GSC
BIA HANDOUT

BIA **VOLUNTEERS 2007**

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July '07 Edition of GSC BIA Handout Contributors:

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I BIA INTRO

Bio-Intensive Agriculture (BIA) is a kind of organic farming rooted in maintaining soil fertility/ living soil. BIA is called Bio-Intensive because it maintains a natural biological balance between soil, nutrients and plants. It employs crop rotation and intensive planting to maximize harvest levels while protecting the natural soil health and the local environment.

In much of Tanzania, farmers don't have the money to use pesticides and fertilizers. However in wealthier areas like the Arumeru district, which includes Arusha, farmers use chemicals heavily with few regulations or precautions. Even in areas where farmers don't use chemicals there is a need for BIA training, as farmers are struggling with nutrient-deficient soil.

Important aspects of BIA include:

- ◊ Composting
- ◊ Double-dug, raised beds
- ◊ Intensive planting
- ◊ Carbon and calorie farming
- ◊ The use of open–pollinated seeds

The three core activities are: ***Composting,*** to restore nutrients to the soil, ***Double-digging*** to break up the hard pan, several centimeters below the surface, which impedes the flow of air and water and the penetration of roots, and ***Companion Planting / Crop Rotation***, which provide a mix of plants, encouraging growth, deterring pests and diseases, and conserving soil and space. The combination of these activities enables plants to access nutrients locked deep in the soil.

Double digging has been practiced by at least 2 main groups of people over time; market gardeners of France, and farmer groups in China. The French and Chinese growers worked in areas of high population density with little available land. Both groups developed double digging as a way to maximize their yield from a small area. This intensive method has been revived in the United States recently, notably at the University of California at Santa Cruz and with John Jeavons' organization, Ecology Action.

BIA brings bigger harvests in smaller amounts of space, with a marginal use of resources. Vegetables are healthier to eat, and the costs of production are less. Money not spent on chemicals can instead be spent on other things; like children's education.

photo of kids in the demo plot

In addition to compost and double-digging, BIA employs a number of methods known to traditional farmers but neglected in recent years, such as:

- ◊ Crop rotation: relieves mineral drain on the soil
- ◊ Companion Planting: discourages pests / improves soil cover
- ◊ Liquid manure: made as a top dressing
- ◊ Beneficial plants: lure away or deter pests from crops
- ◊ Natural pesticide sprays: made of plants, weeds and herbs
- ◊ Raised beds: allow closer spacing of crops
- ◊ Water harvesting: retains water during the dry season
- ◊ Planting leguminous shrubs and trees (Agro-forestry): adds nitrogen to the soil / provides fodder, fuel wood and fence posts

Why should we encourage Bio-Intensive instead of using chemicals?

Chemicals don't feed the soil, but provide a treatment like "medicine" for the plants or animal so that it can survive in poor soils.

Bio-Intensive farming on the other hand, restores the soil in order to feed the crops and restore their natural disease/pest resistance. Compost multiplies soil's ability to absorb water, and adds a range of nutrients and microorganisms. Careful transplanting also helps to promote uninterrupted root growth and encourages vigorous, healthy plants. The right amount of water throughout the plants' growing period also reduces the likelihood of stress.

Dangers of Chemicals:

- ◊ Chemicals can poison water sources and the soil
- ◊ Have residual effects that can accumulate in the human bodies causing disease
- ◊ Are indiscriminant, killing beneficial insects, worms and microorganisms either directly or by their effects on environment
- ◊ Create waste by leaching or by the formation of insoluble compounds
- ◊ Are expensive, and use up resources, such as fuel, to make
- ◊ Can be toxic, especially to children, the elderly and the ill, i.e. HIV+
- ◊ Require special training so as not to get poisoned or burnt-
    - o instructions in Tanzania are often lost, ignored, or misunderstood
- ◊ Become less effective over time as insects and disease develop resistance
- ◊ Give crops overdoses, not exact requirements
- ◊ Flood vegetables and water supplies with excess nitrate[1]

It is sometimes claimed that because compost contains a lower percentage of the necessary minerals, phosphorus and potassium, which are often deficient in soil, it is second-rate. This misses the point. BIA techniques are not designed to add minerals; they are adding food for the microbes who will release the minerals needed.

[1] With BIA, plants' cell walls are thick and the sap in the cells is correctly balanced. If plant cells contain excess nitrate, on the other hand, they become attractive to sucking insects. Spraying them with pesticide makes their walls weaker still, so they become prey to disease there is then a vicious cycle more fertilizer, more pests, more biocide, more cost, poor soil, lower yield.

II. GARDEN PLANNING

While our main focus is on growing healthy soil, an additional goal is to make a garden **reflect nature's diversity**. Even weeds have a role to play. Beginning gardeners are often inclined to worry about getting rid of insects and weeds. It is much more enjoyable to think of insects and weeds as part of nature's contribution to a diverse ecosystem. The information and charts of companion planting, crop rotation, beneficials and record keeping in the following chapters help to fully plan a BIA garden while managing pest and disease issues. Here for now are some early considerations in your planning your garden:

Considerations when mapping out your garden:

- ◊ Size of land available- number of beds, nurseries, and compost piles you can build- beds are ideally 1.5 meters wide. The length is whatever you wish, though 20 meters is ideal for planning harvests. Nurseries are ideally 4 by 10 to 20 feet, and compost piles are ideally 1.5 by 1.5 meters
- ◊ Location and abundance of water supply- a garden close to the water supply is ideal
- ◊ Shade and sun availability
    - Shade is useful to protect sun sensitive crops, nurseries, and compost piles, but be careful not to plan near crop-unfriendly trees such as eucalyptus and avocado[2]
    - It is easy to forget that tiny seedlings can turn into tall plants. Crops such as corn can be put where they will shade a plant that enjoys less sun, like peas or potatoes or cucumbers. Sun-loving tomatoes can provide a cooler mini-climate for onions or parsley. Cool weather crops, like lettuce, carrots, onions and potatoes will do well in partial shade in warmer weather.
- ◊ Growing seasons, and which crops grow well in each
- ◊ PH of your soil, and which crops grow well in it
- ◊ Animal pests like chickens, goats, monkeys or dogs, to address
- ◊ Goals of this garden, for example:
    - Nutrition
    - Income
    - Training

  -what portion of the garden will you devote for each?

The sustainable BIA garden includes a ratio of compost, calorie, and nutrition crops:

- ◊ Grain and seed crops, to provide green material for compost
- ◊ root crops, to provide calorie rich food sources
- ◊ fruits and vegetables like dark leafy greens, to provide vitamin and mineral rich food sources

Jeavons, in *Grow More Vegetables*, suggests 60% grain and seed, 30% root, and 10% vitamin rich vegetable crops. Planting a winter compost crop that includes both grains, with their extensive root systems, and legumes, is a way to plan for your compost while feeding yourself and the soil at the same time (legumes, with their nitrogen fixing ability, feed the soil).

Planning a day in your garden:

It's good, first thing each morning, to get an overview of your garden. Stroll through your garden from end to end; you'll see your compost supply, nurseries, how are your beds are doing, what plants look under- hydrated, which beds, pathways, or compost piles need weeding, any disease or pest problems, crops ready to harvest, and so forth. Check for garden pests and insects like snails, slugs and grasshoppers. Killing them and dropping them on the garden beds will make a smell to frighten away other pests. Keep a close eye on any new transplants. Some may have died off, and need quick replacement. You may see beds ready for planting, or which need gaps filled in. Once you've been through the entire garden you will know what is most urgent, and can map out a plan for the day.

[2] these trees secrete acids that are toxic to other plants and microbial life

III. COMPOST

Compost is made of carbon crops/weeds and other materials found naturally on a mixed farm. A sustainable garden grows plenty of carbon crops whose waste (ie. corn stalks) will regenerate into the compost. Some farmers grow a bed of particularly rich crops, just for compost.

Advantages of Compost:

- ◊ **Soil Structure:** Bacteria that feed on organic matter temporarily hold the soil together, improving the health and structure of the soil
- ◊ **Water Absorption:** Compost **holds *6 times* its weight in water-** the addition of compost to the soil cuts water consumption by as much as **75% per pound** of food produced
- ◊ **Soil Health:** Improved soil structure increases workability and resistance to erosion
- ◊ **Increases Nutrition of Crops:** Organic acids in compost help dissolve minerals in the soil, making mineral nutrients more available to crops - more nutritious soil = more nutritious food
- ◊ **Increases Water and Nutrient Uptake of Roots:** Organic acids also increase the permeability of root membranes, increasing the uptake of water and nutrients by roots
- ◊ **Disease and Pest Resistance:** Well nourished and hydrated crops naturally resist pests and disease
- ◊ **Free:** all materials needed to successfully 'grow' compost are readily available on most small farms- compost is reliable and essentially free of cost

Materials for Building Compost:

1. Course materials- sticks, twigs, maize stalks, etc , to lay a foundation and provide drainage
2. Browns - dry grass, leaves, weeds, hay, etc. that have already been breaking down for a while
3. Greens - recently cut weeds, tree leaves, green plant materials, etc.- also kitchen scraps
4. Wood ash
5. Manure or slurry from bio-gas pit. Quality of animal manure, richest to least rich, is as follows: chicken, pig or rabbit, sheep or goat, horse, cattle. Use the best manure you can find, but any type will do
6. Top soil
7. Water

The important thing is to build your compost pile as the materials become available, without worrying too much about the details at the beginning. As you practice making compost and your garden produces more and more material for you to use, you will improve your technique.

The three critical elements in building compost are:
1. Have **enough air** in the pile
2. Use as **many different compost materials** as you can
3. Keep the compost **moist enough**

Materials NOT to add to a Compost Pile:

- ◊ Plants infected with a disease or a severe insect attack where eggs could be preserved or where the insects themselves could survive in spite of the compost pile's heat
- ◊ Poisonous plants, such as oleander, hemlock, or castor bean
- ◊ Plants which have acids that are toxic to other plants and microbial life such as acacia, juniper, and eucalyptus
- ◊ Plants that may be too acidic (However, special compost piles can be created using acidic materials to raise the pH level in soils that do not have enough acid.)
- ◊ Invasive weeds such as wild morning glory, couch grass, bermuda grass, and/or black jack - these weeds may not breakdown in the pile and then when you spread the compost on your soil, you may be spreading their seeds as well
- ◊ Manure from cats and dogs, both of which contain pathogens and are toxic

Building a Compost Pile:

Preparing the land:

1. Select a shady place, not far from the garden and water source
   -if no natural shade, build a shelter or cover with mulch, burlap, etc to protect from the sun
2. Measure area- **1.5 by 1.5 meters is ideal** - if pile is smaller it won't generate enough heat to for good decomposition - very big piles take longer to decompose
3. Clear leaves, weeds and other debris until you can see the soil
4. Loosen soil 12 inches deep using a fork or jembe, for water absorption

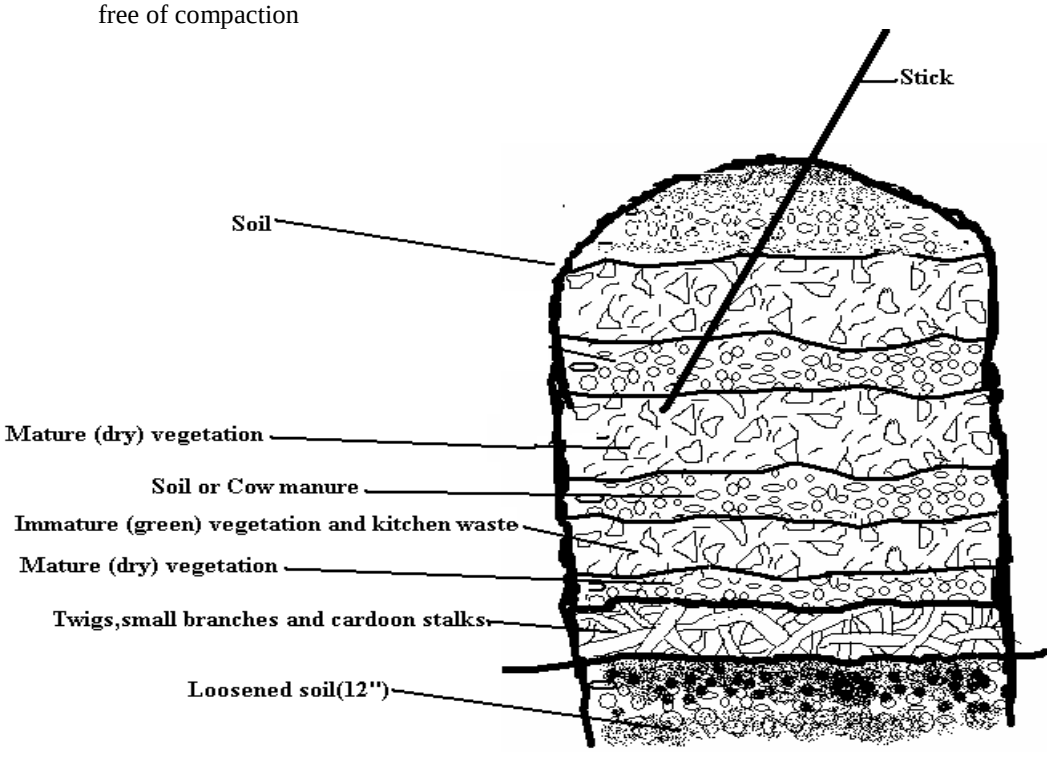
Building the Pile:

Chop materials into small pieces, to facilitate decomposition

1. Lay course materials 5 -10 cm high
2. Lay browns 5 – 10 cm high.
3. Add green materials and food scraps 5 – 10 cm high.
4. Sprinkle wood ash about 1 – 1 ½ kg
5. Add manure about 2-3 cm high
6. Add top soil 2-3 cm high.
7. Water the pile with 20 liters or more -enough water to dampen, not soak, the pile
   -pile should be like a sponge that has been squeezed
8. Repeat steps 1 - 7 until pile reaches a height of 3-5 ft. (1-1.5 meters)

Protecting and Monitoring the Pile:

1. Cover the top of the pile with extra soil to maintain the moisture in the pile. A light layer of straw on top of the soil during the rainy season keeps out excess moisture and prevents the pile from becoming soggy
2. Put a stick of about 2 ½ m in the middle of the pile to act as a thermometer - when the end of the indicator is too hot to touch then the compost is cooking correctly; when it starts to cool the decomposition process has slowed, so this is the right time for turning the pile
3. Water the pile as needed to keep it moist - check the moisture in the middle of the pile from time to time—it is easy to either underwater or over water the pile
4. Once you've got your compost pile don't sit on it - the pile needs to breathe and aerate well, so must be free of compaction



(This picture shows compost building, though it lacks the wood ash and top-soil layers.)

Turning the Pile:

The pile can be turned after two to three weeks. No new material should be added during turning except water or top soil. Turning speeds up decomposition.

The purpose of turning is to ensure even decomposition of a pile. In turning, make sure the top becomes the bottom of the pile and the inside becomes the outside. This is because the decomposition at the bottom and outside goes slower then at the top and inside.

A good tool to use is a pitchfork, since it is lighter than a spading fork and is shaped to allow easy turning of the material. Start by loosening the soil in an area about one half to two thirds the original area (since the pile has shrunk), and add a layer of rough materials at the bottom. Move the materials from the original pile to the new pile, bringing the drier materials to the inside. Add water as you go, if necessary, to be sure that the turned pile is evenly moist.

Storage:

Once the pile you have built has completely broken down, you will be left with compost that looks like loose, dark, rich soil. Now you simply spread a thin layer of it on your crops and everything will be healthier. If not immediately used, cured compost must be stored properly to avoid continued decomposition. Continued decomposition will lead to a pile that is devoid of nutrients.

To Store:

1. Spread the cured compost pile out to about three inches thick; let the pile dry for two days.
2. Bag the dried compost (compost won't be completely dry) or repile and store in a shaded, protected place. Stored compost will stay for one year.

Using Your Compost:

The best time to put compost in your growing beds is in the spring, just before transplanting the seedlings for the major growing season. As a general rule, you can spread ½ inch of cured compost over the surface of the bed. This comes to approximately six 5-gallon buckets per 100-square-foot bed. Then work it evenly into the top 2 inches of the soil. One application of compost per 4-month growing season is adequate.

Records:

To keep track of your compost piles you can use a simple chart like the following:

COMPOST RECORDS

Pile #	Date Constructed	Date Turned	Date Spread Out	Date Stored	Amount Stored
1					
2					
3					
4					
5					
6					
7					

IV. WATERING

- Joshua Machinga

picture of yusufu watering

Water is very important for both soil and crops. Water is a cooling agent, carries nutrients in solution in the soil, and keeps plants turgid and erect.

The retention of water in soil depends on:

- ◊ Soil type
- ◊ Structure and texture of soil
- ◊ Climate and air temperature
- ◊ Humidity and wind characteristics
- ◊ Plants themselves

BIA's emphasis on healthy soil should not be overlooked when examining your beds' capacity to absorb and retain moisture to the benefit of the plants. The deep soil preparation and the addition of good compost allow the soil to hold its moisture longer. Compost has a sponge-like ability to retain water. Other aspects of the Bio-Intensive method further increase water efficiency. Due to the living mulch of Bio-Intensive spacing, evaporation can be reduced by 13%-63%. Since a high level of soil fertility is maintained, transpiration by a plant can be reduced by 10%-75%. We should all know that plants lacking nutrients use more water to try to get the necessary elements.

Water your garden approximately 2 hours before sunset, when water has over half a day to sink down to the root zone before the hot sun appears again. This saves considerable water otherwise lost to evaporation. The water is available and percolates into the soil the whole night, which is critical since plants do a significant amount of their growing at night.

Immature plants and seedlings in flats may have to be watered in the morning and again in the afternoon if there will be sun the whole day. As the living mulch effect develops due to their leaves growing close together, less water will be required.

When watering a new bed, the shiny layer should stay for 2-3 seconds. On older beds it will stay for 5-15 seconds. If the shiny layer disappears sooner, continue watering. If the water is not being absorbed well at all, it may be that the bed is so dry that it is acting like a barrier to the water. Try to wet the soil under the surface to allow water to be absorbed.

It is wise to check the soil moisture before starting to water, to determine at what depth the soil is moist and how much water is needed. A soil can look very dry and be wet just under the surface, or appear damp when it is very dry. Also check how deeply water is going into the soil when you irrigate.

Climate considerations that indicate the amount of watering that will be needed are:

- ◊ rainfall
  - amount per day
  - distribution per day
  - intensity per hour
- ◊ temperature- mean monthly and extremes
- ◊ evaporation rate

Points to remember when watering:

- ◊ Different stages of a plant's growth require different amounts of moisture
- ◊ Being near to the soil surface **small seeds** dry out easily. Water them well but carefully- too much water or pressure can wash them right off the bed
- ◊ Carelessness with a watering-can or hose can break stems, damage leaves, remove flowers, and bruise fruits - be gentle
- ◊ Pay attention to a bed's corners and edges as they dry out easier
- ◊ Frequent, light watering encourages roots to grow near the soil surface making them prone to drying out and less capable of surviving drought conditions - it also reduces a plants ability to absorb minerals from deep in the soil
- ◊ **Does a plant wilting mean its time to water?** Midday wilting on a hot day is normal for most plants. They lose water through transpiration quicker than their roots can pull it from the soil, and will usually recover overnight - if they are wilting in the morning they should be given water quickly
- ◊ Salty conditions interfere with a plants ability to absorb water because the mineral competes for available moisture
- ◊ Be careful of using large amounts of poultry or feedlot manure. Both of these are mixed with urine which has a high salt content. Certain crops are more tolerant of salty conditions. These are **beets, spinach, lettuce, broccoli, and tomatoes.** The salt sensitive crops are **beans, carrots, onions** and **radishes**
- ◊ Potassium affects the rate of a plant's water retention by regulating the opening and closing of its stomata. Thus the availability of this major nutrient determines how rapidly photosynthesis takes place
- ◊ **Fruiting crops and crops in the tomato family, ie. tomatoes and eggplant, dislike overhead watering.** For this same reason they are bad crops for rainy season - they need their soil, but not their leaves and fruit, to be watered
- ◊ Letting your spray of water travel high through the air before hitting the crops oxygenates the water, to the benefit of your plants

Under- and Over-watering:

Under-watering:

- ◊ Slows down photosynthesis, reducing amount of food manufactured by a plant
- ◊ Harmful wilting
- ◊ Prevents adequate transport of nutrients

Over-watering:

- ◊ Compacts soil / can suffocate roots
- ◊ Creates environment for damping off
- ◊ Prevents proper transport of nutrients, interfering with plant growth
- ◊ Leaches nutrients from soil

Both under-watering and over-watering weaken plants by making them more vulnerable to insect infestation, and less resistant to disease and harsh environmental conditions.

TERMS USED:

Soil Pore space*: portion occupied by air and water. In sandy soil pore spaces are large, and in clay soils pore spaces are numerous and smaller.*

Soil Texture*: different sized particles a soil has in it. There are stones, gravel, sand, and silt and clay particles. The water holding capacity of a soil depends largely on its texture –the amount of sand, silt and clay in the soil.*

Soil Structure: *grouping together of the particles in a soil into larger pieces or granules. The structure has a large influence on the retention and release of water.*

*The addition of **organic matter** to your soil will significantly improve its water holding and drainage capacity; compost is the best material for this.*
***Capillary water**: water held in between soil particles.*
***Gravity water:** percolates through soil under the force of gravity.*
***Infiltration:** rate at which water moves into the soil, measured in millimeters per hour.*
***Field Capacity:** moisture holding capacity of the soil after gravity water has been removed. Water added beyond field capacity will not be held in the soil's pore spaces. The field capacity of light soils is les than that of heavy soils. Light soils need much light irrigation, and heavy soils can take fewer, heavier waterings.*
***Permanent Wilting Point:** level of moisture at which plants are not able to extract any more water and from which they do not recover but wilt and die. Structure, texture and organic material affect the permanent wilting point.*
***Plant Root Zones:** (deep rooted or shallow rooted plants) determine the frequency and the amount of watering required. Deep rooted plants need heavy, infrequent watering. Shallow rooted plants want light, shallow watering frequently. Plants make most use of water from the upper area of their root zones.*
***Evaporation** is high in initial plant growth. As the plant matures its larger leaves shade the soil. Transpiration is a larger factor of water loss than evaporation.*
*The **Hydrologic Cycle:** movement of water from the earth's surface and back.*

V. COMPANION PLANTING, CROP ROTATION, AND BENEFICIALS

Companion planting, crop rotation, and the use of beneficials are ways in which you can plant crops to naturally deter pests and disease, conserve soil and space, and maintain long-term soil health. With this information you can plan out your garden.

COMPANION PLANTING:

As in human relationships plants have the habit of liking and disliking each other. For plants, this is due to their root excretions, scents, and flowers. The four main benefits of companion planting are:

1. Stronger plants
2. Insect deterrence
3. Soil conservation
4. Space conservation

Stronger Plants and Insect Deterrence:

Each plant releases different chemicals into the soil, which can either encourage or discourage the growth of particular other plants. Plants whose chemicals encourage each other's growth are called 'companion plants'. Plants whose chemicals discourage each other's growth are antagonists. This is why it is important to plant vegetables next to one another that will help both to grow stronger. As the plants are strengthened they are less susceptible to pest and disease.
Insects can more easily attack a field of one type of crop than one that has many different types. Therefore, variety in each bed is a type of natural protection. Crop variation is important because your crops will be less susceptible to large disastrous invasions by a pest.

A List of Common Vegetables, Their Companions and Antagonists:

	Companions	Antagonists
Asparagus	Tomatoes, Parsley, Basil	
Beans	Almost all vegetables	Onions, Garlic
Beets	Onions	Some Beans
Cabbage Family (Cabbage, Cauliflower, Kale, Nightshade, Broccoli)	Aromatic herbs, Potatoes, Dill, Sage, Mint, Rosemary, Beets, Onions	Strawberries, Tomatoes, some Beans
Carrots	Peas, Lettuce, Chives, Onions, Leeks, Rosemary,	Dill

	Sage, Tomatoes	
Chives	Carrots	Peas, Beans
Corn	Potatoes, Peas, Beans, Pumpkin	Cauliflower, Cabbage
Cucumbers	Beans, Corn, Peas, Radishes, Sunflowers	Potatoes, aromatic herbs
Eggplant	Beans	
Leeks	Onions, Carrots	
Lettuce	Carrots (very good with Lettuce and Radishes), Strawberries, Cucumbers	
Onions (and garlic)	Beets, Strawberries, Tomatoes, Lettuce, Parsley	Peas, Beans
Parsley	Tomatoes, Asparagus	
Peas	Most vegetables	Onions, Garlic, Potatoes
Potatoes	Beans, Corn, Cabbage, Horseradish, Marigolds, Eggplant	Pumpkins, Squash, Cucumbers, Sunflowers, Tomatoes,
Pumpkins	Corn	Potatoes
Radishes	Peas, Nasturtiums, Lettuce, Cucumbers	
Soybeans	Grows with anything	
Spinach	Strawberries	
Squash	Nasturtiums, Corn	
Strawberries	Beans, Spinach, Lettuce	Cabbage
Tomatoes	Chives, Onions, Parsley, Asparagus, Marigolds, Nasturtiums, Carrots	Potatoes, Fennel, Cabbage

Soil Conservation:

Soil conservation is achieved by what we call 'living mulch'. The companion plants grow so close together as to create the protective qualities that mulching can provide.

1. Since the plants are placed as close to one another as possible without interfering with each other's growth, the soil structure will be stronger and therefore more resistant to erosion
2. As your plants grow larger they will block potentially harmful rains from eroding the top layer of soil
3. Your soil will retain more water because it will be shaded more by the leaves and will not dry out as much. Because the soil stays moist it is better able to receive water without having run-off
4. Weeds will have less area to grow, and it will be more difficult for them to grow with a lack of sunlight

It is important to realize that the plants will not be able to serve this function in the early stages of growth. So, organic mulch can be used to temporarily serve the same purpose as what the living mulch will eventually be able to do. Things that can be used for mulch are any natural browns, examples are: dried leaves dried banana leaves, hay, corn husks, etc. Once the plants do become big enough to work as living mulch, the two types of mulch can work together to achieve maximum health.

Space Conservation:

Rather than planting vegetables in rows, we plant so that each plant is the same distance from the next in the diagonal offset pattern shown below. When this is done more plants can be grown than by planting in rows.

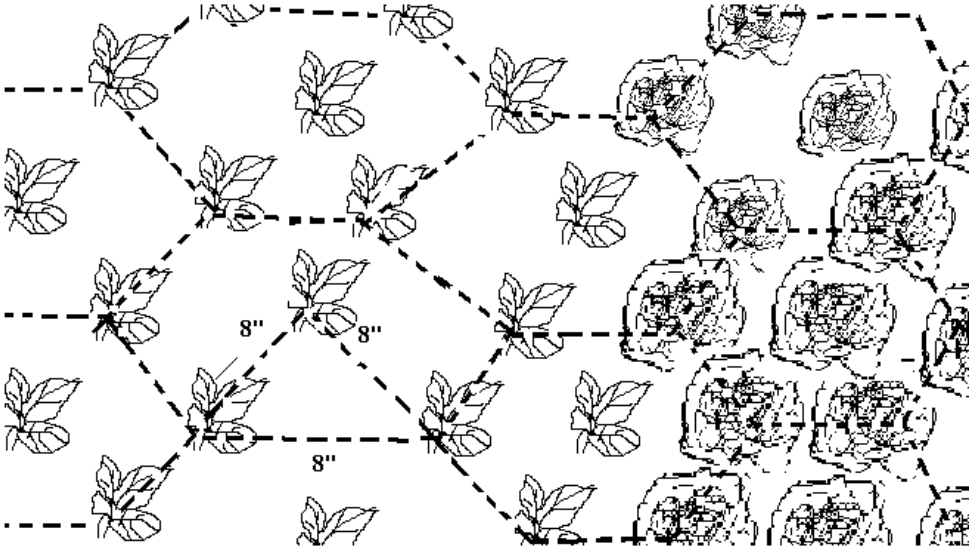


Figure 1: Hexagonal spacing-Leaf lettuce is spaced on 8'' centers

***Common Plants, HF, LF, HG, and Plant Spacing*:**

Plant	Distance (Spacing)	HG, HF, or LF
African Eggplant	60cm	HF
Amaranth (for greens)	15cm	HF
Asparagus	30 cm	HF
Basil	15cm	HF
Beans	17cm	HG
Beets	10cm	LF
Broccoli	35cm	HF
Chin. Cabbage	25cm	HF
Cabbage	35cm	HF
Carrots	7cm	LF
Comfrey, Russian	30cm	HF
Cauliflower	35cm	HF
Swiss Chard	20cm	HF
Collards	28cm	HF
Corn	40cm	HF
Cucumbers	25cm	HF
Eggplant	44cm	HF
Garlic	10cm	LF
Horseradish	28cm	LF
Kale	35cm	HF
Leeks	15cm	LF
Lettuce, Head	30cm	HF
Lettuce , Leaf	22cm	HF
Mustard	15cm	HF
Nightshade	20cm	HF
Okra	15cm	HF
Onions	10cm	LF
Parsley	10cm	HF
Peas	10cm	HG
Peppers, Hot	30cm	HF

Peppers, Sweet	30cm	HF
Potato, Irish	22cm (15cm depth)	LF
Potato, Sweet	22cm (15cm depth)	LF
Pumpkin	50cm	HF
Radishes	5cm	LF
Shallots	10cm	HF
Soybeans	15cm	HG
Spinach	15cm	HF
Strawberries	30cm	HF
Swiss Chard	20cm	HF
Sunflower	45cm	HF
Tomatoes	40cm	HF
Tomatoes, Cherry	40cm	HF
Turnips	10cm	LF
Watermelon	50cm	HF
Zucchini	45cm	HF

CROP ROTATION

For a number of reasons, it is good not to plant the same crop in the same plot year after year. Different plants take different nutrients and different quantities of nutrients out of the soil. Planting the same crop on the same land in succession creates soil nutrient deficiencies and also encourages insect and disease problems. The two main benefits of crop rotation are:

1. Preservation of nutrients in the soil
2. Insect deterrence

Nutrient Preservation in the Soil:

Different plants interact in different ways with the nutrients in the soil. Some take a small amount of nutrients and are called Light Feeders (LF); some take a large amount of nutrients from the soil and these are called Heavy Feeders (HF), and some plants give nutrients back to soil and they are called Heavy Givers (HG). One can't expect to have healthy soil over time if a Heavy Feeder is planted year after year into the same soil. Crops need to be rotated so that the soil doesn't become depleted of nutrients. Every one or two seasons the crops that you have been planting in one area should be changed. (Refer to the charts on the following pages that label each plant as LF, HF, or HG). Light feeders can follow both heavy feeders and heavy givers, but never plant two heavy feeders or two heavy givers in two consecutive seasons.

1. Heavy Feeders: These take large amounts of nutrients, especially nitrogen, from the soil
2. Heavy Givers: These bring large amounts of nitrogen into the soil and excrete substances, which help eradicate wilt-causing organisms
3. Light Feeders: These take small amounts of nutrients from the soil

Insect Deterrence:

Crop rotation alternates crops from one season to the next in a given field. This takes advantage of the fact that most pests are limited to feeding on one kind of crop. When the crop changes, the pests lose their host, and do not survive. This is why normally the same vegetable should not be put in the same bed each season -this invites diseases. Crop rotation is a natural way to break the pests' feeding cycle.

List of common vegetables organized according to crop rotation and companion planting guidelines:

HEAVY GIVERS:	Companions	Antagonists
Beans	Potatoes, Carrots, Cucumbers, Cabbage	Onions
Bush beans	Potatoes, Cucumbers, Maize, Lettuce, Tomatoes	Onions
Peas	Carrots, Cucumbers, Beans, Maize	Onions, Potatoes
Soybeans	Grows with anything and helps with anything	

HEAVY FEEDERS:	Companions	Antagonists
Cabbage family	Aromatic Plants, Potatoes, Tomatoes Dill, Rosemary	
Maize	Potatoes, Peas, Beans, Cucumbers, Pumpkins	
Potatoes	Beans, Maize, Cabbage, Marigolds	Pumpkins, Cucumbers, Sunflowers, Tomatoes, Potatoes
Pumpkins	Maize	Potatoes
Tomatoes	Chives, Onions, Carrots, Marigolds	Potatoes, Fennel, Cabbage

LIGHT FEEDERS:	Companions	Antagonists
Carrots	Peas, Lettuce, Chives, Onions, Leeks, Rosemary, Tomatoes	Dill
Chives	Carrots	Peas, Beans
Cucumbers	Beans, Corn, Peas, Sunflowers	Potatoes, Aromatic Herbs
Leeks	Onions, Carrots	
Lettuce	Carrots, Cucumbers	
Onions	Beets, Tomatoes, Lettuce	Peas, Beans

PLANT FAMILIES

It is helpful if you understand Heavy Feeders, Light Feeders, and Heavy Givers according to the 'plant families'. Check how the plant families below fit into the HF, LF, and HG charts above.

1. SOLANUMS
    a. Tomatoes
    b. Egg plants
    c. Irish potatoes
    d. Peppers
    e. Solanum nigrum

2. LEGUMES
    a. Common peas
    b. Peas
    c. Ground nuts
    d. Green and black grams
    e. Cowpeas
    f. Soya beans
    g. Lab beans
    h. Winged beans
    i. Other lesser beans

3. GRAMINACEA
    a. Maize
    b. Sorghum
    c. Sugar cane
    d. Rice
    e. Oats
    f. Finger millet
    g. Bulrush millet

h. Wheat
i. Barley

4. CHENOPODIUM
    a. Spinach (S. Oleracea)
    b. Beets (Beta Vulgaris)
    c. Swiss chard

5. ALLIUMS
    a. Onion (spring, bunch, bulbs)
    b. Leeks
    c. Garlic
    d. Chives

6. UMBELLIFERAE (UMBELS OR PARSELY FAMILY)
    a. Carrots
    b. Several herbs
        1. Coriander-coriandum sativum
        2. Parseley-petroselinum srispum
        3. Caraway-carum
        4. Pimpinella-anise anisum
        5. Foeniculum-fennel vulgare
        6. Anetum graveoleus-dill

7. CUCURBITS
    a. Cucurbita-Pumpkin, Squash, Gourds
    b. Cucumis melo-Musk melon, Melous, Cantaloupe, Cucumbers and Water melons
       Chayote (Sechilim edule)

BENEFICIALS:

The following are herbs and flowers that can be included into your garden to deter insects and strengthen soil. Some deter pests, while others attract helpful insects, or lure birds and pests away from the crops. Bees and butterflies play an important part in the life cycle of plants, so a garden will benefit if it includes their favorite meals. Bees love blue flowers, especially borage and rosemary. Butterflies are attracted to purple, red, yellow, and orange flowers and will beautify our garden as well.

Other beneficial insects are attracted to the flowers of parsley, dill and cilantro/coriander. Try letting a few of those plants go to seed to serve as feeding stations for helpful insects. The perennials are best planted at the end of the beds where they will not get in the way of double digging. Another good idea is to plant beneficials like lemon grass and marigolds around the borders of your garden.

Benefits of Beneficials:

- ◊ Beneficials are usually flowers or herbs that give you a natural way to make your plants more resistant to insects and to make your garden look nice at the same time
- ◊ Some beneficials attract "good" insects that eat the "bad" ones: predator vs. prey. Instead of killing all the insects with pesticides, these beneficials allow good insects to help your plants
- ◊ Some beneficials attract insects to themselves, luring the potential pests away from crops
- ◊ Finally, some beneficials deter pests away from the garden altogether

Common Beneficials:

Basil	Companion to tomatoes dislikes rue intensely - improves growth and flavor. Repels flies and mosquitoes
Chives	Companion to carrots; improves growth and flavor
Dill	Companion to cabbage; dislikes carrots; improves growth and health of cabbage
Fennel	Plant away from gardens - most plants dislike it
Garlic	Deters beetles and birds
Hyssop	Deters cabbage moth; companion to cabbage
Marigolds	The workhorse of the pest deterrents - plant throughout garden - discourages many insects including beetles and nematodes
Mint	Companion to cabbage, and tomatoes; improves health and flavor; deters white cabbage moth
Nasturtium	Companion to radishes and cabbage - plant under fruit trees - deters aphids, squash bugs, stripped pumpkin beetle. Improves growth and flavor
Petunia	Protects beans
Horseradish	Plant at corners of potato patch to deter potato bug
Calendula	Companion to tomatoes, but plant elsewhere in the garden too - deters asparagus beetle, tomato worm, and general garden pests
Rosemary	Companion to tomatoes, cabbage, beans, carrots, and sage, but plant elsewhere in garden too - deters cabbage moth, bean beetles, asparagus beetles, and carrot fly
Sage	Plant with rosemary, cabbage, and carrots; keep away from cucumbers deters cabbage moth, carrot fly
Tarragon	Good throughout garden
Morning Glory	Allow to grow in corn - mosquito repellant
Thyme:	Plant here and there in the garden - deters cabbage worms

VI. RECORD KEEPING

-Daphne Jochnick

There is a lot to keep track of in a BIA garden. In addition to companion planting, crop rotation and beneficials, there are other considerations which require good garden records. Garden records enable the gardener to know when to begin the nursery process to have seedlings ready to plant in beds in coordination with harvest schedules. Records can chart insect and disease issues, what solution was applied, and how successfully. Records chart the balance of nutrition, income, and compost crops in the garden. At a basic level, the dates of bed construction and amount of compost used, and when, are kept in the records, so that a gardener knows when to re-dig, and also how well crops do with different amounts of compost.

If a garden is supplying for market, records enable a gardener to chart the profitability of each crop. Records also enable the gardener to plan a rotation schedule using different beds in order to consistently supply a marketed vegetable, tracking it's harvest date in each bed, so that one bed completes harvest when another is entering harvest. Alternatively if marketing as a group, records enable farmers to coordinate their gardens, knowing when crops will come to harvest in one garden, and planning for another garden to harvest when the first is finishing. The charts below are sample record sheets that we've found useful in the GSC demo-plot in Tengeru, Tanzania. Sample charts are also provided at the end of the 'Compost' and 'Preparation of the Nurseries' chapters.

UTUNZAJI WA KUMBUKUMBU ZA TUTA/**CROP RECORDS FOR BED #_____**
Tarehe Ya Kuchimba/**Date of Construction:** Ukubwa Wa Tuta/ **Size of Bed:**
Kiasi Cha Mboji/ **Amount of Compost Used**:
Tarehe na Kiasi Cha Mboji/ **Dates and Amounts of Compost Added:**

Up to 3 companion plants tracked in the bed: ZAO/ **Crop 1** ZAO/ **Crop 2** ZAO/ **Crop 3**

Jami Ya Zao **Crop Category (HF, LF, HG)**			
Tarehe Ya Kuoteshe **Planting Date**			
Tarehe Ya Kuvuna **Expected Dates of Harvest**			
Zao Litakalopandwa Wakatujayo, na tarehe **Next Crop Planned, and Date**			
Tarehe yakupanda zao lingine kwenye kitalu (kama ni miche) **Date Next Crop to be Planted in Nursery -if seedling**			
Kusudio -Pato/ Kutumia/Mboji **Intention:** **Income?Consume?Compost?**			
Tarahe Ya Mavuno **Dates of harvest**			
Kiasi Kilichouzwa na kwa bei gani- Jumla Ya Pato **How much Sold, Price- Total Income**			
Kiasi kilichotumika kwa chakula **Amount Consumed**			
Gharama Ya Mbegu/ Miche **Cost of Seedlings**			
Faida Iliyopatikana/ **Net Profit**			
VITU VINGINE Mfano: Wadudu na Magonjwa Dawa Zolizotumika/ Matokeo Ya Dawa **OTHER** **Example: Pests and Diseases** **Pest Solution Applied and Date** **Results of Pest Solution**			

BOLD type = crops currently in garden, *ITALICS* = next crop planned

Bed	Next Harvest Date	1st Planting	2nd Planting	3rd Planting
1	July 11	**HF cabbage**	*LF karoti -direct*	
2	Aug 1	HF Nightshade-birds got it- we uprooted	**HFeeders: Kale+ Sw.Chard+amaranth**	*LF garlic LF lettuce*
3	July 18	**HF cabbage**	*Beets, lentils -direct*	
4	Aug 1	HG Kunde- birds " "	**HFeeders: Ethiopian Mustard**	*HG Kunde -direct*
5	Oct. 14	HG Kunde + HF Lettuce+ HF Kunde	**HF Cabbage**	*LF Tomatoes and Parsley*
6	Aug 4	**HG maharage + LF Eggplant**	*HG Kunde -direct*	
7	Aug 4	**HG green beans**	*Leek/dill/broccoli*	
8	Aug 4	**HG green beans**	*Leek/dill/broccoli*	
9	Aug 4	**HF mchicha + HG maharage**	*Kunde + ?*	
10	Aug 15	**LF onion+ LF karoti**	*HF Chinese+ HG Lentils*	
11	July 25	**HFeeders Nightshade+mchicha**	*tomatoes, chives, garlic, basil*	
12	October 15	HF mnafu+mchicha	**HF hot pepper +HF cabbage**	*HG Sweet Peas*
13	July 5	HG Kunde	**Empty**	*HFeeders Kale + Broccoli*
14	October 4	HG Kunde	**HF Mint**	*?*
15	October 4	HG Kunde	**HF Spanish onion**	*?*
16	July 11	**HF Cabbage**	*Beetroot + Onions*	
17	September 25	HF nightshade- ndege	**HF Ethiopian Mustard -growing for seed**	*LF beets and LF onions*
18	July 20	**LF Leeks**	*HF Broccoli + Dill*	
19	August 4	HG Kunde-	**HF lettuce + HF amaranth**	*HF mahindi + HG maharage*
Key Hole	July 11	**HF Cabbage**	*LF Carroti, garlic, chives*	

NURSERY: Chinese, to be sold, July 11
Broccoli to be transplanted July 11, bed 18
Tomatoes and Chives to be transplanted July 25
Cabbage to be transplanted as needed
Hot Peppers July 11-plant around garden border, for pest solution

AVAILABLE SEEDS:
Thyme,Beet,Been,
Rosemary,Onion

ACTIVITIES FOR NOW: Plant rosemary around garden. Plant Thyme in nusery Beef up plan with companion plants and beneficials, find answers for question marks Harvest Plans for beds 1, 3, 16?

VII. PREPARATION OF THE NURSERIES

picture of mary digging in the nursery

A nursery is a well-dug and fertilized portion of land with good soil drainage and shade protection, to grow seeds into healthy seedlings, ready to be transplanted into a bed. In this chapter we cover how to get your nurseries going and sowing your seeds. The 'transplanting' chapter will cover the next stages of the nursery, up to getting your seedlings into their final bed.

Why use a nursery?

- ◊ Lower the 'die-off' rate of plants in your beds - select healthy seedlings from the nursery to plant in your bed, rather than planting seeds directly which may not thrive or germinate at all
- ◊ Use seedbeds to grow crops in succession- see 'record keeping' chapter
- ◊ Save water - seedbeds require much less water and time than do crop beds
- ◊ Ensure strong stems: transplanting seedlings **in the ground up to their first leaves** ensures a strong stem for the plant, enabling plants to grow to their full potential
- ◊ Protect small seedlings– nurseries offer a sheltered environment from bad weather and insect attack
- ◊ Seedbeds benefit the growth of fibrous rooted vegetables
- ◊ Contain insect and disease infestations: keep seedlings attacked by disease or pests out of the growing beds, so the seedlings don't introduce the pest to the other plants

Not all crops use the nurseries. Some plants, like beans of all kinds and carrots and corn, do best directly seed-planted into beds. Many others, like leafy vegetables are best first planted in nurseries. Seed packets will indicate whether or not to direct seed-plant. Always make sure you have worked out the crop rotation schedules, and have a bed to plant your seedlings before you stock your nursery! Later chapters will give you the information to begin planning schedules, sowing and transplanting. This chapter is just for preparation of the nursery.

Different types of soil mixes:

Healthy plant growth in these first nursery stages is very important to a plant's future health.
There are different soil mixes for different growing situations. Consider the stage of plant growth and its environment: container, pot, or bed. The three main types of soil mixture are a seed planting or sowing mix, first transplanting mix, and potting mix.

1. **Sowing (seed transplanting) mix:** The initial sowing mix does not need so many nutrients. What's essential to the sowing mix is good drainage, moisture holding, and textural qualities.

2. **First transplanting mix:** plants begin to need more nutrients approximately when they get their first leaves. At this time they are transplanted. We make this mix richer in nutrient content.
3. **Potting mix:** often used to grow trees or perennial plants. The plant is being grown in the container for a long period of time, so it requires a lot of nutrients. More manure, compost, fish meal, etc. can be added to help this problem.
4. **Nursery bed:** nursery beds do not have the same aeration problems that containers create, so they are easier to work with. One wheelbarrow manure or compost and 4 spades sand should be a good mix. Bone meal, fishmeal, lime can also be added if required. This mix should be put on at about 1 or 2 inches, or 2-5 cm covering the surface of the bed. It is then mixed with the top 3 or 4 inches, or 7-10cm. of the bed. If you mix the material any deeper, it will not be usable to the plant.

INGREDIENTS OF SOIL MIXES:

Material	Is a Source of:	Notes:
Compost	Balanced Nutrients, and Soil Structure: Aeration & Moisture	Can be low in nitrogen
Manure	Nitrogen	Must be aged or it will burn plants
Lime	Calcium	Raises soil PH, making it less acidic. Used in acidic soils.
Bone Meal	Phosphorus	
Fish Meal	Nitrogen	
Artificial Fertilizers	Balanced Nutrients	Often used in nurseries
Soil: loam, good garden soil or topsoil	Nutrients and Structure-Aeration	Bad soil causes problems. To get good topsoil, take a little from a bed each time you dig
Sand	Increases Drainage	Not good for moisture retention. Rivers are often the best source

How to make a soil mix:

There are different recipes for soil mixes. One set is below. Another follows it. Use the one that works best for you. Compost, soil and sand can be sifted through a ½ cm screen. By passing all the material through a sieve, we reduce the physical obstruction of larger clumps of soil and introduce air into it. The materials are then mixed thoroughly on any flat, convenient surface. A loose and aerated soil mix will reduce physical resistance to root growth and seed germination. As you mix the materials, you water to achieve good moisture.
Eventually you will be able to make a soil mix without having to count or measure out each ingredient.

SOWING MIX
5 parts of soil
4 parts of compost.
1-2 parts of sand

1st TRANSPLANT MIX
5 parts of compost.
4 parts of soil.
1 part manure (optional)
Handful bone meal (optional)

Creating the Nurseries:

There are two phases to nursery management: primary nursery and secondary nursery.

Primary Nursery
1. Select a piece of land (approximately 4 ft by 20 ft) – a shaded area close to a water source is best
2. Clear the weeds from the selected area and loosen the soil 1-ft. deep
3. Rake or shape the area into a raised bed or beds – provides better water infiltration and limits run-off due to excess rain or force of water at watering
4. Fertilize the 9 square meter bed with 3 wheelbarrows of a mixture of sharp river sand and old manure or compost at the rate of one wheelbarrow of manure/compost and 4 spadefuls of sharp river sand

5. Distribute the mixture at various places in the bed and spread it evenly, then mix it thoroughly into the top 3 inches of the soil. This kind of mixture provides the soil with good drainage and ample nutrients for growing seedlings in the nursery bed
6. Using a watering can or any other available water implement, water the bed and observe the rate of infiltration. If it sinks uniformly, then your mixture is perfect - if not add half again the amount of mixture of old manure or compost and sand to improve drainage
7. Spread the mixture all over the bed and work it into the upper 3″ of the soil thoroughly mixing it with the soil. The bed will be raised a bit to limit run off. Rake until fine, then water well and again watch the rate of infiltration
8. Make shallow furrows and spread the seeds and cover with the soil about ¼ in. thick with the soil/compost mix
9. To provide cover or protection for the nursery bed:
    a. At all corners of the bed put strong support sticks measuring 1.2 meters high, ideally forked sticks. Tie the sticks across from each corner to the other.
    b. Then tie on smaller supports horizontally and lightly cover the top with grass, banana leaves, mats etc. or you can simply cover your nursery bed with some dry grass to provide moistness in the soil. This is okay when your nursery bed is situated near a large tree or someplace with good shade all day long.

Secondary Nursery:

Construction of flats:
Best size: 23 in. by 14 in by 3 in deep
Flats can be constructed with sticks banana stems, etc. A soda crate can also be used. The bottom slats should be strong and spaced ¼ ″ apart allowing for drainage and aeration. The depth is the important factor. If the flat is too shallow, the plants roots will touch the bottom, resulting in slower growth and early, weak maturity. Jeavons calls it "premature senility". To help prevent disease of the soil mixture, flats should be kept clean and dry between different sowings.

Preparing flat:
Lay down a ¼" layer of leaf mulch or straw o the bottom of the flat. This provides aeration and prevents loss of soil. A fine layer of crushed eggshells may be placed upon the straw for calcium loving plants (i.e. tomatoes, cabbage, and kale). Next mix the following:

-Top soil (about 2 spades full)
-Compost (about 5 spades full) *Compost should be very fine
-Sand (about 1 spade full) * If the water settles on top when you water, more sand is needed
(Some say the combination is 1/3 of each of these ingredients ***by weight***)

Fill the flat with the moist soil mixture, tap down, slightly firm down edges and level flat with a long stick.

Sowing Your Seeds in the Primary Nursery:

Broadcast your seed evenly over the surface of soil. The size of seed and plant variety will determine the proper spacing. Many herb and flower seeds are very small, requiring careful sowing so that an over-abundance of seedlings doesn't result. With the vegetables that we will be most frequently sowing, the average spacing is ¼- ½″ between each seed. John Jeavons suggest placing of seeds at a distance so that seedlings leaves will barely touch when at transplanting stage. Close spacing helps encourage growth by creating a complete mini-climate.

Cover the seeds with a sowing soil mixture or sifted compost to a depth of ¼- ½ ″. Newly planted seeds need adequate moisture, shade and air. Water your seeds at least twice a day for quick germination.
Water gently, careful not to miss the corners and edges. A simple watering can may be made by placing small, closely-spaced holes in the bottom of a tin, providing and even, gentle flow. The nursery should never be allowed to dry out completely. The proper amount of water is critical. Too much or little water can lead to death or disease (such as damping off). Finally, cover the area with light straw to help retain moisture.

Records:

Keep track of your nurseries with a chart like the following:

NURSERY RECORDS

Area #	Crop, HF, LF, HG Date planted in nursery	Estimated date for final transplant into bed:	Bed # it's going to	Crop, HF, LF, or HG, in the bed now, and date it will be harvested:	Next Crop Coming into Nursery, and Bed it will Go Into
1					
2					
3					
4					

VIII. DOUBLE DIGGING

Soil preparation is the key to a healthy, productive garden. You have little control over the texture of your soil – it is either sandy or clayey or something in-between. But there are several things you can do to improve the structure of your soil. One of them is aerating the soil by double digging. Another is adding organic matter to the soil in form of compost.

The goal of double digging is to produce a "**living sponge-cake"** in the soil, to a depth of 24 inches, with 50% pore space for air and water. (The other 50% of the soil is mineral matter, including rock fragments and a small amount of organic matter). In a new garden the sponge-cake may turn out to be only 15 or 18 inches deep, but the microorganisms, worms, plant roots and water will usually cause it to become a little deeper each year. After a bed is completed it will typically last for three to four years, depending on the climate.

A Double-Dug Bed = A Lazy Bed:

The double-dug bed requires a high initial input of **labor**. Digging one bed can take up to 8 hours.
We are creating, however, **a permanently improved soil**, which will be much easier to work over time, than a conventional garden bed. A bed with two feet of loose soil allows plant roots to grow evenly and provides a steady supply of nutrients to the rest of the plant. Water is able to move through the soil freely, and weeds are easy to pull out. The plant roots have so much loose soil to grow into that more plants grow in an even area; this means more food from a smaller garden.

In conventional gardening people often grow their plants in rows and walk around them to cultivate, weed, harvest, e.t.c. continuously compacting the soil right on to the roots of the growing plants. Each year they must re-dig working against compaction they have created during the previous growing season.

With BIA you have a permanent raised bed and a permanent path to walk on in the growing area. In this way we maintain the aeration of the bed. This is a major reason that working with permanently raised beds will become easier to work than a conventional garden. The other major improvement is the addition of organic matter to the soil. It may take 8 hours or so to double dig a bed the first time, but in later years it can take only 20 minutes to dig the same bed.

Soil Aeration vs. Soil Compaction:

Air is necessary in the soil for plant respiration. Both the roots and leaves of the plant are breathing. Any thing that puts weight on the soil compacts it, reducing its amount of air. Heavy machinery, heavy rains and irrigation, and walking on the soil, are all common sources of soil compaction. In heavily compacted soils especially wet

areas, roots fail to get enough air, causing plant roots to suffocate. Compacted soil creates physical resistance to root growth; plants roots have to push harder to grow. This physical resistance is lessened when we aerate the soil.

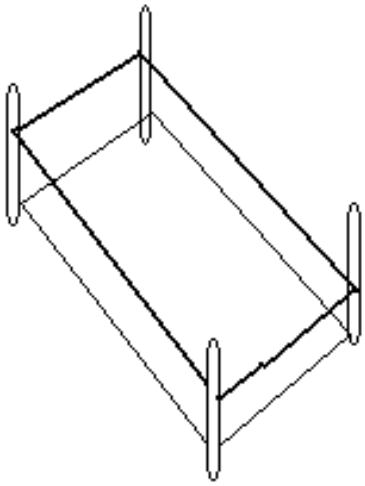
When we dig, whether it is conventional or double digging, we bring air into the soil. Aeration is the major reason that we practice digging. While conventional digging often loosens the surface soil, leaving a hardpan of unaerated soil underneath, double digging breaks up the hardpan, and loosens the soil below.

Advantages of double digging:

- ◊ Increased Microbial Life: In addition to plant roots, many soil microbes are dependent on air. The microbes are largely responsible for the texturing, structuring and cycling of nutrients in the soil. One cannot have good soil without good microbial life.
- ◊ Deep growth of roots enables Intensive Planting: With compacted subsoil roots grow downward, hit the hard pan and then grow laterally. Each plant needs more lateral space in which to gather nutrients and water. With double digging plant roots strive deeply downwards and take up less space laterally. Therefore plants can be spaced closer together –with this intensive planting can we can get 4 -6 times the yield in the same space.
- ◊ Water conservation: with the intensive planting that double digging allows, plant leaves just touch one another at maturity. The plants shade the soil, creating a 'living mulch' which keeps the soil cool and conserves water.
- ◊ Increased water absorption: The double dug bed also makes better use of rainfall, establishing a greater reserve of water for drier periods. Water penetration is improved because of the greater amount of pore space and looseness of the double-dug bed. As you irrigate or as the rain falls, water soaks easily and quickly into the soil. On more compacted soils, the soil is unable to absorb water well. In heavy rains especially, water runs off and is wasted for agricultural purposes.
- ◊ Less Soil Erosion: Soil erosion becomes less of a problem as there is less water run-off and not as much valuable topsoil carried within it.

The best time to double dig is in the spring, just when seedlings are ready to be transplanted into the bed. Seedlings grow best in a newly loosened soil. If you are starting a new bed, it is also possible to single dig (to loosen the soil 12 inches deep with a fork) and sow compost crops. Then in the spring, the double digging will be that much easier.

Starting a new bed:



Tools: *hoe, plank for standing (roughly 6ft or 2m), measuring string, and wooden stakes of approximately 75cm.*

The area to be selected is most important as it will be a permanent gardening area.

- ◊ A raised bed should be about 1 ½ meters, so that the middle can be reached from both sides
- ◊ The bed length can be whatever desired, however if too long you can spend a lot of energy walking around beds
- ◊ Paths should be as narrow as possible, to maximize the growing space- just enough space to walk is fine for the paths
- ◊ A good bed size is 6 x 1 ½ meters with a 45cm wide path, roughly 100 square feet

This is a convenient area for calculating fertilizer applications and crop yields

Before starting a new bed, make measurements and put in stakes to mark each corner, connecting the stakes with a string. Depending on the condition of your soil, you may also need to do one or more of the following:

1. Remove any grass and weeds, including their roots, from the area before digging- this material can go into a compost pile.
2. If the soil is dry and hard, water it well, thoroughly soak the bed to depth of 2 feet or 65 cm. if water is not available, waiting for the rain is advisable or one can try dry digging. After the bed is soaked. Its best to wait

until the soil is a proper moisture for digging two days after watering. The soil should not be sticky and muddy nor should it be so dry that it won't form a ball when squeezed in the hand.
3. Loosen the soil 12 inches deep with a spading fork.
4. Water lightly for a day or two (5 minutes or so per 100 square feet), or even longer if very dry/ hard.
5. Let the soil rest for 1 day.
6. Spread a layer of compost or manure on the area to be dug 1-3 in or 2-8cm, depending on the soil fertility.

Digging Your Bed:

Stand on a digging board so that your weight is distributed evenly and does not recompact the soil.

1. Across the narrow end of the bed, dig a trench 1 foot wide and 1 foot deep with a spade. Put the soil into buckets or a wheelbarrow or pile it on the ground. It can then be put in a bin to use for making compost and flat soil, or it can go back into the bed after double digging is completed to fill the last trench. The last trench will not really need this soil because of the increased volume of aerated soil in the bed, while soil that is used in making compost will be returned to the bed as part of the cured compost.
2. Loosen the sol in this trench an additional 12 inches with a spading fork. Dig the fork onto its full depth (or as deeply as possible) and push the handle downward so the fork tines lever through the soil, loosening and aerating it. If the fork will not go through easily, pull it out a little and then push down. You should go only as deep as the tool will loosen easily. The next time you double dig that bed, you will be able to go a little deeper. If the soil in the lower trench is dry, water the loosened soil well before continuing. It is easier to get water down into the lower 12 inches of soil at this point than it is after the bed preparation has been completed.
3. Dig out the upper part of the second trench 1 foot deep and 1 foot wide with the spade-Dig the spade in to its full depth (or as deeply as possible), lift the soil out on the loosened, aerated soil into the upper part of the first trench. Try not to mix the soil layers – the less their living quarters are disturbed when the bed is dug, the more ready they will be to get on with their business of providing nutrients to the newly planted seedlings. Move each spadeful of soil forward in the same way until you have dug across the entire trench.
4. Loosen the lower 12 inches of soil in the second trench with the fork.
5. Continue in this way with the third trench and as many more trenches as you need to finish the bed.
6. After the third or fourth trench (and every 3 to 4 trenches after that), rake the accumulated soil forward and level the double dug portion of the bed. There will be less soil to move round when you reach the end of the bed and have less energy to move it! (You will not need the soil from the first trench to fill in the last trench, if you are using that soil for compost and flat mix).
7. When you have loosened the lower part of the last trench, rake the whole bed level. (Add the soil from the first trench, if you are not using it for other purposes).
8. Spread a 1-inch layer of cured compost over the surface of the bed.
   Sift it into the top 2-inches with a spading fork. It is a good idea to put compost on your bed and plant your seedlings as soon as possible after double digging. If you cannot transplant your seedlings immediately, cover the double-dug bed with a shade net and keep the soil evenly moist to keep microorganisms alive. Put the compost on the bed just before transplanting.
9. Once the bed has been dug, don't walk on it. One of the reasons for double digging is to put air in the soil.

By Hand?

Some people prefer to let a machine do their digging for them. But your garden soil will not benefit from rot tilling. A rot tiller destroys the earthworms and other soil creatures that help make your soil fertile. It also compacts the subsoil and destroys the soils structure. Dr. Robert Parnes, in *Soil Fertility*, notes that if we are to be sensitive to soil processes, we should avoid rot tillers.

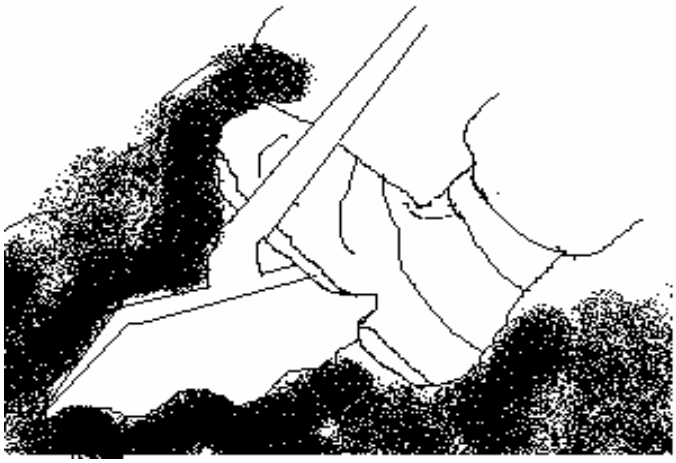
How Long Should it Take?

An expert can double dig an established bed in 1-2 hours but the first time you double dig, it may take you the whole day to prepare a 100 square foot bed, especially if the soil has never been double dug before. As you become familiar with what double digging is all about, and as your garden gets more used to being double dug, it will gradually take less and less time and effort to dig a bed. The important thing is to **take your time** and learn to do it well. Increased speed will come from experience and skill – not from rushing which will only tire you out.

Taking Care of Your back:
When double digging is properly done, your whole body weight does most of the work, with a little help from your knees and arms. If you feel excessive pressure on your back, you should stop and think about how to put less

pressure on it. Use your body weight to push the spade and the fork into the soil.

Place your foot on the spade or the fork so that it is under your arch just in front of your heel. Your body weight is used more efficiently that way. Lift the spade only as high as you need to and let the soil slide off on its own as you tip the spade. When loosening the soil in the lower trench, use your body weight, rather than your leg and arm muscles, to push the fork through the soil.



If double digging really seems like it will be too much for you, you might also consider single digging and using much wider spacing for the plants.

There are a number of shapes to make your bed:

1. Flat top with sloping edges.
2. Rounded bed without any abrupt edges.
3. Flat bed with a raised lip around the edge. This is highly recommended for dry conditions. It will catch rain most effectively and make irrigation easier.

ANOTHER METHOD:

In the Arumeru district GSC has been training in an adapted method, as described below:

1. Select an area approximately 5 ft. by 20 ft. (the bed can be any length, but it must be 5 ft. wide so planting and harvesting can be done easily from either side of the plot). Ideally, choose an area close to the house, compost supply, and a water source. The area may need to be fenced off to prevent animals from entering.
2. Mark the bed with sticks and strings. Remove grass and weeds from the top soil.
3. Loosen the top soil one foot deep and remove the soil, placing it on one side of the measured area.
4. Loosen the sub soil one foot deep and place this soil on the other side of a measured area. Now you will have a trench two feet deep.
5. With the third layer of soil now loosen one foot deep but the soil is not removed from the trench. Instead mix it with compost, at an interval of one bucket full of compost per meter length of the trench.
6. Now return the subsoil to the trench, and intermix it with compost at the same amount as in step five.
7. Finally return the top soil to the trench, intermixing it with compost of the same amount as previous layers.
8. The bed now will have the shape of a semi-cylinder. The shape obtained increases about 25% of an area. The bed is covered by cry grass (mulch).
9. The bed is ready to be planted with any crop.

NOTE: We may advocate 'triple digging' in Tanzania to provide extra aeration for soil compacted by tropical rains.

TERMS USED:

- ***Extensive agriculture****-agriculture requiring a large area to produce a crop for example maize, wheat etc.*
- ***Intensive agriculture****-agriculture requiring a smaller area to produce the same amount of crop.*
- ***Aerate****-to supply with air.*
- ***Compaction****-to pack together, to make denser. In the compaction of soil we reduce the pore spaces and aeration.*
- ***Hardpan****-a harder layer of compacted soil that may lie anywhere from 6 inches to 2 ft below the soil surface. A hardpan makes it difficult for plant roots and water to penetrate downwards.*
- ***Respiration****-the process of breathing. Soil aeration affects plants ability to respire.*
- **Mulch-**a layer of material placed on the soil to consume moisture and hold down weeds. Living mulch applies to plants themselves shading, protecting, and holding down weeds in the bed.

IX. TRANSPLANTING

Some plants, like carrots, beans and corn, go directly into the beds as seeds. Others, like leafy greens, tomatoes and onions, are best grown in stages, using nurseries. Seed packets will indicate whether to plant from seed or as a seedling.

The challenge for the gardener is to complete the planting and transplanting process without interrupting the plants growth. The goal is to stimulate growth, not slow it down. Proper timing, good bed preparation, and careful water application are critical factors affecting successful planting. The entire nursery process takes about 4-5 weeks.

Transplanting often takes two stages. When small seedlings in the primary nursery have produced two true leaves or are overcrowded they are **transplanted to a secondary nursery**, called being **'pricked out'**. The secondary nusery provides the seedlings with slightly more nutritious soil and increased space. (Sow seeds thickly in your primary nursery bed). When seedlings in the secondary nursery attain 3-5 true leaves, a fairly developed though shallow root system, and are usually 3-5 ″ tall, they get their **final transplant**, into a garden bed.

Transplanting Your Seedlings:

1st Transplant:
Once seedlings attain two true leaves prick them out into the secondary nursery. The secondary nursery should be prepared with a proper soil mixture. Mark out where seedlings will be placed using a diagonal offset pattern and 2″ spacing, then make small holes in which to place the roots. Carefully drop a trowel full of seedlings on the ground or working surface. Their soil mix should be fairly dry, allowing roots to easily separate. Handling the seedlings by their leaves, place them in new flats. Firm in gently and water lightly. Newly transplanted seedlings should remain out of direct sun and strong wind for 2-3 days. If materials for a secondary nursery are unavailable, seedlings can remain in the primary nursery until they are ready to be transplanted into the final bed. Don't let the seedlings get too much water. Studies have shown that smaller plants have a higher survival rate. This is partially due to their limited surface area which reduces water loss. Their smaller roots are also less likely to be damaged

Final Transplant:
When the plant grows 5 true leaves, it can be transplanted to the final double-dug bed. However, **before final transplanting, seedlings need to be hardened off,** thus left without water for 2-3 days. When this is done, the seedlings will appear as if they are wilting and declining. About 2 hours before transplanting, water them. The gardener should choose those seedlings which have good **root– leaf balance.** Example: crowded conditions in a seed flat will result in long, spindly, "top heavy" seedlings with shallow, weak, and often interwoven roots. For a plant to undergo a healthy transplant, its roots must be able to provide adequately for top growth.

Transplanting is best done late in the evening or on a cool day. Prepare bed, laying down mulch if desired, and mark the location where seedlings are to be transplanted. See the lists in the 'Companion Planting, Crop Rotation, and Beneficials' chapter for common plants, their companions, and their spacing. A more comprehensive list is in Jeavons, *How to Grow More Vegetables*. The diagonal offset pattern is again used making the most efficient use of bed space and helping create an eventual living-mulch. Dig holes large enough to place seedlings up to their first true leaves. This is done for several reasons:

- As the soil settles, the roots will remain covered
- Members of the cabbage family as well as tomatoes form adventurous roots from their stems
- It prevents seedlings from bending over

Press down firmly, but not too tightly, allowing for aeration, water penetration and nutrient uptake. Finish by giving the seedlings a gentle yet thorough watering, enough to settle the soil around the roots, eliminate excess air space, and provide an adequate amount of water for growth. Again, if one can provide the seedlings with some form of sun and wind protection for a few days, a more successful transplant will result.

To reduce transplant shock:

1) Expose roots to the air for shortest time possible
2) Carry soil with roots
3) Minimize handling of seedlings and handle them gently
4) Place seedlings into a more nutritious, moist flat/garden bed
5) Provide shade if necessary

6) "Harden off" the seedlings by reducing watering and introducing them to slightly harsher environmental conditions several days before transplanting
7) Transplant in the early evening, or on a cool, cloudy day, and avoid windy, very dry conditions

Water necessity:

Lack of water is a major cause of death to transplants.
Reasons new transplants can lack water:

- ◊ Simply not enough water
- ◊ Improper shading: seedling loses water faster than it can absorb it
- ◊ No protection from wind
- ◊ Soil ball, with good aeration and drainage, is placed into a garden bed lacking these qualities, resulting in poor absorption of water

Recommended Reading:

N. Bubel, *The seed starter's handbook*
M. Rogers, *Growing and sowing vegetable seeds*
H. Rickett, *Botany for gardeners*
D. Patent and D. Bilderback, *Garden Secrets*
Hartmann, Kester, *Plant Propagation*, pp.190-193
Hartmann, Flocker, Kofranek, *Plant Science*, pp.417-418
Jeavons, *How to grow more vegetables*
Seymour, *Self Sufficient Gardener*

X. LIQUID MANURE

Liquid manure is good a source of quick plant food during the growing season or when your plants look yellow, showing they are short of nitrogen.

How to make liquid manure:

Material and Tools: *Manure: cattle manure, rabbit manure, or chicken manure from sawdust*
drum or a debe
strong pole and rope

1. Put cattle manure or a mixture of rabbit and chicken manure in a strong sack or gunny bag (50 Kg of manure for 1 drum of water). Fill it in such a way that you can tie the rope of the bag securely.
2. Suspend the bag containing the manure in a drum full of clean water. The bag should be tied securely with a rope and suspended on a strong pole that is placed across the top of the drum.
3. Leave it to stand for 14 to 21 days. Cover the drum to prevent excessive evaporation.
4. After 3 days stir the drum by lifting the bag several times using the pole.
5. After 14 days the water will have turned blackish, and most of the plant food in the manure will have turned blackish, and most of the plant food in the manure will have washed into water
6. Remove the bag from the drum by lifting the pole.

Water your crops using the tea, the solution should not be sprayed on the leaves but applied around the stem once a week for a period of 3 weeks. It is effective as top dressing after planting the crop, but it usually ranges from between 250 gm to 500 gm per plant.

Another approach to liquid manure:

Use fresh or dry chicken, cattle or goat manure, but never put the solid manure directly on the garden as it is too strong and may kill your plants or bring pests to the area.

1. Put one liter of manure in a bucket. Cover with water and leave for 3 days for chicken manure and 6 days for cow or goat manure. Strain the liquid and put the solids on a new compost heap.

2. Dilute the liquid manure with 40 cups of water to one cup of liquid manure. Use this to water seedlings. Dilute with 20 cups of water to one cup of manure to water the soil around more mature growing plants once a week. Do NOT pour it directly on the leaves.

XI. DISEASE & PEST CONTROL

Not all insects are bad in the garden. Without butterflies and bees many flowers would not give seed or fruit. Earthworms break down soil, letting air and water through and helping bacteria to break down natural rubbish to feed plants.

A thriving diverse garden with healthy soil will attract beneficial insects that will make themselves useful pollinating, cleaning up rotting debris, and eating harmful insect larvae. In fact, in a balanced mini-ecosystem, for every seven or eight good bugs, there will be only one harmful one. If we get rid of all the bad bugs in our garden, the good bugs have less to eat and have no reason to stay around to help.

In bio intensive agriculture we emphasize organic natural pest control. There are various types that are discussed in detail below.

1. Cultural controls
2. Physical controls
3. Biological controls
4. Organic pest deterrents

Cultural Controls:

These are regular farm operations designed to destroy pests that do not require the use of specialized equipment or extra skill. The operations make the environment less favorable for survival, growth and reproduction of the pest species. Methods of cultural controls:

- ◊ Time of planting. - For a pest that emerges early in the season, planting of most of the crop can be delayed so that most of the pest population starves before the plants are available. On the other hand, later emergence of a pest population can lead to early planting of the host.
- ◊ Crop rotation. - This is the practice of alternating crops from one year to the next in a given field. This practice takes advantage of the fact that most pests are limited to feeding on one kind of crop.
- ◊ Destruction of crop residues (sanitation). - Many pests complete part of their life cycle in the dead leaves, stems, or other plant residues that remain in the field after harvesting. Raking and burning these materials may be effective in keeping pest populations to a minimum level where it cannot cause damage to the succeeding crop.

Physical Controls:

We introduce barriers to control insects from damaging crops. Examples:

1. Banding trees with tart-lime for crawling insects
2. Constructing a fence around the garden to keep predators away. Materials to do this include sticks, grass, old maize, and fertilizer sacks, old fishing nets, etc.
3. Netting crops
4. Bagging fruits against boring insects (melon flies)
5. Introduction of the attractants (Pheromone and color attractants)
6. Planting crops together with repellents (herbs-i.e.. French Marigolds)
7. Planting thorny plants like Sisal, around the garden

Biological Controls:

Enlisting the aid of nature can encourage natural insect control. Some sources are:

1. Children around the house –can chase animals away from the garden
2. Birds -remove bed insects from the garden
3. Toads, snakes and spiders -eat insects and other garden pests
4. Ladybugs -eat aphids, but they don't eat beneficial insects
5. Praying Mantis -eat harmful and beneficial insects, therefore they should only be used in emergencies
6. Organic Pesticides –deter harmful pests without harming beneficial insects and microorganisms

Organic Pest Deterrents:

Three Basic Kinds of Insects and How to Control Them Easily:

KIND	CONTROLLING
Chewing or biting, soft bodied and hard bodied	Aromatic and distasteful sprays such as garlic, onion and pepper spray.
Sucking soft bodied	Soap solution sprays (not detergents)
Sucking, hard bodied	Hand picking

GARLIC/ONION TEA INSECT REPELLENT.

Mash 10 cloves of garlic or a medium onion.
Mix with 2 quarts/liters of water.
Let it sit. Strain.
Spray without diluting.
(Good against nematodes).

"THE BOMB" INSECTICIDE
Melt ½ bar of bar soap (not detergent) in 8 quarts/liters of water.
Spray.
For strong pests, add 2 teaspoons of slat and about 30 mashed cayenne peppers.

LIST OF ORGANIC PESTICIDES AND HOW TO PREPARE THEM
-Evans Javasson

The main purpose is to avoid the use of chemical products that kill not only pests but also beneficial organisms in the environment. Many chemical pesticides quickly affect human beings. Others have residual effects and can accumulate in the body causing diseases. Therefore there is still considerable use of various plants and traditional practices in controlling pests in field and store. Use of plants and other local resources in pest control is not, then, a novel idea for Africa farmers. However difficulties can arise when trying to introduce "new" approaches.

Subsistence farmers will naturally be conservative towards suggestions that they attempt anything but the known and trusted methods. Hence, introduction of different means of pest control requires a careful program of demonstration and reinforcement. Care must be taken to ensure that the pest control solutions are prepared and applied in the recommended manner. By not following the procedures on preparing these natural solutions will render the solution less effective and less convincing to farmers.

A good natural pesticide from plant origin should have the following characteristics:

1. EASILY AVAILABLE
   The plant should be easy to raise and not compete for space or nutrients with food crops. Ideally, the plant should be perennials and have a multi-purpose function.
2. SIMPLE TO PREPARE
   The process of collecting plant matter and preparing the insecticides solution should not be too time-consuming or requires too high technical input.
3. VISIBLY BENEFICIAL
   Since organic solutions generally repulse, rather than kill, garden pests, their action is less impressive than that of synthetic pesticides.
   They may also be skeptical towards the use of retrogressive local solutions as opposed to modern imported factory solutions. Therefore education to farmers on the action of organic pesticides is necessary.
4. COST EFFECTIVE
   Where synthetic insecticides are readily available at low cost, farmers will gravitate towards their use. The extra labor required for cultivation and preparation of organic pesticides must be weighed against the financial cost of synthetic solutions.

5. TOXIC ONLY TO TARGET SPECIES
Beneficial insects like bees and the environment in general, should not be adversely affected by use of organic solutions.

There are sixty seven local solutions to crop pest control but only few are mentioned here, which are easily available in most farmers' local environments.

1. Papaya
Leaves of papaya contain fungicidal properties. Diseases such as coffee rust, powdery mildew and rice brown leaf spot can be controlled with papaya leaf solutions.
   a. To make a solution effective against aphids, bugs, caterpillars, cutworms, root knot nematodes, termites, coffee rust, powdery mildew and rice brown leaf spot. Mix one kg. of finely crushed leaves per liter of water, filter and dilute the solution with soapy water at a ratio of 1:4 (soapy water = 100g. soap mixed with 25 liters of water). Add two teaspoons of paraffin to this mixture (2 : 5) per five liters of solution before spraying
   b. Spray or water the ground around plants against cut worms.

2. Tomato
   a. Boil stems and leaves of tomato plant in water; one kg. of chopped leaves in two liters of water.
      Allow to cool, filter and then spray the solution on plants to deter attack from caterpillars, black or green flies.
   b. Apply this spray every two days when butterflies of cabbage worm and present.
      Pound two cups of tomato leaves and stems
      Soak in one liter of water and let stand for overnight
      Filter and add one half liter of water and spray on plants, good against aphids.
   c. Finely crushed tomato stems are covered with some quantity of hot water (one kg. of crushed tomato stems covered with four liters of water)
      Let stand for five hours.
      Filter and spray on cabbage, this repels butterflies of cabbage worms and diamond black moths.

3. Asthma Weed (Euphorbia Hirta)
Crush 1 kg of Asthma Weed plant
Soak in one liter of water
Filter and make a spray by adding two liters of water.
Effective against aphids, red spider mites, termites and most other insects. Also some fungi and viruses in general

4. Garlic
Steep three finely crushed garlic bulbs for two days in liquid paraffin. Use a glass not a tin container. Filter this solution and then stir in a large spoonful of soap and dilute with ten liters of water. This solution is said to kill most insects.

5. Urine
Fermented urine from cattle can be used to prevent attack from various pests and diseases. Urine has been demonstrated as effective in protecting green beans, melons, cabbage, tomato, okra etc. from most pests. It can also prevent mosaic virus disease in chilies and tomato and leaf curl virus in red peppers.
Let the cow urine stand for two weeks in container exposed to sunlight.
Dilute with water at a ratio of 1: 1 before spraying at weekly intervals. Two or three applications should be enough to prevent mosaic viral disease.
Less concentrated solutions of one part human urine to four parts of water can prevent fungal diseases such as downy mildew and vine powdery mildew, etc.
Dilute with water at a ratio of 1: 6 fermented cow urine is said to control stalk borers.

6. Castor Oil Plant
The leaves and green fruits (seeds) can be used to produce a contact poison to crop pests. A plant with red stems is said to be more effective than those with green stems. Care must be taken in using the seeds as they are poisonous to humans, chickens, guinea fowl, and other birds.
   a. To produce a spray effective against a wide range of insects:

Soak green leaves and seeds in water for one full day, filter this solution and spray on plants or target insects.

b. To make a powder for dusting on plants or insects:
dry green seeds and leaves and crush then powder.

c. Cutworms can be killed by a solution made by mixing four cups of crushed, shelled seed with two liters of water and boil for ten minutes. Add two teaspoons of paraffin and liquid soap for adhesion and more water to make ten liters. Apply this solution immediately into the soil.

d. To kill fungal diseases, mix seeds, leaves or oil cake with soil.

e. To keep termites away from plants, apply leaves and branches as mulching materials.

f. Seeds will repel rats

g. Application of cake from the castor oil plant to field, at a rate of 1800 kg/ha, can significantly reduce population of nematodes.

7. Baking Soda (sodium bi-carbonate)

Solution of Sodium bicarbonate can prevent or cure several plant diseases. Prepare a spray by dissolving 100g. baking powder in one liter of water. Add soap, filter, and dilute with nine liters of water. Stronger solutions may be required to cure that plant leaves are not harmed by the treatment. Sodium bicarbonate solution has a long protective effect in the field.

8. Manure

Manure from chicken, goats, cows and sheep can be used to add soil fertility, protect tree saplings from attack foraging ruminants and protect garden plants from a variety of pests and diseases.

a. Mix 2-3 dried cow patches (1 shovelful of manure) with ten liters of water in a bucket and stir daily for fourteen days to ferment the solution. If the smell becomes too disagreeable, sprinkle clay or stone dust over the surface (will also add useful minerals to the solution). Dilute with water at a ratio of 1 : 3 – 5 and spray on all green parts of vegetable and fruits. Sprayed on leaves of plants will deter attack from animals, aphids, birds, caterpillars, etc.

b. Mix a shaveful of fresh donkey manure in a bucket of water and allow this to sit overnight to make an effective spray.

9. Milk

Solution made from one liter of milk with nine liters of water can be effective in controlling spider mites, and killing caterpillars' eggs on plants in the crucifer plants (family) as well as preventing fungal and virus plant diseases.

a. Spray every ten days, this will also help in preventing Mosaic Virus in tomatoes, tobacco, and sugar cane.

b. A weaker solution of one part milk to ten to fifteen parts of water applied every ten days can also effective at controlling mites and plant diseases on a wide variety of plants.

c. To control mildew, make a spray with one heaping teaspoon of wood ash mixed with one liter of water. Allow to steep overnight, filter, then mix with one cup sour milk and dilute with three liters of water.

10. Sweet Potatoes and Cassava

Aphids and various fungal diseases including rice brown, leaf spot and rice blast can be controlled with solution made from sweet potatoes leaves which have been crushed and mixed with water. Heavily starched water left after cooking sweet potatoes or cassava can be used also.

11. Neem

Neem is pre-eminent as a multi-purpose plant. Drought resistant and shade providing, the Neem tree has also earned a world-wide recognition for its many uses in medicines, soap making, and pest control. The Neem tree comes closest to best fulfilling the condition for a good source of plant-derived insecticides acceptable to local farmers. Neem plant can be used in four ways.

Use of plant leaves
Use of plant seeds
Use of Kernel powder
Use of Neem cake

a. Plant leaves:
Crush one kg. of Neem leaves and soak in one liter of water.
Allow to stay fro twelve to twenty-four hours or even for a week because for longer it stays the better solution is achieved.
Add four liters of water with 30 grams of soap, stir well until the soap is dissolved.

Sieve and use at a ratio of 1:15.

b. Plant Seeds
Fresh Neem seeds can be used to make a solution which is effective to most crop pests.
Shred and crush two kgs. of Neem seeds (fruits) with little water.
Add one liter of water and allow this mixture to sit overnight.
Sieve properly and add more water until you make the total of amount of 15 liters then apply onto plants.

c. Plant Kernel
Collect the plant kernel by lightly pulverizing the seeds to separate the brown kernels from the husks.
Crush the kernels and then dry the pulp in the sun.
Mix Neem kernel powder with sawdust of clay at a ratio of 1: 1, and sprinkle on young plants.
One kilogram of this powder is enough for 1500 to 2000 plants but must be repeated after each rain.

d. Neem Cake: This is the solid remaining after the extraction of oil from the seeds.

12. Persian Lilac:
This is a plant closely related to the Neem plant.

a. Leaf spray solution:
Mix 150 grams of fresh leaves or fifty grams of dried leaves in one liter of water.
Soak for twenty four hours.
Filter and spray on plants ratio 1 : 20.

b. Leaves and fruits of Persian lilac mixed with Mexican Marigold:
Soak Mexican Marigold along with leaves and fruits of Persian lilac in one liter of water for a few days.
Dilute the liquid obtained until the solution in pale green or brown in color. Filter and spray.

13. Wood Ash

a. Apply wood ash directly around the stems of young seedlings after transplanting. It controls the cutworms from furrowing around the seedlings. It can control well if mixed with paraffin.

b. Mix wood ash and soapy water to make solution; two teaspoonfuls of ash with one liter of soapy water.
Add five more liters of water.
Filter and apply (spray) on plants or

c. Mix one tablespoonful of wood ash with one liter of water and let the mixture stand overnight.
Filter and add one cup of milk or buttermilk.
Dilute this again with water at a ratio of 1: 3.

14. Amaranthus Spp
Solution obtained from leaves and stems of this plant has a deterring effect on plant and fungus, especially against gray mold of fruits etc.
Crush one kg. of Amaranthus stems and leaves and soak in one liter of water.
Let stay overnight
Mix with thirty grams of soap, stir then add two more liters of water. Ratio 1: 10.

15. Annonas
Seeds are pounded into powder and mixed with water at a ratio of 1:10, meaning one kg. of powder in ten liters of water. Filter and then spray.
Caution: while preparing this solution avoid the powder getting into one's eyes as this is very painful.

16. Lantana:
This plant has a contact poison against a wide range of insects.
Crush one handful of leaves per one liter of water.
Add some soap, filter and apply as a spray on plants.

Or:

a. Crush one kg. of leaves of lantana and add one liter of water. Let stand for 12 – 24 hours. Add four liters of water with thirty grams of soap. Stir well. Filter and spay on plants. Ratio 1: 15.

18. Lantang: Branches and leaves of Lantang control potato moth during storage. Lay the potatoes on fresh Lantang branches during storage.

19. Chilies Hot Peppers
Chop the fruit of chilies (500 gr. of fruits for 5 litters of water) boil the peppers for 20 minutes to make hot tea, sieve, and add equal amounts of beetles, cabbage worms and caterpillars.

17. Red Pepper:
Red pepper powder or liquid solution from or mixed with the ingredients is effective at killing or repelling many insects.

a. Mix ½ cup of crushed red pepper or ¼ cup of dried red pepper in two liters of water.
Let stand for twenty four hours, filter, add soap and spray.

b. Or crush or finely chop ½ cup of red pepper or ¼ cup dried red pepper mix with one cup of mint leaves, one cup of onion tops.
Let stand for twenty four hours in one liter of water.
Filter and add ¼ cup of liquid soap, apply to plants.

c. Or boil half a kilo of chopped red pepper in three liters of water for 15-20 minutes.
Filter and add thirty grams of soap, and an additional three more liters of water.
Stir well until soap is dissolved, then spray.

d. Or chop ripe peppers into small pieces- one hundred grams, about twelve large peppers. s
Soak in one liter of water for twenty four hours.
Filter and add five liters of soapy water then spray.

e. Or mix two finely crushed garlic cloves with two teaspoonfuls of red pepper powder in four liters of hot soapy water. Stir well and spray.

18. Rubber Hedge:
Commonly used to make a living fence.
Chop few leaves of Rubber hedge (Euphorbia) and add them to the planting holes to protect seedlings from termite attack.
To make a spray effective against most insects:
Mix rubber hedge sap with water at a ratio of 10 drops sap per one liter of water (The solution should appear a bit milky)
Take care to avoid contact with the sap since it is poisonous; do not spray on windy days.

19. Thorn Apple:
This plant has anti-feedant and insecticidal properties to general and some fungal diseases.
Dry the entire plant and crush into a powder for use as a dust.
Or crush a handful of leaves and mix with one liter of soapy water to use as a spray solution.

20. Tobacco:
When kiraiko tobacco or filters of cigarette ends are boiled in water, they control maize stalks, cutworms, ticks, aphids, cabbage, larvae, caterpillars, grain weevils and leaf miners.
Use 500 gm of tobacco in 8 litters of water
Boil and sieve after cooling.
Dilute with equal amount of water containing 60 gm of bar soap to improve the effectiveness. NOTE: Tobacco is poisonous to man and animals; therefore, it must be kept away from children and domestic animals. It is recommended that crop harvesting be done 4-5 days after application.

21. Tephrosia (Fish Poison)
This plant is said to be effective for most crop pests. Some of the farmers use this plant as toxaphine to their animals.
Crush one kilo of fish poison leaves
Add one liter of water
Let the solution steep for 12-24 hours.
Add four more liters of water with 30 grams of soap. Stir well for soap to dissolve.
Sieve and spray at a ratio of 1:20.
Harvest should be delayed for 3-4 days after application of this solution.

22. Marigold:
This is a plant commonly used by most farmers to control nematodes in the soil. It is also used as one of pest repellants, and also against all fungi.
a. Crush 100-200 grams of marigold plant at flowering stage.
Soak in one liter of water (warm, preferably), for 24 hours or for 5-10 days.
Sieve and spray at a ratio of 1:1.
b. Or crush any amount of marigold which is dried
Apply the powder.
c. Or mix marigold plant with your soil while cultivating your land.

23. Bidens Pilosa:
This plant is said to be effective against most pests and other local people use it as a vegetable.
a. Use the seeds –one teacupful-:
in one liter of water and boil for 10 minutes
Leave to stay for 24 hours.
Add another liter of water with 30 grams of soap and spray at a ratio of 2:15.
b. Use the whole Plant:
Crush the plant – one kg.
Soak in one liter of water overnight (12 hours)
Sieve and spray on plants at a ratio of 1:15.

24. Solanum Incumum (Sodom Apple)
Take 20-40 Solanum fruits and squeeze the juice from fruits. Add one liter of water. Leave to stay overnight. Add 30 grams of soap and additional two liters of water. Sieve carefully and spry at a ratio of 1:15.

25. Tithonia Diversifolia (Wild Sunflower)
This is a plant which is found in most parts and some people use it as a living hedge. It's sometime grown beside the road.
a. Crush 100 grams of Tithonia.
Soak in one liter of water with 30 grams of soap.
Sieve and add more water until you get 15 liters then spray.
b. Ash from burned plant is also effective against termites and other insects.
c. The leaves of this plant can be used in compost making as it has a high nitrogen content.

26. Stinging Nettle:
Has a strengthening effect on the crop as it contains a good amount of iron.
Take 3 Kg of the leaves at flowering stage and place in a Debbie full of water.
Let it stand for 5-10 days, stirring occasionally.
After sieving the residues can be used as mulches.
Dilute the solution with water containing soap, this is effective on aphids, flies and caterpillars.

27. Onion or Garlic: Work as a repellant against many pests. They can be mixed with any one of the natural pesticides described above when applying in order to ensure the repellant effects.

XII. SEED PROPAGATION

- Joshua Machinga

What is a seed?

A seed is a dormant embryo; a living, resting plant whose life processes is operating very slowly. It maintains internal metabolic activity by consuming small amounts of energy from its endosperm wiithin a protective seed coat. It contains all the necessary instructions for the making of a new plant as well as a reserve supply of carbohydrates, fats, proteins, and minerals to nourish the dormant, encased seedling.

Kinds of seeds:

1) **Dicots-** majority of flowering plants. They have two seed leaves or cotyledons which store food for the young germinating plant for example-legumes, brassicas, and solanums.

2) **Monocots-** contain only one cotyledon. Food is stored in the endosperm tissue which surrounds the embryo, rather than leaves. For example- alliums and graminaceae.

Seed formation:

Though differing greatly in many respects, every flower contains the two essential ingredients for manufacturing seed.

- ◊ **Stamen-**the male pollen bearing part of a plant. Containing a long thin stalk (filament) and pollen sacs (anthers).
- ◊ **Pistil-**the female organ which receives pollen and nurtures future seeds. It contains a pollen receptive region (stigma) and a long, thin tube (style) leading from the stigma to a cavity (ovary) which contains one or more eggs (ovules).

Grains of pollen after landing on the stigma must travel to the ovary. In doing this, they form long tubes of tissues which grow cell by cell down through the style. A growth hormone (**auxin)** from the pollen causes the ovary to begin to enlarge once it's pollinated, even before actual fertilization occurs.

As a pollen tube approaches an egg, its tip bursts open and releases two sperm cells. One of these unites with an egg cell to produce the embryo (also called zygote). The other fuses with polar nuclei and develops into the endosperm. This dual process of sperm cells uniting with female cells is known as **fertilization**.

Types of pollination:

1. Self pollination- the flower is capable of pollinating itself with the aid of wind or insects. Pollen rarely travels from plant to plant. They all have COMPLETE flowers. A gardener may easily grow more than one variety at the same time, feeling confident that the next generation will resemble the parents. For extra precaution, simply plant another crop between different varieties of same vegetables. Includes: Solanums, Legumes, Wheat, and Lettuce.
2. Cross pollination- the pollen from one flower fertilize another flower, either on the same or on a different plant. Pollen is carried by wind or insects (usually bees). Some cross pollinated plants may be complete flowers yet be SELF-STERILE, thus requiring pollen from other plants for pollination.

Insect - bbrassicas, cucurbits, carrots, onions
Wind-maize, beets, swish chard, spinach

Many of these vegetables easily cross with other varieties of their family. So caution is should be taken if saving seed from them. Minimal distance is usually recommended to prevent undesired genetic combinations. If required separation is impossible, hand pollination may be applied. This involves caging and isolating plants you want to propagate. Understanding the pollination process of each of the vegetables you raise for seed is necessary for a successful seed saving program. For fertilization to take place, pollen must be of correct kind and it must arrive at the right time, when the plant's parts are well enough developed to enable it to reproduce. Pollen from an unrelated species will be rejected. Some plants will not receive pollen from other plants in their species. Some flowers can discharge pollen before their stigma is ready to receive it, while others are simply sterile to their own pollen. Fertilization is fascinating, complex process posing an exciting challenge to anyone interested in seed production.

Why save seed?

There are many good reasons. Here are a few: economics, security, increased self reliance, production of plants best suited to your climate and conditions, preservation on genetic diversity, gaining of knowledge, personal satisfaction and adventure.

Careful selection:

Selection is the key to a successful seed saving program. It allows you not only to increase the quantity of garden plants but also to improve and refine their quality. Choose the superior plants whose seed will produce another generation with the same desirable characteristics. It is important to observe plants throughout their entire growing season to be able to rate their full performance. Take into consideration the **WHOLE PLANT.** For example save a seed from a tomato plant with many excellent fruits, not just one, or from African spider flower with vigorous growth and not too quick to set flower. As a general rule, one is advised to save seed from more than one plant in order to maintain a broader genetic base. Most seeds remain viable for several years, so it is

necessary to save seed from every variety each season. Take into account those plants which may cross with each other and plan to save seeds from only one variety each season.

Some qualities to consider:

Flavor, yield, color, size, vigor, storage life, disease and insect resistance, drought tolerance, good germination, early bearing (fruits, heads, e.t.c.),late in bolting, quality of seed, texture, juiciness, e.t.c.

XIII. IRRIGATION AND WATER SUSTAINABILITY

-William Rite

Water as a Resource:

The importance of water for social-economic development cannot be overemphasized. It forms a vital part of social infrastructure, playing a key role in health, industry, agriculture, energy and general consumption for human welfare for which there is no substitutes.

Water is essential for all forms of life, yet the total amount of water that is available is limited. It is estimated that 80% of the countries in the world currently suffer from serious water shortages and this is expected to worsen in the coming decades.

Africa, despite its substantial water resources, experiences chronic shortages owing to uneven distribution of water and rainfall, underdevelopment of potential water resources and poor management of existing resources. In Tanzania for instance, the rise of population is creating pressure on the existing supplies and demand for additional water . The result has been overuse and pollution of the available water resources, leading to shortages even where water was previously abundant. To satisfy the projected demands, major investment in water development will be needed.

The relationship of global environment and agriculture is an important issue of concern which has drawn attention all over the world. There is a very close relationship between agriculture and the environment and in particular regarding soil and water. Ancient agriculture has been considered to be a link between nature and human society.

Therefore, sound development of agriculture based on appropriate management, control and effective use of water can play significant role in preserving the natural environment sustainably.

IRRIGATION PRACTICES

Irrigation is adding water to the soil so as to meet crop water requirements, and for the following purposes;

- To cool the soil and atmosphere to make a more favorable environment for plant growth
- To wash out/dilute salts in the root zone
- To soften the tillage pan

Importance of Irrigation:

Agriculture is the mainstay of the majority (80 – 90) of Tanzanians. Agricultural sector contributes over 50% of the countries GDP and over 75% of export earnings (1990- 2000). But one of the most significant risk factors in agriculture is the weather. Seldom is rainfall adequate to obtain optimum crop production even in humid areas. During the growing season a rainfall does not meet crop water needs. Sound development of agriculture can be achieved through appropriate on farm irrigation water management practices.

Sources of Irrigation Water:

The main water sources are;

i. Atmospheric moisture (Precipitation)
ii. Surface water
iii. Subsurface water (underground water)

Surface sources of water:

Surface water exists in natural basins, streams and artificial reservoirs, ie. lakes, ponds, rivers and reservoirs. Water in these sources fluctuates widely from year to year and season to season.
Normally peak water demand occurs in the seasons of minimum flows. The water shortage that results has its impact during the high rainfall seasons. The parched land can't absorb the rainfall, causing surface runoff – a waste of badly needed water.

Subsurface water:

Subsurface water is the zone of water saturation underground (aquifer), supplied by infiltration and percolation of rainfall. In areas where the underground water is a source of water supply, i.e. through wells, it is being withdrawn faster that it is replaced by the rainfall.

Challenges Facing Water Sustainability:

1. Extreme drought: depletes water from all sources (surface and subsurface)
2. Unregulated activities: development activities like farming on steep lands without soil and water conservation measures, over cutting, overgrazing and the destruction of river banks, finally lead to a serious loss of soil and water through soil erosion and drought. Soil erosion, drought and starvation are always in vicious cycle, with the water and soil loss contributing to drought and starvation which contributes to more destructive desperate activities.

Approaches to Water Sustainability:

The approaches can be grouped as follows

1. Water storage for future use:
   i. Construction of big dams by intercepting water flows in big rivers (institutional and national projects) to cater for energy and irrigation purposes.
   ii. Rain water harvesting techniques at farm scale through:
      a. Collection of rain water in small reservoir, tanks and wells from house roofs catchments and other locally available sources.
2. Appropriate on farm irrigation water management practices, through selection, planning and design of suitable irrigation methods which are efficient, equitable and sustainable.
   a. On farm rain water harvesting by soil and water conservation practices. These can be categorized as:
      Biological, cultural and physical soil & water conservation measures.
      i. Biological & Cultural Measures:
         1. Crop rotation
         2. Intercropping
         3. Strip cropping
         4. Trash lines
         5. Tillage practices
         6. Mulching
         7. Organic fertilizers like farm yard manure, compost green manure etc.
         8. Contour farming and ridging

      ii. Physical conservation measures: i.e. terraces, cut–off drains and artificial water ways.

      Terraces are cross slope barrier at suitable spacing with acceptable grades for the following purposes:
      - ◊ Reduce soil erosion
      - ◊ Provide maximum retentation of moisture for crop use
      - ◊ Reduce surface runoff water at a non- erosive speed
      - ◊ Reform land surface
      - ◊ Reduce sediment content in runoff-water
      - ◊ Reduce peak runoff rates at installations down stream
      - ◊ Improve formability

XIV. SACK GARDEN

Multi-Story Bags:

This method of planting is particularly good for people who have little space available.

- Place a sack on the ground. Place a 2 kg tin (with the top and bottom removed so that you can see through it) in the middle of the sack.

- Fill the tin with small stones. Fill around the tin with a mixture of topsoil and manure. Make sure the soil surrounding the tin is the same level as the rocks.

- Pick the tin up and fill with small stones again. Fill around the tin with the mixture of topsoil and manure. Keep doing this until the bag is full. (When you are done the bag will be full. There will be a column of rocks in the center and topsoil/manure mixture all around the sides.) When you have filled the last bit, leave the tin around the rocks at the top.

- Punch holes around the bag, with about 6 inches between holes. The holes must be large enough to plant sukuma seedlings.

- Water the bag by pouring water through the rocks in the center—the rocks will disperse the water to the sides of the bag. To make sure all the plants get water, check the holes. Water accordingly.