticides have been restricted for use in the United States, based on human hazard, and their use should not be encouraged in international small farmers' agricultural

projects:

methyl paralthion	methamidophos
ethyl paralthion	methomyl (lannote) tamaron (monitor)
parathion	carbofubon (except granular formulations) dyfonate trithion

The following pesticides are being investigated by the U.S. Environmental Protection Agency under the Rebuttable Presumption Against Registration (RPAR) Program. These pesticides have possible risks in the following five areas, but the risks have not been proven and they are therefore still permitted for use:

1. **Acute toxicity;**
2. **Chronic toxicity including oncogenic and mutagenic effects;**
3. **Other chronic effects;**
4. **Effects on wildlife; and**
5. **Lack of emergency treatment.**

Pesticides presently under RPAR review include the following:

Beronyl	EBDC's, including Maneb, mancozeb, metiram, nodam, zireb, amobam
Cadmium	Ethylene dibromide
Captan	Ethylene oxide
Diallate	Inosyohk Arsenicals
	Lindane Maleic
	Hydrozide
	Sulfate
	Toxaphene

	Toxaphene
	Trifnralin

General Information on Common Insecticides

I Bacillus Thuringiensis

A biological insecticide made from a natural bacteria that kills only certain types of caterpillars; most effective against cabbage loopers but also against hornworms (Protoparce) and earworms (Heliothis). Non-toxic to humans and animals. Insects don't die immediately but stop feeding within a few hours - it may take a few days for them to die. Apply before the caterpillars are large for best results. Needs no stickerspreader for most formulations. Compatible with most other pesticides. Don't store the diluted spray for more than 12 hours. Dosage varies widely with the particular formulation, II Diazinon (Basudin, Diazol, etc.)

Fairly broad-spectrum including control of many soil insects but not as effective on beetles (except for the Mexican bean beetle). Highly toxic to bees. Aboveground insect control: 4cc/ liter of Diazinon 25 percent EC or Basudin 40 percent WP. Dimethoate (Perfekthion^{R} Cygon^{R} Rogor^{R} etc.)

A systemic insecticide of moderate toxicity to humans (Class 2). Specifically for sucking insects (aphids, leafhoppers, thrips, stinkbugs, mites, etc.) and leaf miners. Should provide control for 10-14 days. Don't apply within 1421 days of harvest. Highly toxic to bees with a one- to two-day residual effect. General dosages for the three most common formulations (all emulsifiable concentrates are given below):

Formulation of dimethoate	Dosage-cc/100 liters
200 grams active ingred./liter	100-200

400 grams a.i./liter	50-100
500 grams a.i./liter	50-75

Dipterex (trichlorfon, Dylox[R],Danex[R], Klorfon[R] etc.)

Provides fairly broad spectrum insect control but not as effective on aphids, mites and thrips. Dipterex causes severe injury when applied to sorghum. Low to high toxicity for humans.

General above-ground insect control: 125-250 cc (100-200 grams) of Dipterex per 100 liters of water or 5-10 cc .

Armyworms or earworms feeding in the leaf whorl or maize: Dipterex 2.5 percent granules give longer control than sprays; apply a pinch in each whorl which works out to about 10-15 kg/ha (lbs./acre) of granules. 100 cc of the granules weigh about 60 g. Furadan (Carbofuran)

A systemic insecticidenematocide available in 3 granular formulations (3 percent, 5 percent, 10 percent) and as a wettable powder. The wettable powder formulation is considered too toxic for normal use, however; the pure strength chemical has an extremely high oral but very low dermal toxicity. Furadan granules are usually applied to the soil either in the seed furrow or in a band centered over the crop row; furadan kills soil nematodes and soil insects but is also absorbed by the roots and translocated throughout the plant where it controls sucking insects, stem borers, and leaf feeding beetles and caterpillars for up to 30-40 days. Band treatments are recommended for root feeding soil insects, while seed furrow applications can be used for foliar insects. Furadan can also be band applied during the growing season if it is cultivated into the soil or can be applied to the leaf whorl of maize. May cause minor foliar injury to peanuts; do not place in contact with sorghum or bean seed.

Kelthane (dicofol, Acarin, Mitigan, Carbax)

Kills mites only; not harmful to beneficial insects. Gives good initial control of mites and has good residual activity against them; non-systemic. Spray undersides of leaves. Don't feed crop residues to dairy or slaughter anitreatment is effective approximately four months.

Sevin (carbaryl, Vetox, Ravyon, etc.)

Broad-spectrum insect control except for aphids and mites. Very low toxicity for humans (Class 3). Very toxic to bees with a 7-12 day residual effect. General dosage for Sevin: Use the 50 percent WP at 8-16 cc per/1. Use 80 percent WP at 5-10 cc/1 or 1.252.5 tablespoons/gallon. Can be applied right up to harvest time on the reference crops.

Household dosages: For cockroaches and ants, use as a 2.5 percent strength spray (active ingredient basis); this equals about 100 cc of Sevin 80 WP per liter of water; don't use more than twice a week.

Ticks, lice, fleas, horn flies on beef cattle, horses, swine: Use 20 cc Sevin 80 percent WP per liter of water. Don't apply within five days of slaughter.

Mites, lice, fleas on poultry: Use at same rate as for beef cattle and apply about 4 liters per 100 birds; don't apply within seven days of slaughter.

Volaton (Valexon, phoxim)

A less toxic and persistent replacement for Aldrin for soil insect control. Low toxicity for humans. Also available as a liquid formulation for leaf insects. General dosage for Volaton: Use the 2.5 percent granules at 60 kg/ha for furrow application and 120 kg/ha for broadcast application. Work into the top 5-7.5 cm of soil. Fungicides: Except for mercury

based fungicides used for seed treatment like Agallol, Semesan, and Ceresan, fungicides pose little hazard to health. Their oral toxicity is comparatively low, and there is little danger of dermal absorption. Some may cause allergies in sensitive people through skin contact and can be eye irritants as well.

Low toxicity (Class 3). General dosage: Use the 35 percent WP formulation at four to five cc per liter of water. Use the 18.5 percent EC at 1.5cc per liter of water.

Lebaycid (Fenthion, Baytex, Baycid)

A relatively low toxicity (Class 2) organic phosphate for chewing and sucking insects, including mites. Don't spray plants when temperatures exceed 32°C. Very toxic to bees with two to three days' residual activity. General dosage for Lebaycid: Use Lebaycid 40 percent WP at 1.5-2 g per liter of water; use Lebaycid 50 percent EC at 1-1.5 cc/liter of water.

Malathion (Cythion, Unithion, Mala spray)

A broad-spectrum insecticide of low human toxicity (Class 3). Not as effective on armyworms, earworms, and flea beetles. Its residual activity is decreased if mixed with water above pH 8.0.

Can be mixed with other pesticides except Bordeau and lime sulfur. Liquid formulations are moderately toxic to bees with less than two hours' residual effect; wettable powder formulations are highly toxic but have less than one day's residual effect on bees. General dosage for Malathion: Four to five cc of Malathion 50 percent or 57 percent EC per liter of water. Use Malathion 25 pecent WP at 12 cc/liter.

Using Malathion for Control of Stored Grain Insects

Grain which is to be held in storage should be protected from stored grain insects. An approved grain protectant applied to the grain at time of storage will help prevent an early infestation. Premium grade Malathion is the only protectant available. Malathion can be applied as a dust or spray at the following rates:

1. **One percent dust on wheat flour at the rate of 60 lbs. per 1000 bushels of grain.**
2. **One pint of 57 percent (five pounds/gallon) EC in three to five gallons of water per 1000 bushels of grain.**

CROP AND PEST MAIZE	INSECTICIDE	AMOUNT OF ACTIVE INGREDIENT NEEDED kg/ha	REMARKS AND PRECAUTIONS
Cutworms	carbaryl	1.7-2.25	Recipes for cutworm baits are given.
	trichlorfon	0.9-1.1	Direct spray at base of plants; use trichlorfon on soils high in organic matter.
	chlorpyrifos	1.1-2.25	Baits will give better control. Use higher rates of chlorpyrifos for heavy infestations; don't apply chlorpyrifos within 50 days of harvest. Granules should be applied in an 18 cm wide band over the row at planting.
Rootworms (Diabrotica spp.)	Diazinon	1.1	Use Diazinon as a post-emergence basal spray treatment applied in a band over the row when symptoms appear.
	carbofuran	0.85-1.1	Apply Furadan granules in an 18 cm wide band centered over the row at planting or in the seed furrow.
Wireworms	carbofuran	1.1-2.25	Apply in seed furrow or in an 18 cm wide band over the row at planting; may not be effective in dry weather.
	Diazinon	2.25	Broadcast over entire soil surface and work into the top 10 cm 1-2 weeks before planting

1. These rates are based on the latest information (1978-80) from the U.S. Dept. of Agric., North Carolina State University, Clemson University (South Carolina), and CIAT.

Table J-2: Some insecticide recommendations for specific insects attacking the reference crops

CROP AND PEST MAIZE, cont.	INSECTICIDE	AMOUNT OF ACTIVE INGREDIENT NEEDED kg/ha	REMARKS AND PRECAUTIONS
Seed corn beetles, seed corn maggots, attacking seeds	Diazinon wireworms Lindane may also be used (see label for dosage)	mix dust or WP seed at the rate of 15 grams active ingredient per 10 kg of seed.	Handle treated seed with rubber gloves. Other products like Lindane can be used.
White grubs (Phyllophaga)	see wireworms	see wireworms	Don't use more than 1.1 kg/ha active ingredient Furadan if white grubs are the only problem.
Aphids, maize leaf (Rhopalosiphum)	Malathion	0.9-1.2	
Caterpillars feeding in the leaf whorl (Spodoptera, Heltiothis, etc.)	Carbaryl	1.7-2.25	Direct spray into whorl; use lower rate on young maize.
	Malathion	1.4	Direct spray into whorl.
	trichlorfon	1.12	Direct spray into whorl or use Dipterex 2.5% granules at 10-15 kg/ha (about a pinch per whorl).
Flea Beetles	carbaryl	1.1	
	Diazinon	0.55	

Table J-2: Some insecticide recommendations for specific insects attacking the reference crops - continue 1

CROP AND PEST MAIZE, cont.	INSECTICIDE	AMOUNT OF ACTIVE INGREDIENT NEEDED kg/ha	REMARKS AND PRECAUTIONS

Maize rootworm beetles (Diabrotica spp.)	carbaryl Diazinon Malathion	1.1 1.1 1.1	Apply when there are 5 or more beetles feeding on the silks of each ear. Direct spray at the silks.
Stem borers (Diatraea, Zeadiatraea, Busseola, Sesamia, Chilo, Eldana)	Various non-systemics like carbaryl, Dipterex, Furadan.	See caterpillars	Most non-systemics will control stemborers if applied between hatching and stem entry; timing is critical; spray the leaf whorl. Furadan granules can also be used in the whorl or at planting; check local recommendations.
Lesser cornstalk borer (Elasmopalpu lignosellus)	carbaryl trichlorfon	Use general dosage rates given in previous section.	Spray base of plants so that both stalk base and nearby soil are covered.
SORGHUM			
Aphids	Malathion dimethoate Diazinon	0.55-0.9 0.25-0.37 0.28	Do not use Dipterex or methyl parathion since they injure sorghum.
Earworms or armyworms feeding on the heads	carbaryl	1.7-2.25	Begin application when there is one medium to large caterpillar per head. Don't apply within 3 weeks of harvest.

Table J-2: Some insecticide recommendations for specific insects attacking the reference crops - continue 2

CROP AND PEST SORGHUM, cont.	INSECTICIDE	AMOUNT OF ACTIVE INGREDIENT NEEDED kg/ha	REMARKS AND PRECAUTIONS
Sorghum midge (Contarinia sorghicola)	carbaryl Diazinon	1.4-1.8 0.28	Wait until 30-50% of heads have begun to bloom; begin spraying if two or more adult midge are found per head; timing is critical; repeat in 3-5 days where adults still exceed two per head.
Sorghum shoot fly (Atherigona)	See remarks	-- --	Seek local recommendations; Furadan may be used at planting but should not touch the seed.
MILLET Refer to sorghum and maize			
PEANUTS Rootworms (Diabrotica)	Diazinon	2.25-3.3	Apply in a band 40-50 cm wide centered over the row just prior to pegging and work into top 5-7.5 cm of soil.
White grubs or wireworms	Diazinon	2.25	Broadcast before planting and work into the top 7.5-10 cm of soil.
Thrips, leafhoppers, aphids wireworms, at planting treatment	carbofuran	1.1	Apply in the seed furrow at planting; reduce dosage by 25% on sandy soils, especially where runner varieties are used. Furadan is highly toxic orally.

Table J-2: Some insecticide recommendations for specific insects attacking the reference crops - continue 3

CROP AND PEST PEANUTS, cont.	INSECTICIDE	AMOUNT OF ACTIVE INGREDIENT NEEDED kg/ha	REMARKS AND P
Lesser corn-stalk borer (Elasmopalpus lignosellus)	Diazinon granules	2.25	Apply the granules in a band over the row; Don't apply u plants exceed 10% before blo after; don't use plants tor days or for hay within 21 da
Caterpillars on leaves	carbaryl	1.4-1.8	Peanuts are quite tolerant o apply unless there are 12 or per meter of row length; app still small. Don't feed Tox plants to dairy animals or t ished for slaughter.
Leafhoppers	carbaryl	1.1-1.4	May be applied up until harv
	Methoxychlor	1.1	Don't feed Methoxychlor trea 10 days.
Thrips	carbaryl	1.1-1.7	Can be applied up to harvest
	Malathion	0.9-1.1	Don't feed plants for 10 day

	Malathion	0.9-1.1	Don't feed plants for 30 day
		1.7-2.25	Don't feed plants to dairy a being finished for slaughter
Mites	Sulfur dust	17-23	Apply to undersides of leave so controls leafspot desease

Table J-2: Some insecticide recommendations for specific insects attacking the reference crops - continue 4

CROP AND PEST BEANS	INSECTICIDES	AMOUNT OF ACTIVE INGREDIENT NEEDED kg/ha	REMARKS AND PRECAUTIONS
Cutworms	Baits	25 kg of bait/ha	For bait recipes, refer to the start of unit IX, this section.
	trichlorfon	1.1	Spray base of plants and nearby soil.
White grubs, wireworms	carbofuran	0.9	Apply in an 18 cm wide band over the row or in the furrow but not in direct contact with the seed; Furadan has very high oral toxicity.
	Diazinon	3.3-4.5	Broadcast over entire soil surface and worked into top 10 cm before planting.
		1.7	Banded over the row and worked into the top 10 cm before planting.
Aphids	Diazinon	0.55-0.85	
	Malathion	1.4	
	naled	1.1	
Bean leaf beetle (Cerotoma) and Diabrotica beetles	carbaryl	1.1-1.25	Use the lower rates on the bean leaf beetle.
	Malathion	1.4	
	Methoxychlor	1.1-3.3	
	Diazinon	0.44	

Table J-2: Some insecticide recommendations for specific insects attacking the reference

crops - continue 5

CROP AND PEST BEANS, cont.	INSECTICIDE	AMOUNT OF ACTIVE INGREDIENT NEEDED kg/ha	REMARKS AND PRECAUTIONS
Bean pod weevil (Apion godmani) (granular)	carbaryl	2.25	Apply 6 days after flower initiation and then one week later.
	Methoxychlor	1.7	
	endosulfan	0.55-1.1	
Earworms (Heliothis spp.)	carbaryl	1.7-2.25	
	Methoxychlor	1.1-3.3	
Leafhoppers	carbaryl	1.1-1.7	
	Malathion	1.1-2.0	
	Methoxychlor	1.1-3.3	
	naled	1.1	
	carbofuran	0.7-1.0	Apply under the seed but not in direct contact; carbofuran has a very high oral toxicity; control lasts 30-40 days.
Lesser cornstalk borer (Elasmopalpus lignosellus)	Diazinon	1.1-2.25	Spray in a band 15 cm wide over the row to cover base of stems and nearby soil.
	trichlorfon	1.1	

Table J-2: Some insecticide recommendations for specific insects attacking the reference

crops - continue 6

CROP AND PEST BEANS, cont.	INSECTICIDE	AMOUNT OF ACTIVE INGREDIENT NEEDED kg/ha	REMARKS AND PRECAUTIONS
Mexican bean beetle (Epilachna)	carbaryl	0.55-1.1	
	acephate	0.75	Don't apply acephate within 14 days of harvest.
	endosulfan	1.1	Don't apply within 3 days of harvest.
	Malathion	1.35	
	Diazinon	0.55-0.85	
	Methoxychlor	1.1-3.3	
Mites	Kelthane	0.55-0.66	Don't apply dicofol within 7 days of harvest
	dimethoate	0.28-0.56	
Slugs, Snails	Metaldehyde, carbaryl or trichlorfon	25 kg of bait per hectare	
Stinkbugs (Nezara spp.)	carbaryl	2.25	
	naled	1.7	Don't apply within 4 days of harvest.
	endosulfan	1.1	Don't apply within 3 days of harvest.

Table J-2: Some insecticide recommendations for specific insects attacking the reference

crops - continue 7

Bee Poisoning Hazard of Pesticides

Most bee poisoning occurs when insecticides are applied during the crop's flowering period. Spray drift is another hazard. To avoid bee kill:

- **Do not apply insecticides toxic to bees when crops are flowering. Insecticides applied as a dust are the most harmful to bees.**
- **Do not dump unused quantities of dusts or sprays where they might become a bee hazard. Bees will sometimes collect any type of fine dust when pollen is scarce.**
- **Use insecticides of relatively low toxicity and residual effect for bees.**
- **Plug up or cover the hive entrances the night before spraying and then reopen them once the residual effect is over.**

None of the fungicides is toxic to bees. The same is true with most herbicides, although Gesaprim (AAtrex, Atrazine) and the 2,4-D herbicides are low to moderate in toxicity.

Here is a partial guide to the relative toxicity of various insecticides for bees. Note the differences in residual effect.

WHEN APPLIED AS A SPRAY		
Insecticide	**Toxicity to Bees**	**Residual Effect**
Aldrin	Very high	Several days
Diazinon	High	One day
Dipterex	Low to High	2-5 hours

Lebaycid	Very high	2-3 days
Kelthane (dicofol)	Low	
Methyl parathion	High	Less than one day
Malathion	Moderate (liquid)	Less than 2 hours
	High (wettable powder)	Less than one day
Metasystox	Moderate	None
Dimethoate	Very High	1-2 days
Sevin	Moderate to High	7-12 days

Insecticide Safety Guidelines

1. Read and follow label instructions: If the label is vague, try and obtain a descriptive pamphlet. Not all insecticides can be applied to all crops. Inappropriate use can damage plants or result in undesirable residues. The label should state the minimum allowable interval between application and harvest.

2. Never buy insecticides that come in unlabeled bottles or bags; you may not be buying what you think. This is a serious problem in developing countries where small farmers often purchase insecticides in Coke bottles, etc.

3. When working with farmers, especially those using backpack sprayers instead of tractor sprayers, NEVER use or recommend those insecticides in toxicity Class 1. Their safe use requires extraordinary precautions and safety devices (gloves, special respirators, protective clothing, etc.). Whenever possible, avoid using Class 2 products. Unfortunately, extension pamphlets in many developing countries commonly recommend Class 1 and Class 2 products.

4. If using Class 2 insecticides, wear rubber gloves and a suitable respirator (good ones cost $15$25), as well as long pants and a long-sleeve shirt; wear rubber boots if using a backpack sprayer. This clothing should be washed separately from other garments.

5. Do not handle plants within five days after treatment with a Class 1 insecticide or with Gusathion (Guthion). Do not handle plants within one day of using methyl parathion.

6. Class 1 and 2 insecticides are likely to be especially common in tobacco and cotton growing areas.

7. Do not smoke or eat while applying pesticides. Wash up well afterwards.

8. Repair all leaking hoses and connections before using a sprayer.

9. Prepare insecticide solutions in a wellventilated place, preferably outdoors.

10. Never spray or dust on very windy days or against a breeze.

11. Notify beekeepers the day before spraying.

12. Insecticide poisoning hazards increase in hot weather.

13. Store insecticides out of reach of children and away from food and living quarters. Store them in their original labeled containers which should be tightly sealed.

14. Leftover spray mixtures should be poured into a hole dug in the ground well away from streams and wells.

15. Do not contaminate steams or other water sources with insecticides either during application or when cleaning equipment.

16. Make sure insecticide containers are never put to any other use. Burn sacks and plastic containers (don't breath the smoke). Punch holes in metal ones and bury them.

17. Make sure that farmers are well aware of safety precautions. It is important that they understand that insecticides vary greatly in their toxicity.

18. Make sure that you and your client farmers are familiar with the symptoms of insecticide poisoning and the first aid procedures given below.

Symptoms of Insecticide Poisoning

Organic Phosphates & Carbamates (Parathion, Malathion, Sevin, etc.)

Both groups affect mammals by inhibiting the body's production of the enzyme cholinesterase which regulates the involuntary nervous system (breathing, urinary and bowel control, and muscle movements).

Initial Symptoms:	Dizziness, headache, nausea, vomiting, tightness of the chest, excessive sweat-ing. These are followed or accompanied by blurring of vision, diarrhea, watering of the eyes, excessive salivation, muscle twitching, and mental confusion. Tiny (pinpoint) pupils are another sign.
Late Symptoms:	Fluid in chest, convulsion, coma, loss or urinary or bowel control, loss of breathing.

Note: Repeated exposure to these organic phosphate and carbamate insecticides may

increase susceptibility to poisoning by gradually lowering the body's cholinesterase level without producing symptoms. This is a temporary condition. Commerical insecticide applicators in the U.S. usually have their cholinesterase levels routinely monitored.

Symptoms of Chlorinated Hydrocarbon Poisoning (Aldrin, Endrin, Chlor cane, Dieldrin, etc.)

Apprehension, dizziness, hyper-excitability, headache, fatigue, and convulsions. Oral ingestion may cause convulsions and tremors as the first symptoms.

First Aid Measures

1. In severe poisoning, breathing may stop, which makes mouth to mouth resuscitation the first priority. Use full CPR if the heart has stopped.

2. If the insecticide has been swallowed and the patient has not vomited, induce vomiting by giving a tablespoon of salt dissolved in half a glass of warm water. An emetic like Emesis (syrup of Ipecac) may be more effective, This should be followed by 30 grams (1 oz.) of activated charcoal* dissolved in water to help absorb the remaining insecticide from the intestines.

3. Get the patient to a doctor as soon as possible. Bring along the insecticide label.

4. In the meantime, make the patient lie down and keep warm.

5. If excessive amounts are spilled on the skin (especially in the concentrate form), immediately remove clothing and bathe the skin in generous amounts of water and soap.

6. If the eyes have been contaminated by dusts or sprays, flush them immediately

for at least five minutes with copious amounts of water. Insecticide absorption through the eyes is very rapid.

Antidotes

Whenever possible, antidotes should be given only under medical supervision. Too much or too little

Appendix K - Guidelines for applying herbicides with sprayers

The farmer should calibrate his/ her sprayer when a pesticide needs to be applied at an accurate dosage in order to avoid applying too much, which wastes money and might make the product ineffective. When working with small fields, farmers can usually use generalized recommendations given in cc/liter or tablespoons/gallon for insecticides and most fungicides. However, most herbicides require more accurate application, which means that sprayer calibration is usually needed.

The Principles Involved

When a pesticide recommendation is given in terms of kg/ha or lbs./ acre of active ingredient or actual product, the farm needs to know two things before he/she can apply the correct dosage:

- **The amount of pesticide needed for his/her particular field.**
- **The amount of water needed to convey the pesticide to the plants or soil and give adequate coverage.**

Once these are know, it is a simple matter of mixing the correct amounts of water and pesticide together, then spraying.

Calibration of backpack sprayers

NOTE: Only backpack sprayers with continous pumping action should be used when calibration is needed; compression type sprayers (the garden variety that needs to be set down to be pumped up) are not suitable because of their uneven pressure.

Step 1: Fill the sprayer with three to four liters of water and begin spraying the soil or crop using the same speed, coverage and pressure that will be used in applying the pesiticide Measure the area covered by this amount water. Repeat this procedure several times to determine the average area sprayed. You can measure the area in terms of squre feet or in terms of row length.

Step 2: Based on the area covered, you can calculate the amount of water needed to cover the field. For example, if three liters covered 60 square feet, and the field measures 20 x 30 feet, it would take 30 liters of water to cover the field.

Step 3: Determine the number of sprayer tankfuls of water needed to cover the field. For example, if the backpack sprayer holds 15 1, it will take two tankfuls to cover the field.

Step 4: Determine how much actual pesticide is needed for the field. If 4 kg of Sevin 50 percent wettable powder are needed per hectare and the farmer's field is 600 square feet, this would mean that 240 l of insecticide are required. Here's how we worked it out:

600 sq. m / 10,000 sq. m = X / 4000

X = 240

Step 5: Divide the amount of pesticide needed for the field by the number of sprayer tankfuls of water to determine how much pesticide is needed per tankful:

240 g Sevin 50% WP / 2 tankfuls = 120 g Sevin/ tankful

NOTE: A sprayer should be recalibrated each time it is used on a different crop, different of stage of crop growth or when another pesticide is used.

Alternate Method Using Row Length

When a pesticide is to be applied to a crop grown in rows, you can use row length instead of area as the basis for calibration. PROBLEM: Label instructions advise Juan to apply Malathion 50 percent strength liquid at the rate of 4 1/ha. His field measures 40 x 50 m and the bean rows are spaced 50 cm apart. His backpack sprayer hold 15 1, and he needs to know how much Malathion should be added to each tankful.

SOLUTION

1. Follow the same procedure as with Step 1 of the 'first method but measure the amount of row length covered by the 34 1 instead of area. Suppose that Juan was able to cover 150 m of row length with 3 1.

2. Find out how many meters of row length his field has. Let's say the crop rows are running the long way (i.e. 50 m).

Number of rows x 50 m = field's total row length

Number of rows = 40 m / 0.8 m

(i.e. the field's width)

(80 cm)

50 rows x 50 m = 2500 m of row length in Juan's field

3. Find out how much water will be needed to cover the 2500 m of row length based on 3 1 per each 150 m

150 m / 2500 m = 3 1 / X 1

150 X = 7500

X = 50 l of water needed to cover the field

4. Find out how much Malathion 50 percent liquid will be needed for the field based on 4 1 of the pesticide per hectare (10,000 sq. m). Since Juan's field measures 40 x 50m, its area is 2000 sq. m.

2000 sq. m / 10,000 sq. m = X 1 Malathion / 4 1 Malathion

X = 0.8 1 or 800 cc of Malathion needed

5. Find out how much Malathion is needed per sprayer tankful based on a capacity of 15 1.

50 1 of water needed / 15 1 tank capacity = 3.33 tankfuls needed

800 cc Malathion / 3.33 tankfuls = 240 cc of Malathion 50% liquid needed per sprayer tankful

Calibration of tractor sprayers

Things To Do Before Calibrating a Sprayer

- **Rinse out the tank and refill it with clean water.**

- **Remove and clean all nozzles and screens. Use an old toothbrush.**

- **Start the sprayer and flush the hoses and boom with plenty of clean water.**

- **Replace screens and nozzles and make sure that they are of the correct spray pattern type and size.**

- **Check all connections for leaks.**

- **Adjust the pressure regulator to the correct pressure with the tractor engine running at field operating speed and with the nozzles running.**

- **Check the water output of each nozzle and replace any that are 15 percent above or below the average. Remember to:**

- **Calibrate the sprayer using the same tractor speed and spray pressure that will be used to apply the pesticide.**

When using water to calibrate, the spray rate of the water may differ somewhat from that of the actual pesticide-water solution due to differences in density and viscosity,

Calibration Method

1. Drive the tractor at field operating speed in the appropriate gear and measure the distance covered in terms of meters per minute (1 k.p.h. = 16.7 m per minute)

2. Operate the sprayer at the correct pressure with the tractor stationary, and measure the total output of the spray boom in liters per minute. To do this, use a jar to measure the individual output of several nozzles, calculate the average, and then multiply this by the number of nozzles to get the total output.

3. Measure the width of coverage of the spray boom in meters. Do this by multiplying the number of nozzles on the boom by their spacing in centimeters and then divide by 100 to obtain the total width in meters.

4. Use this formula to determine how many liters of water are needed per hectare:

Liter/hectare = 10,000 x output of spray boom in l/m / tractor speed in m/mint x boom width in m

Once you know the volume of water needed per acre or hectare, you can determine how much pesticide needs to be added per tankful of water by using the same procedure as given for backpack sprayers.

Adjusting Sprayer Output

If the water output is too low or too high per hectare, change nozzle sizes or tractor speed. Changing the spraying pressure is relatively ineffective and may distort the spray pattern or cause excessive drift. Pressure must be increased four-fold in order to double output.

How to clean sprayers

In most cases, herbicide residues can be removed from sprayers by rinsing them out thoroughly with soap and water. However, the phenoxy herbicides (2,4-D, 24-5-%, MCPA, Tordon, etc.) cannot be removed with normal cleaning procedures, and contaminated sprayers may cause damage when used to apply pesticides to broadleaf crops. In fact, farmers should preferably use a separate sprayer for applying phenoxy herbicides, but reasonably good cleaning can be achieved as follows:

For backpack (knapsack sprayers: Fill the sprayer with water and add household

ammonia at the rate of about 20 cc (ml) per liter of tank capacity. Spray part of the mixture out through the nozzle, and then let the sprayer sit for a day. Spray out the rest of the solution and then rinse with detergent and water. To test the sprayer, refill it with water and spray a few sensitive plants (tomatoes, beans, cotton, etc.). If injury signs are not noticed within a day or two, the sprayer is probably safe to use on broadleaf crops.

NOTE: Household ammonia or lye may damage the inner pressure cylinder if it is made of brass; in this case, use activated charcoal as below.

For tractor sprayers: Use two pounds of washing soda or soda ash (a 50-50 mix of washing soda and lye) 250 grams per 100 liters in the same way as for backpack sprayers. Activated charcoal, if available, will do a very quick job in just two to three minutes when used at 1 kg per 100 liters. Rinse out the sprayer with soap and water afterwards.

Symptoms of phenoxy herbicide damage: Only broadleaf plants are affected. In minor cases, the leaves show a slight downward curvature. If injury is severe, leaves and stems become very curved and twisted with considerable leaf distortion.

All washing should be done at a site away from drinking water sources for people or livestock or water bodies that might be polluted by the washwater.

Appendix L - Important planting skill for extension workers

Most extension workers need five basic planting skills:

1. How to calibrate a planter.

2. How to calculate the probable final stand, given seed spacing and row width.

3. How to calculate the inrow seed spacing needed to provide a given population at various row widths.

4. How to determine the amount of seed needed for a given field size.

5. How to determine a farmer's actual plant population in the field Using a measuring tape.

Calculation of final stand

The calculation of the final stand is accomplished by the following formula:

Plant population/ha = [100,000,000 cm² /ha] / [seed spacing in the row in cm × row width in cm]

For example, if the row width is 40 cm and seeds are spaced 10 cm apart. the final stand, assuming 100 percent germination and no plant mortality, would have:

100,000,000 / 40 x 10 = 50,000 plants

Likewise if the crop is planted in hills the calculation made is:

Plant population/ha = [100,000,000 (cm²/ha) x number of seeds/hill] / row width (cm) x hill spacing (cm)

Thus planting in 50 cm width with 50 cm between hills and two seeds planted per hill yields:

100,000,000 x 2 / 50 x 50 = 80,000 plants/ha

The same formula can be used to calculate the in-row seed spacing needed to provide a

given population at various row widths. For example, if an optimal population of 100,000 plants/ha is desired, then:

100,000 plants/ha = 100,000,000 / [row seed width × seed spacing (cm)

or:

row width x seed spacing = 1000 cm²

This spacing can be achieved using:

10 cm seed-spacing in 100 cm row width,
20 cm seed-spacing in 50 cm row width,
15 cm seed-spacing in approx. 70 cm rows, etc.

Note again that the calculation does not account for losses due to poor germination or plant mortality. You may want to plant 15 or 20 percent more than the amount you wish to harvest in order to account for these probable losses.

How to determine amount of seed needed to plant a given field size

You first need to know how many seeds of each crop are contained in a kilogram. The most accurate way of calculating this is to weigh out a 60 g sample of the seed and count it if you can find a reliable scale (i.e. at the post office or at a pharmacy). Multiplying the number by 10 will give the number of seeds per kilogram. Ot wise, you can use the table below as a rough guide:

Table 15 Number of Seeds per Kilogram

Maize	1760-2860
Sorghum	26,400-44,000

Sorghum	26,400-44,000
Peanuts	1100-1540
Beans	3000-3960
Cowpeas	3960-4040

To find the kilograms of seed needed per hectare, simply divide the number of seeds needed by the number of seeds/kg. Multiplying this times the size of the field in hectares will give the total amount of seed required.

How to determine a farmer's actual plant population

When troubleshooting a farmer's field, it is usually valuable to check out his plant population, since this has an important influence on yield potential and response to fertilizer. This can be easily done by counting the plants in 510 randomly selected strips of row each equal to 1/1000th of a hectare.

Step 1: First determine the field's average row width by measuring the distance across 10 complete rows and then dividing by 10. Do this at several random locations to get a representative average.

Step 2: Refer to the 1/1000th hectare row length chart for the proper random selection procedure.

Step 3: Select at random five to ten row strips of the appropriate length and count the number of plants in each and record it.

Step 4: Multiply the average number of plants in the row strips by 1000 to yield the plant population per hectare.

How to Make A Pre-Harvest Yield Estimate

A pre-harvest yield estimate can be accurate to within 5 percent of the actual harvested yield if the correct procedure is used. When working with trial and demonstration plots, you should always take such a pre-harvest yield sample of both the test plot and the control plot. There is always the chance that the plots might be inadvertently harvested before the agreed-upon time without the yields being measured. Pre-harvest yield sampling is also a quick way of estimating crop yields in farmers' fields.

General Principles Of Yield Sampling

1. Samples should be collected at random for various portions of the field or plot. Do not purposely select samples from higher- or lower-producing areas within the plot or your estimate may be very inaccurate A random sampling pattern should be determined before you enter the field so you will not be tempted to choose them by visual appearance.
2. Don't collect yield samples more than one week before the actual harvest.
3. When taking each sample, the area (or row length) to be harvested must be precisely measured. Do not estimate' Remember that any error in the sample area size will be magnified hundreds of times when converting the yield to a larger land unit basis.
4. You must adjust the sample weights to account for factors like excess moisture, damage, and foreign matter.

How to Take Samples and Estimate Yields

1. The Sampling Procedure

> **a. Number of samples: For plots less than 0.5 ha, take a minimum of five samples. For plots of over 0.5 ha, take between five and ten. If crop growth is not very uniform, take ten samples.**

b. Size of each sample: Take each sample from the samesized area or same amount of row length. Individual sample size should be between 2.5 and 5.0 square meters. For row crops, the area of a sample is determined by multiplying row length by row width. (Harvesting three meters of corn row planted in rows one meter wide will give you a sampling area of three square meters.) Alternatively, use a section of row length equal to 1/1000th of a hectare. This will make later math calculations simpler, and the 1/1000 ha row length can be taken from the following table.

Row Width	1/1000th hectare Row Length
50 cm	20.00 m
60 cm	16.67 m
70 cm	14.28 m
75 cm	13.33 m
80 cm	12.50 m
90 cm	11.11 m
100 cm	10.00 m
110 cm	9.10 m

c. Taking a random sample: Decide on the sampling pattern before entering the field, and do not deviate from it. To randomize, the field can be divided up into sections and each section given a number drawn from a hat. Or you can pick randomized starting points at the side of the field and then enter random distances from the starting point. A good system for row crops is to number the rows and select them at random, then select the distance into the row (field) at random. NOTE: Exclude three meters or four rows of perimeter from your sampling area along all four sides of the plot to ensure sampling from the heart of the plot.

2. Accuracy: Use a tape to measure each sampling area or row length. Use an accurate scale to record the total weight of the samples within one plot.

3. Handling the Samples: The samples should be harvested and processed according to local prevailing methods. If drying is required before shelling or threshing, be sure the location is secure and free from rodents or birds.

4. Weighing the Sample: Use an accurate portable scale. You do not need to weigh individual samples separately, but only the fatal collective sample from the plot. If you cannot find a good portable scale, have the grain weighed in town.

5. Checking Grade: Take a random sample of the collective sample and have it checked for moisture content and any other graded qualities if necessary. (Refer to the storage section in Chapter 7 for how to determine grain moisture content.)

6. Yield Calculations:

Size of total sample area = No of samples × size of individual sample areas

$$\text{Estimated yield} = \text{weight of collective sample area} \cdot \frac{\text{total size of the plot}}{\text{total sample}}$$

7. Correcting for Moisture: Yields are usually based on grain that is dry enough to store in shelled form (usually 13-14 percent moisture content). If you base your estimates on the weight of a high moisture sample, you should revise the yield downward using this simple formula (otherwise, dry the grain first).

Grain weight after drying = [% dry matter before drying / % dry matter after drying] x original grain weight

Example: Suppose you weigh a collective sample of "wet" grain and then estimate the plot

yield to be equal to 3500 kg/ha. A moisture test shows the sample has 22 percent moisture; what is the actual yield based on 13 percent moisture?

22% moisture = 78% dry matter,
13% moisture = 87% dry matter

78% / 87% x 3500 kg/ha = 3138 kg/ha yield based on 13% moisture

A Yield Estimate Example

Suppose you are taking a yield estimate on a farmer's maize plot which is slightly less than 0.5 hectare. The rows are planted 90cm apart, and you decide to take six samples, each consisting of 1/1000th hectare of row length. The collective weight of the shelled, dried maize is 18 kg. What is the estimated yield on a per hectare basis?

Solution:

area of collected sample = 6/1000ths of a hectare = 60 sq. meters

18 kg x [10000 sq.m (1 hectare) / 60 sq. meters] = 3000 kg/ha estimated yield