USAID-ATEP
AGRIBUSINESS AND TRADE EXPANSION PROGRAM

HORTICULTURAL PRODUCTION MANUAL:
TOMATO PRODUCTION
MARCH 2008
HORTICULTURAL PRODUCTION MANUAL

TOMATO PRODUCTION

MARCH 2008

MELAKU TEDLA & RICHARD PLUKE

This publication was made possible by the assistance provided by the Office of Business, Environment, Agriculture & Trade (BEAT) of the United States Agency for International Development (USAID). It was prepared by Fintrac Inc. under IQC #EDH-I-00-05-00007-00, Task Order 01 (663-T-06-001). The opinions expressed here are those of the authors and do not necessarily reflect the opinions of the United States Agency for International Development or the Government of the United States.

Please note: The use of company, pesticide names and brand names in this publication is for reference only and doesn't imply any support or preference given to the product mentioned or a criticism to other products correctly labeled that are not mentioned. Please refer to the labels of pesticide products for information on restrictions, personal protective equipment, re-entry, days of harvest and other instructions for their application. While the manual follows the guidelines found in this project's PERSUAP, it is recommended that you seek up-to-date information on any changes to pesticide regulations and legislation, which may have affected pesticide use, registration, and restrictions (such as MRLs).

USAID-ATEP promotes the use of Integrated Pest Management and good agricultural practices. Please refer to other technical publications and the project’s PERSUAP for further guidance.
Content

1. INTRODUCTION ................................................................................................................... 1
2. CLIMATE & SOIL REQUIREMENTS ..................................................................................... 1
3. VARIETIES .......................................................................................................................... 1
   3.1 Fruit type...................................................................................................................... 1
   3.2 Plant habit.................................................................................................................... 1
   3.3 Disease resistance ........................................................................................................ 1
   3.4 Adaptation to season ................................................................................................. 2
   3.5 Hybrid or non-hybrid seeds ...................................................................................... 2
4. FIELD PREPARATION ......................................................................................................... 2
5. PLANTING DENSITY .......................................................................................................... 3
6. SEEDLING PRODUCTION .................................................................................................. 3
   6.1 Seedling tray production ............................................................................................ 3
   6.2 Field nursery production .......................................................................................... 4
7. TRANSPLANTING ............................................................................................................. 5
8. WEED CONTROL ............................................................................................................ 6
9. WATER MANAGEMENT ................................................................................................... 6
10. PLANT NUTRITION ........................................................................................................ 8
11. CULTURAL PRACTICES ................................................................................................. 8
   11.1 Windbreaks ............................................................................................................... 8
   11.2 Staking & trellising .................................................................................................... 9
   11.3 Pruning .................................................................................................................... 10
12. PEST AND DISEASE CONTROL .................................................................................. 11
   12.1 Integrated Pest Management .................................................................................... 11
   12.2 Tomato pests ......................................................................................................... 13
   12.3 Tomato diseases .................................................................................................... 20
   12.4 Application of pesticides ....................................................................................... 27
13. HARVEST ....................................................................................................................... 29
14. POSTHARVEST ............................................................................................................... 30
   14.1 Selection ................................................................................................................... 30
   14.2 Packing & transport ............................................................................................... 30
   14.3 Storage .................................................................................................................... 30
1. INTRODUCTION
Tomato is one of the most widely grown vegetables in the world due to its wide variety of uses. Tomato is also an important source of Vitamin A and C. This manual presents a complete technical package that gives the foundation to successful tomato production. The actual success of the tomato crop will depend on the individual farmer. Not only will hard work be necessary, but attention to all aspects of the production cycle and an organized approach will be needed to guarantee success.

2. CLIMATE & SOIL REQUIREMENTS
Tomato grows well in temperatures between 20 – 27°C. Tomato prefers well drained soils as the crop is susceptible to water logging. Optimum soil pH is 6.0 – 7.0. This crop is best grown with irrigation but if none is available, the crop will require about 600mm of rain during the life of the crop. Tomato is best grown on level ground but can also be grown on slopes if the proper contouring is done during land preparation.

Tomatoes benefit from crop rotation. Avoid planting in fields where a solanaceous crop has previously been planted. Tomato is a solanaceous crop (belonging to the Solanacea family), which puts it in the same group as eggplant, peppers and potatoes. All plants in this family share the same pests and diseases.

3. VARIETIES
Factors to consider:

3.1 Fruit type
• Fresh market – fruits are usually red in color and come in different sizes
• Processing – fruits have an intense red color and have a high solids content
• Cherry – usually small in size (30g) and come in a variety of colors.

3.2 Plant habit
Tomatoes are classified according to the plant habit, i.e. determinate, and semi determinate and indeterminate.
• Determinate and semi-determinate varieties do not continue growing once the plant begins to produce fruit. They are generally short plants with a defined fruiting period. Semi-determinate varieties grow a little taller than fully determinate varieties.
• Indeterminate varieties continue to grow, producing new leaves and flowers for an extended period of time. They can grow very tall. Longer harvest periods help deal with fluctuations in market prices. Indeterminate varieties require more work as they need to be staked or trellised and generally require more management.

3.3 Disease resistance
Some varieties are resistant to different kind of diseases. Information on seeds will be available from seed companies but all use the same letter code for disease resistance (V-verticillium wilt, F-fusarium wilt, N-nematodes, T-tobacco mosaic virus).
3.4 Adaptation to season
Most tomato varieties are adapted to dry seasons. Successful wet season production requires a combination of suitable varieties and careful management practices (raised beds, proper nutritional programs, Integrated Pest Management practices and preventative disease control).

3.5 Hybrid or non-hybrid seeds
Hybrid varieties are popular because of their higher yields and more uniform fruit. Hybrid seed is more expensive however and seeds cannot be saved for future production. Non-hybrid seeds give lower yields but seeds can be saved from previous crops and produce similar crops in future plantings.

The recommendation for any farmer is that if you don’t know a variety, don’t substitute it for the ones you are growing; instead test the new variety in an area that is no bigger than 10% of your planting area to assess its performance. These new varieties should be tested in the dry and wet seasons before switching an entire crop to the new variety.

4. FIELD PREPARATION
Soil sampling should be done once a year to determine the nutritional and pH status of the soil. Soils that are acidic, (pH of 5.5 or less), should be limed to bring soil pH to between 6 and 7. Fertilizer efficiency is greatest at this range. It is also useful to calculate the soil’s water retention values (permanent wilting point and field capacity) to help with the design and management of the irrigation program. Calculating these values only needs to be done once unless there is any large change in quantity of organic material in the soil.

The soil should be prepared 30 days before the planting takes place. This helps avoid any delays and allows for timely completion of all the other pre-plant tasks. The soil preparation should be done to a depth of at least 30-40cm. The field has to be plowed at least once and then harrowed. When plowing, make sure that all the clumps have been worked out of the soil but do not over-cultivate it as this destroys soil structure. Depending on the type of soil and previous activity on the land, there may be compaction or presence of a hardpan. If this is the case, then the land should be subsoiled first.

Raised beds should be made irrespective of the irrigation practices used. Beds have a number of agronomic advantages:
- Good drainage - tomatoes are easily damaged by water logging
- Good aeration (roots need oxygen – plants absorb 90% of their oxygen through the roots)
- Good soil structure to allow proper root growth and development
- Cultural practices such as weeding, scouting, application of pesticides and harvest are all easier
- Soil compaction is avoided because people are forced to walk in the rows and not on the beds

The tomatoes are planted on the top of the beds, which protects them from excess water. Usually, beds are 1 meter wide with furrows of 30-40cm in width. Bed height varies depending on the season; 30cm in dry season and 40 cm in rainy season. Plastic row covers can then be put over the beds for weed control. Mulch is also recommended as an alternative to plastic row covers because it reduces fertilizer leaching and moisture loss in addition to weed control.
It is essential to emphasize good soil preparation - there is no substitute for its beneficial impact on a crop. It has been estimated that a good soil preparation can have a positive impact of up to 25% on yields.

5. PLANTING DENSITY
The desired planting density is 13,333 - 22,220 plants/hectare, although it can rise to 33,000 plants per hectare in indeterminate plants (¾m between rows and 45cm between plants). Density will depend on the variety of tomato grown. Plum tomatoes require the higher densities (18,000 - 22,220 plants/hectare) while the regular salad tomatoes are planted the lower densities (13,333 - 18,000 plants/hectare).

The beds should be about 1.2-1.5 meters from center to center with a plant every 30cm to 50 cm. Depending on planting density, there can be one or two rows of plants per bed. If there are two, the plants should be staggered in a zigzag pattern.

We recommend using a straight stick or pole that can be marked at the required planting distances. This will ensure correct planting distances when making the planting holes. Remember, it is the small details that lead to success.

6. SEEDLING PRODUCTION
When planning seedling production, remember to plant more seeds than the number of plants needed for your planting density. The exact number will depend on percent seed germination and on the number of replants required after transplant. As a guide, an extra 3% of hybrid seeds and an extra 10% of non-hybrid seeds should be sufficient. In total, about 250g of seed is required to produce enough seedlings for one hectare.

Seedlings can either be produced in trays in a nursery or in field nurseries. Seedlings grown in trays are healthier and more vigorous compared to those grown in beds, which tend to suffer root damage when pulled out of the soil.

6.1 Seedling tray production
Choose seedling trays that have 128 to 200 cells; hard plastic trays are preferred because they can be disinfected more easily than polystyrene trays. Disinfect the trays before use with chlorinated water at 100 ppm by submerging for 20 minutes. With calcium hypochlorite at 65%, use 25 cc in a 200 liter drum. A 200 liter drum can treat at least 300 trays. An alternative disinfection method is to treat the trays in hot water (160°F/70°C) for 45 minutes. The trays should be uniformly filled (but not
compacted) with a disinfected planting mixture. The seeds should be planted in the middle of the cells about ½cm in depth (2.5 times the seed’s length). It is essential that the depth of the hole is the same for uniform germination – a marker can be used to ensure proper depth.

The trays are then given a heavy watering so that water starts to drip out of the bottom of the cells. The cells can then be placed in a germination chamber (a black plastic bag for example) and kept out of the shade. The germination chamber makes sure that the seeds germinate together. Much of the management of seedlings is directed at producing a uniform stand of plants in the field – this is the only way to maximize yield potential across all the plants. Once the first seedlings have emerged, the trays are taken out of the germination chamber. The trays are watered 3 times a day until all the seedlings have emerged. From that point on, the seedlings are watered daily. Make sure that a gentle spray is used to prevent washing out the substrate. Watering should not occur after 3.00pm to avoid damping off problems.

Seedlings should be fertilized once or twice a week and application of a systemic insecticide and preventative fungicides should also be included in seedling management. In preparation for transplant, the trays should be watered heavily 2 hours before removal from the trays.

### 6.2 Field nursery production

Choose a well drained area that has not recently had a solanaceous crop on it. Also remember to remove all broad-leaf weeds from the immediate area. Prepare the soil and sow the seeds in rows 6 cm apart. Cover the bed surface with a thin layer of compost and water. Do not allow the soil to dry as this may form a crust that might hinder seedling emergence. Water the seedbed regularly so that it is moist but not waterlogged. Seedlings will emerge within 8 days at an optimum soil temperature of 20 - 30°C.

The seedlings should be thinned 2-3 days after the first 2 leaves appear. At the 2 leaf stage, the seedlings should be fertilized with urea (2.5g urea dissolved in 1 liter of water). Do not over apply nitrogen or the seedlings will grow tall and thin, which will make them vulnerable to physical damage during transplant. Seedling death (damping–off) and poor growth can be due to fungal infection. Fungicides can be applied to the seed bed at or before sowing to control damping–off. Seed can be treated with broad spectrum fungicide to reduce losses from damping–off.
A good seedling, ready for transplant, is in the four or five leaf stage (about 4 weeks old, vigorous and stocky). Care should be taken when removing the seedlings from the field nurseries to prevent root damage. A heavy watering 12 hours before removal will lessen the damage.

Before any seedlings are taken to the field for planting, they should be selected for size - ‘small’, ‘medium’ and ‘large’. The seedlings are then transplanted in rows of plants of their size group. This is done to prevent competition between plants.

7. **TRANSPLANTING**

This activity has three steps to it:

1. **Marking the planting holes:** It is important to ensure correct planting distances and densities. To achieve this, use a marking stick or tube. Put marks or bits of string along the stick at the required planting distances. These marks will guide the worker making the planting holes.

2. **Starter solution:** This solution is a mixture of water and fertilizer (10 kg of DAP in 200 liters of water). 250cc of this solution is placed into each planting hole just before the tomato plant goes in. The value of the starter solution includes:
   - Saturating the soil so that it moulds around the soil plug of the transplant.
   - Acts as ‘glue’ between the transplant and the soil.
   - Gives uniformity to the moisture in the soil.
   - Gives some early nutrients to the plant.
   - Allows the plant to recuperate quickly from ‘transplant shock’.
   The starter solution can be applied using different methods (cups, buckets, backpack sprayers…) the important thing is to make sure each hole gets some of the solution.

3. **Planting:** this should be done once the starter solution has been absorbed by the soil, but before the planting hole dries (no later than 5 minute after applying the starter solution). It is very important to avoid air pockets forming around the transplant in the soil. These tend to fill up with water causing severe root problems. Press the soil firmly around the roots to avoid this. Make sure that the soil water content is optimum (field capacity) at planting. For a few days after transplanting, do not irrigated the crop – a slight amount of water stress will stimulate the plants to produce a more extensive root system. You can start irrigating once the plants start to show signs of wilting at the middle of the day.

Five days after transplant, check for establishment and replant where needed.
8. **WEED CONTROL**

Weeds need to be controlled in the field to prevent them from competing with the crop. Remove the weeds from the furrows by hoeing. Cultivation of the beds can be done to remove weeds and to help soil aeration and water infiltration. Make sure not to damage the plants.

Weeds surrounding the crop should also be controlled as they act as refuges for pests and diseases of tomato. There are a number of herbicides that can be used against weeds in tomato. The exact choice of herbicide will depend on your cultural practices (use of plastic row covers for example) and type of weed.

**Tomato Herbicides**

<table>
<thead>
<tr>
<th>Commercial Name</th>
<th>Active Ingredient</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glyphogan 480 SL, Agro-sate 48 SC, Mamba 360 SL, Glyfos 360 SL, Kalach 360 SL, Roundup 36 SL, Hellosate 48 SL</td>
<td>Glyphosate</td>
<td>If there is nutsedge, it should be applied at least 15-20 days before planting</td>
</tr>
<tr>
<td>Fusilade 12.5 EC</td>
<td>Fluazifop-P-butyl</td>
<td>Only controls grasses</td>
</tr>
<tr>
<td>Dual Gold 960</td>
<td>s-metolachlor</td>
<td>Apply to top of beds prior to transplant. Can also be applied to row middles</td>
</tr>
<tr>
<td>Gramoxone Super 20 SL</td>
<td>Paraquat 20%</td>
<td>Non-selective, burns vegetation. Apply premergence or pretransplant. Can also be used in the middle of the rows or as a plant desiccant after the crop.</td>
</tr>
</tbody>
</table>

9. **WATER MANAGEMENT**

The water requirements of the tomato crop will depend on the type of soil, the climatic conditions of the region and the growth stage of the crop. Insufficient water at any growth stage will reduce yield and fruit quality. Tomato is most sensitive to water deficit during flowering, somewhat sensitive immediately after transplanting and during fruit development and least sensitive during vegetative growth. Because indeterminate varieties flower and form fruit continuously, they are always sensitive
to water deficits. Tomato grows well in moist but not soggy soil, and well-timed furrow or drip irrigation can be effective. Wilting in the late morning indicates that the crop should be irrigated.

To manage an irrigation program, you have to know what the water is doing in the soil. To help visualize this, think of the area of wetted soil as a bulb. This bulb is where the majority of roots grow. If fertilizers are delivered through the irrigation system, they will reach the areas covered by the bulb. The shape of the bulb will depend on the soil type and on the volume and speed of the water delivered by the irrigation system. You don’t want to deliver too much water too fast, which forces the bulb deeper than where the roots can grow – this is a waste of water and fertilizer. There is also the risk of water logging and death of the roots. Alternatively, if the irrigation is too light, you will be restricting root growth and efficiency by which they and the plant grow. Remember, if the irrigation program is bad, even the best fertilizer program in the world won’t make much of a difference. On the other hand, if the irrigation program is good, even a mediocre fertilizer program will produce significant yield increases. This is because plants feed on the nutrients dissolved in soil water – without water there is no nutrient uptake.

As a general rule in the dry season, irrigate every 3 days for the first month after transplanting, and every 3-5 days until crop completion. The root zone of young transplants is shallow so irrigation...
should be frequent and just enough to recharge the root zone. As the crop develops, the root zone expands and so less frequent but heavier irrigation is required. Tomato plants are sensitive to water logging and field should be drained regularly.

10. **PLANT NUTRITION**

Tomato plants can be fertilized with a mixture of organic and inorganic fertilizers. Before beginning any fertilizer program, make sure a soil test is done. The results from the test will be able to tell you what the fertilizer program needs to deliver to make up the difference between what the crop needs for optimal growth and what the soil has available. Fertilizer uptake efficiency by a crop is highly variable and depends on many factors, including fertilizer formulation and placement (surface, incorporated, banded, fertigation), as well as irrigation method and management.

In the tropics it is recommended that 60-120 kg of N, 60-140 kg of P₂O₅ and 60-120 kg K₂O/hectare. It is recommended that half of the fertilizer be applied as a base application (during or soon after land preparation) and the remaining at first fruit set. Fertigation is where soluble fertilizers are delivered to the crop using the drip irrigation system. This is a very efficient means of fertilizing a crop and it can lead to large yield gains. The fertilizer is applied in small quantities on a regular basis (can be as frequent as every day) and the quantities and ratios of fertilizers are altered depending on the crop’s needs. This type of fertilization also can reduce negative environmental impact.

11. **CULTURAL PRACTICES**

11.1 **Windbreaks**

Wind damage is one of the main factors that can damage crop yields and so we need to take measures to lower its impact. It is estimated that 35% of potential yields are lost due to wind damage when the crop is not protected. Ways in which wind can damage crops:

- Mechanical damage that causes lesions and entry sites for plant pathogens
- Movement of insects and the diseases that they vector into the crop
- High transpiration rates leads to increased respiration and loss of energy and yield. Also, if the high transpiration rates lead to water stress, the plant closes the stomata in the leaves, photosynthesis stops and the plant ceases to grow.

The windbreaker barriers can be made of netting or a grass species – they are indispensable for good yields.
Windbreaks can be made from fabric or from plants – if the latter is used, then the windbreak is usually referred to as a live barrier. Grasses such as corn or sorghum make the best live barriers. They grow dense and tall to form a continuous barrier around the crop. Because they come from different plant families to tomato and other crops, there is no chance of them sharing the same pests and disease as the crop. In the case of some insect-vectored viral diseases, the virus is removed from the insect during feeding on the live barrier.

The live barriers should be planted at least a month before transplant. This is so the live barrier forms a dense wall that is higher than the seedlings after transplant. The first few months after transplant are a vulnerable time for plants and the windbreak needs to be in place. It maybe necessary to plant live barriers or construct windbreaks within the crop as well as around the crop. This is because, for every meter high a windbreak is, it gives protection for 6-8 meters downwind. In the case of corn and with beds 1.5 meters apart, a bed of corn would have to be planted every 13 beds of tomatoes. It is recommended that this bed of corn is made up of 4 rows of corn. If a physical windbreak is used, remember that the material used should allow some air through it; otherwise the wind goes over the top of the windbreak and whips around back down the other side.

### 11.2 Staking & trellising

Staking & trellising tomato plants with bamboo poles, wood stakes or other sturdy material provides support and keeps the fruit and foliage off the ground. Staking can increase fruit yield and size, reduce fruit rot, and make spraying and harvesting easier. The stakes should be placed 1.0 - 1.2m

It is important to place stakes before transplant

A homemade tool for hammering the stakes into the soil
from each other, using the shorter spacing with plants that have high yields. The height of the stakes should be between 1.2 - 2m.

For the trellising you can use twine (disinfected if it’s not new) or old irrigation tape. The number of rows of twine used depends on the final height of the tomato variety planted. The trellising begins at 20 days after transplant (DAT) by putting a row of twine either side of the plant about three-quarters of the way up the plant. An additional row of twine should be added every 10 days until 10 days before harvest. There will be around 5-7 rows of twine by the end of the crop.

If old twine or drip tape is to be recycled, it has to be properly disinfected. Use Vanodine (iodine) to disinfect since it works better than chlorine on dirty surfaces. The correct procedure for disinfecting the twine is:

- Wash the twine or tape with clean water to eliminate most of the dirt and plant residues.
- Shake off excess water and place it inside an empty barrel. Put a weight on top of it (a rock or something similar so that the twine doesn’t float) and then fill the barrel with vanodine - diluted it at a ratio of 1 to 500 (200 ml for each 100 liters of water).
- The twine should be left to soak for at least 8 hours (if a shorter time is required, use a higher concentration). Use a new solution of vanodine for each set of twine.

There are other methods of plant support and these include the use of twine suspended from above and the use of individual plant stakes.

11.3 Pruning

Pruning or the selective removal of side shoots to limit plant growth can be used to force fruit maturation, attain larger fruit size and general uniformity. Pruning also improves air circulation within the canopy, reducing foliar disease problems and helping with cultural tasks such as spraying and
harvesting. Normally, because of the amount of labor required, pruning is usually found in greenhouse tomato production.

In greenhouses, all lateral buds are removed from the main stem to help with trellising and fruit management. An alternative pruning technique is to allow one other main branch to grow just below the first fruit cluster. This doesn’t overburden the plant with fruit and gives greater shade to help reduce sunburn and blotchy ripening of the fruit. Fruit pruning is also done to increase fruit size. Depending on market requirements on fruit size, excess fruit are removed at an early stage to allow those that remain to get bigger. Lower leaves can also be pruned to give better ventilation into the canopy of the crop.

12. **PEST AND DISEASE CONTROL**

12.1 **Integrated Pest Management**

Pests and diseases can ruin a high yielding, profitable crop. Plans to protect the crop should begin a long time before planting and control strategies should not be limited to just pesticides. We recommend an Integrated Pest Management (IPM) approach. IPM depends on:

- Healthy plants
- Planning and prevention
- Field sanitation
- Scouting & monitoring
- Integrated control interventions
- Record keeping

12.1.1 **Producing a healthy crop**

The healthier a plant is, the less likely it is that a pest or disease will harm it. Plants have their own natural defense system that works best when a plant has a good root system, has a good nutrition/water management program and is not under stress from things like flooding or weeds. Using the information from this manual correctly will ensure a healthy crop.
12.1.2 Planning & prevention
This starts with site selection and crop selection. What sort of problems have you had on this site before? Nematodes, crickets, cutworms, soil diseases? When was the last time a solanaceous crop was grown on this site? If a solanaceous crop was planted in the field before, there is a good chance that specialist pests and diseases remain in the field or in the surrounding weeds. What sort of resistance or tolerance to diseases/pests do the seeds you are planning on buying have? All these questions help to decide whether you are doing enough to prevent future pest and disease problems.

12.1.3 Field sanitation
Sanitation or field hygiene is directed at removing or minimizing sources of pests or diseases. Keep the surrounding areas (at least 10 meters) free of broad leaf weeds, especially concentrating on those from the *Solanaceae* family. The weeding between rows should be done regularly and any fallen, damaged or diseased fruit should be removed and buried or burned.

12.1.4 Scouting & monitoring
The majority of insect pests are small. Nematodes and diseases are microscopic. If you don’t look for them, you won’t find them until it’s too late. Do not wait until a plant is damaged or diseased before taking action to control the problem. First of all, you need to know what you are looking for – identifying pests and diseases correctly will save you a lot of money. The next section in this manual discusses the major pests and diseases.

Scouting for pests and diseases should be done at least weekly - more frequently in the weeks after transplant. It should include the field surroundings as well as the crop plants. A hand lens will help you to see and identify the pests and diseases. Sampling stations should not be at the field edges or at the ends of the rows as these do not give representative information. Use the scouting information to plot the development of pests & diseases and to determine when they have reached action thresholds requiring control.
12.1.5 Integrated control interventions
Most of the non-chemical control activities help to prevent or minimize pest or disease problems. If these don’t work and the pests or diseases pass our pre-determined action thresholds, we then need to use pesticides. When choosing pesticides, the objective is to choose an effective one that has the lowest human health risk and lowest environmental/non-target organism impact. In addition to choosing the right pesticide, the choice of adjuvant, the application method and management of equipment is also crucial.

12.1.6 Record keeping
Always keep a record of your actions on the farm. This is particularly important for crop protection activities. Certification programs such as GLOBALGAP insist on very detailed pesticide use records. Responsible farming is about making the right decisions based on accurate information. This can only be achieved by keeping good records.

12.2 Tomato pests
The main insect pests found in tomato in Ethiopia are:
- Whitefly
- Aphids
- Leafminer
- Caterpillars
- Mites

12.2.1 Whitefly
These common insect pests have a broad host range and are common on most horticultural and ornamental crops. The small, white flying adults are easy to detect when infested plants are disturbed. Whitefly enter the crop early from surrounding weeds or from nearby crops, making farm sanitation and the use of live barriers essential to the control of this pest. Not only do they do direct damage through their feeding, but they also vector important plant viruses such as tomato yellow leaf curl (TYLC) virus. Because of their ability to vector viral diseases, the action threshold for whitefly pests is low; how low will depend on the viral disease history in your area.

You should be familiar with the nymph as well as the more recognizable adult. Make sure that this pest does not become established during seedling production or soon after transplant. Systemic insecticides are often used to give early control.
Control:
- Plant varieties that are resistant to viruses
- Keep the borders around the crop free of broad leaf weeds. Grasses can be left.
- Make sure that there are no abandoned crops nearby.
- Use live barriers
- Maintain a regular scouting program and use yellow sticky traps to determine numbers
- Use appropriate insecticides and rotate them. Whiteflies have developed resistance to a number of insecticides around the world. For early protection, the use of systemic insecticides at or before transplant can make a big difference.
- Make sure you have excellent coverage, especially on the underside of leaves, which is where the insects are hiding. Use the right spreader/stickers
- Eliminate virotic plants from the crop when they appear.
- If you use plastic row covers, use the aluminum or silver-colored ones to repel the vectors during crop establishment

12.2.2 Aphids
Aphids are small, soft-bodied insects that do direct damage through feeding but also have the ability to spread plant viruses. They are common insects that can be often found on the underside of leaves. Winged adults enter the crop from weeds and from other crops. Adult females give birth to live young (all female) and these rapidly develop into adults. Within two weeks, these new adults are producing the next generation. Aphid populations can easily explode because of this reproductive ability. Normally, when numbers are low, the female adults don’t have wings. When population density starts to get too high, winged females are produced so that they can leave to find new plants to infest. In this way they rapidly spread through a crop.
Aphid colony (the larger aphids are wingless adults)  
Winged aphid adult

**Control:**
- Plant live barriers weeks before transplant.
- Make sure that there are no abandoned crops nearby.
- Keep the crop borders free of broad leaf weeds. Grasses can be left.
- Maintain a regular scouting program and use yellow sticky traps to determine numbers. This is particularly important with aphids, which because of their small size and tendency to hide under leaves are difficult to spot at low population levels.
- Use appropriate insecticides and rotate them. For early protection, the use of systemic insecticides at or before transplant can make a big difference.
- Make sure you have excellent coverage, especially on the underside of leaves. Use the right spreader/stickers
- Eliminate virotic plants from the crop when they appear.
- If you use plastic row covers, use the aluminum or silver-colored ones to repel the vectors during crop establishment

12.2.3 Leafminers

Leafminers are the larvae of small flies that feed on the inside the leaf, causing white, snaking trails. Once the larvae have grown big enough, they cut a hole in the leaf’s surface and fall to the ground to pupate. Adults eventually emerge and begin the cycle again. The adults make small marks in the leaves, which show where they have fed and laid eggs.

Leafminers are usually controlled by their natural enemies (e.g. ants, wasps, diseases) and are not a serious pest unless there has been a misuse of pesticides. Because these insects feed within the leaf, they are largely protected from contact insecticides, which mean that their natural enemies are the ones that die when pesticides are sprayed. For this reason, leafminers are known as secondary pests. Sometimes their mines can be used as an entry point for fungal leaf diseases such as Alternaria and Late Blight.
Control:

- Remove broad leaf weeds from around the crop – this pest has a wide host range.
- Do not overuse broad-spectrum insecticides, especially pyrethroids & carbamates, which kill the natural enemies. For example, if you are trying to control caterpillars, use a selective insecticide such as those that contain *Bacillus thuringiensis*.
- Scout once a week for this pest – counting leaf mines per leaf is an easy way to measure population levels although make sure not to count empty mines or mines where the larva is dead inside (these are brown in color rather than a pale yellow/white color)
12.2.4 Caterpillars

Caterpillars are moth larvae, which have the ability to cause rapid and substantial damage. There are a variety of species that attack tomatoes and they can attack the stem, leaves and fruit from the time of the transplant through until harvest. Eggs can either be laid singly or in large groups (see the photograph below). For scouting purposes, it is easier to look for small caterpillars if you are not familiar with the eggs of your caterpillar pests. The larvae in the early stages are not hard to control and they tend to do little damage if the fruit is not attacked. Large larvae that are close to pupation and adulthood can cause significant damage and they can be difficult to control.

Control:

- Remove broad leaf weeds from around the crop; also look in the grass weeds as these insects also feed on grasses (the tomato fruit borer is also known as the corn earworm).
- Scout on a weekly basis. If eggs or small larvae are detected, application of an insecticide containing *Bacillus thuringiensis* will kill the caterpillars without harming other organisms. The secret to successful scouting is being able to detect small larvae – they are easy to miss but this is the stage that needs to be controlled. Also, some species have a clumped distribution within a field. Well designed scouting routes will ensure detection of these species.
- Rotate pesticides to avoid resistance development and make sure you have excellent coverage, especially on the underside of leaves. Use the right spreader/stickers.
- If the caterpillars are attacking the fruit, make sure to collect the damaged fruit and dispose of it.
12.2.5 Mites
Spider mites are the biggest mite problem in tomato. They tend to be a bigger problem during hot, dry weather. Like all mites, they are hard to detect early because of their small size - most people can’t see them without careful examination using a hand lens. In general detection occurs once the damage is visible. This damage consists of a speckled clearing of the leaves (see right-hand photo below) where the mites have sucked out the contents of leaf cells. They also produce a fine webbing, which at high populations can cover the entire plant. Like with other pests weekly sampling for this pest is crucial.

Mites have a short life cycle and can go from egg to adult in 4 to 6 days depending on the temperature. These new adults begin producing eggs almost immediately. Eggs are largely resistant to pesticide sprays and so weekly sprays allow mite eggs to hatch, develop through to adults and produce more eggs just in time to survive the next round of spraying. This leads to increasing mite numbers even with a regular spraying program. It is essential to spray every 3 or 4 days to avoid this problem.

Control
• Make sure that field borders are cleared of weeds and that there are no abandoned crops
• Only plant clean transplants
• Scout at least once a week – spider mites are found on the underside of leaves, usually on the lower, older leaves. When population levels are high the mites begin to disperse by climbing to the top of plants where they can be more easily picked up and carried to new plants
• Use the appropriate pesticides – mites are not insects and are more closely related to spiders. Only certain pesticides will work against them. Agricultural oils and soaps are effective but there has to be excellent coverage, especially on the underside of leaves.
• When applying pesticides, it is essential that the spray intervals are 3 to 4 days apart.
12.2.6 Root knot nematode (*Meloidogyne* spp.)

Nematodes are microscopic (0.2mm in length), worm-like, soil organisms. There are many different species and some of them are important pests in agriculture. The root-knot nematode is one of the better known types of nematode because of its widespread distribution, large host range and because of the characteristic root damage it causes swollen nodules or ‘knots’ in the roots (see photograph below). This damage to the roots means that one of the first symptoms of nematode attack is a wilting of the plant during hot periods of the day, when the root system is unable to give the plant the water it needs. In severe cases, this wilting can lead to yellowing of the plant and death. In addition to causing root knots, the lesions in the roots allow diseases to enter the plant.

Root knot nematodes are found in all soils, although they prefer sandy soils. They also prefer high temperatures and wet soil conditions (because they live and travel in the soil water). Soil tests can be done to determine the presence of these nematodes, but these tests have to be done in specialized laboratories. Nematodes are sensitive to periods of drought and the absence of host plants. Also, soil micro-organisms that are associated with organic material reduce nematode numbers, which is why adding compost to soils can lower their numbers.

**Control:**

- Before planting, take a soil sample for testing if there is access to a laboratory.
- There are some tomato varieties that are resistant to nematodes (are not so effective in hot weather).
- Do not bring infected soil in the cropping area on machinery or tools.
- Take care not to over-water. Nematodes are spread around the field in run-off.
- Do not use stakes from other fields that are known to have nematodes – soak them in a nematicide before use.
- If a field has nematodes, do not plant a susceptible crop like tomato on that land. Instead plant a non-susceptible crop (a cereal) or leave it fallow for a year or two.
- African marigold (*Tagetes erecta*) and French marigold (*Tagetes patula*) can be used in rotation programs as an effective means of reducing root-knot nematodes.
- There are not many effective pesticides against nematodes. Those nematicides that exist are generally quite toxic to humans and other organisms. If nematicides are used, always read and
follow the label’s instructions. Take all safety precautions. Nematode eggs are not vulnerable to pesticides and so wetting the soil before application stimulates the nematode eggs to hatch.

### List of pests and their chemical control

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Damage</th>
<th>Chemical Control</th>
</tr>
</thead>
</table>
| Whitefly             | *Bemisia tabaci*, *Trialeurodes vaporariorum* & others | Virus transmission & direct feeding         | Nimbicidine 2% (Azadirachtin)  
Confidor 200 SL (Imidacloprid)  
Actara 25 WG (Thiamethoxam)  
Golan 20% SC, Mospilan 200 SP (Acetamiprid)  
Agricultural soaps  
Agricultural oils |
| Aphids               | *Aphis gossypii*, *Myzus persicae* & others   | Virus transmission & direct feeding         | Nimbicidine 2% (Azadirachtin)  
Confidor 200 SL (Imidacloprid)  
Actara 25 WG (Thiamethoxam)  
Golan 20% SC, Mospilan 200 SP (Acetamiprid)  
Agricultural soaps |
| Leaf Miner           | *Liriomyza* spp.                             | Tunnels in the foliage                      | Nimbicidine 2% (Azadirachtin) – soil drench  
Trigard (Cyromazine) |
| Caterpillars (e.g.   | Several (e.g. *Helicoverpa armigera*)        | Mechanical damage to foliage & fruit        | Nimbicidine 2% (Azadirachtin)  
Xentari, Turex 50 WP (Bacillus thuringiensis)  
Thiodan 35% EC, Thionex 25% EC (Endosulfan) |
| Spider mite          | *Tetranychus* spp.                           | Direct feeding                              | Nimbicidine 2% (Azadirachtin)  
Apollo 50 SC (Clofentenzine)  
Cascade 10DC (Flufenoxuron)  
Diazol 60 EC, Ethiozinon 60% EC, Diazinon 60 EC, Basudin 600 EW (Diazinon)  
Oberon SC 240 (Spiromesifen)  
Polytrin C 400 EC (Profenofos)  
Vertimec, Akrimactin 1.8 EC, Dynamec 1.8 EC, Spidermec 1.8 EC (Abamectin) |
| Root knot nematode   | *Meloidogyne* spp.                           | Root damage                                 | Furadan 350 F (Carbofuran)  
Mocap 10 G (Ethoprop)  
Nemacur 5 G (Fenamiphos)  
Vydate 10 L (Oxamyl) |

### 12.3 Tomato diseases

There are a number of diseases that affect tomato in Ethiopia:

- Viruses
- Early blight (*Alternaria solani*)
- Late blight (*Phytophthora infestans*)
- Powdery mildew (*Leveillula taurica*)
- Wilts (bacterial & fungal)
- Bacterial leaf spot (*Pseudomonas syringae*)
2.3.1 Viruses (various)

Viruses are one of the most serious diseases since once a plant is infected, there isn’t a product that can reverse or eliminate the problem. If a plant has a virus, you often see patterns, color changes and malformation of the leaves, fruits and other plant parts. These symptoms are expressed on new growth after the plant has been infected. In tomatoes, viruses are controlled preventively by controlling the entrance of vectors and eliminating them from the crop. Vectors carry viruses from one plant to another – the most important vectors are insects and humans. We have spoken of aphids and whitefly being vectors but we should also recognize that humans are very efficient vectors, who spread viruses from plant on plant on machinery and equipment. In addition, there are practices such as use of infected seed and abandonment of infected crops that allows the virus diseases to proliferate.

The key to virus control is ensuring that clean seed is used; that the crop surroundings are clean of weeds (& also abandoned solanaceous crops); and that the plants are protected from insect vectors for the first month after transplant. It has been shown that early infection with a virus causes enormous yield reductions. For this reason, in areas with virus problems, people use row covers to protect the plants for the first month or so. Something everybody should do is the planting of live barriers a month before transplant – the barriers reduce the number of insect vectors that enter the crop. Barriers can also remove the virus from the insects in some cases. Systemic insecticides at transplant also give a measure of control.

Control:
- Use clean seed (certified seed guarantees this)
- Control weeds around the field weeks before planting
- Plant live barriers
- Try not to plant in fields that have just come out of peppers, eggplant and potato (solanaceous crops)
- Keep aphids and whitefly away from the seedlings & young plants as long as possible. Have protected nurseries and consider the use of row covers and systemic pesticides
- Scout at least weekly for insect vectors (whitefly & aphids)
- Pull up any infected plants to prevent them from acting as a disease source
- After harvest remove all the plants and fallen/rejected fruit.
2.3.2 Early blight (*Alternaria solani*)

Early blight is a fungal disease that occurs on the foliage, stems and fruit of tomato. It is recognizable by the characteristic leaf spots that have concentric rings in the brown, necrotic center. This center is surrounded by a yellowing area. Symptoms are usually seen first in the older leaves, closer to the ground, but they work their way up the plant and can eventually infect the fruit. The fungus comes from infected plant debris left in the soil, from broad leaf weeds and from abandoned solanaceous plants. It can also come from infected seeds. If this is the case, the seedlings will suffer from damping off and collar rot. Heavy dew and frequent rains trigger disease development, especially in plants that are stressed (this includes those with poor nutrition). The disease is further spread by water splash and winds.

**Control:**
- Use tolerant or resistant varieties.
- Produce healthy plants with a good nutrition program – focus on the correct N:K ratio (2.2 to 1.9 during the vegetative stage and 1.6 to 1.4 during the harvest).
- Staking the plants increases air movement within the plant, lowering disease severity.
- Keep the areas around the crop free of weeds. Begin this 2 weeks before transplanting. Make sure there are no abandoned solanaceous crops nearby.
- Scout for the disease, especially when weather conditions favor disease development.
- If a fungicide is to be used, make sure that the application covers both sides of the leaves. Concentrate on the lower leaves as this is where the infection begins.
- Perform a sanitary pruning in severe cases.
- Personnel should perform the control tasks at the end of the day to avoid taking spores to other unaffected crops.
- Destroy all plants at the end of the harvest.

2.3.3 Late blight (*Phytophthora infestans*)

Late blight is a very severe fungal disease of tomatoes and it can destroy a crop in two to three days if no control action is taken. Late blight attacks foliage, stems and the fruit. It is a disease that appears during rainy weather, especially with relatively high humidity and heavy dew. Symptoms first appear as water-soaked spots, usually at the edges of the upper leaves. These spread rapidly. The photos below show the development of late blight symptoms. Particularly noticeable is the white moldy growth on the underside of the leaves when conditions are wet. Fungicides should be applied as soon as symptoms are detected. Preventative spraying may be used before this if weather conditions warrant pre-emptive treatment.
Control

- Produce healthy plants with a good nutrition program – focus on the correct N:K ratio (2.2 to 1.9 during the vegetative stage and 1.6 to 1.4 during the harvest).
- Staking the plants increases air movement within the plant, lowering disease severity.
- Keep the areas around the crop free of weeds. Begin this 2 weeks before transplanting. Make sure there are no abandoned solanaceous crops nearby.
- Scout for the disease, especially when weather conditions favor disease development.
- Preventative sprays are the normal way of preventing/controlling this disease. When fungicides are used, make sure that the application covers both sides of the leaves.
- Destroy all plants at the end of the harvest.

Development of late blight on tomato. The top row photos are of symptoms on the upper surface of the leaves. The bottom row photos are of symptoms on the lower surface of the leaves. It is important to recognize the early signs when effective control is still possible. The lighter green border around the necrotic spot on the upper surface of the leaf shows that infection is still taking place. The grey mold on the lower surface is also evidence of an active infection.

2.3.4 Powdery mildew (*Leveillula taurica*)

This common fungal disease is normally identified in crops by the white mold that forms on the underside of leaves. The problem in tomato is that it doesn’t show these normal symptoms, making it hard to detect. Yellow spots develop on the upper surface of the leaves with only a faint white mold on the underside (see photos). When the symptoms are obvious, with lots of yellow spots, the disease is already at an advanced stage. At this stage it is hard to control and cause significant damage. The disease is an especial problem when the weather conditions favor it – high sunlight and low humidity. Because of the difficulty in identifying the disease, preventative sprays are sometimes used when weather conditions are right.
Control

- Produce healthy plants with a good nutrition program – focus on the correct N:K ratio (2.2 to 1.9 during the vegetative stage and 1.6 to 1.4 during the harvest).
- A good water management program tends to lower disease incidence.
- Keep the areas around the crop free of weeds. Begin this 2 weeks before transplanting. Make sure there are no abandoned solanaceous crops nearby.
- Scout for the disease, especially when weather conditions favor disease development.
- If this disease has been a problem before and weather conditions are right, use preventative fungicide sprays.
- If curative applications of fungicide are made, use the maximum dose permitted of the sticker. This helps the fungicide penetrate the protective wax of the fungus and improves the effectiveness of the fungicide. Make sure there is excellent coverage on the underside of the leaves as this is where the fungus sporulates.
- Personnel should perform the control tasks at the end of the day to avoid taking spores to other unaffected crops.
- Destroy all plants at the end of the harvest.

2.3.5 Bacterial & fungal wilts

Wilts are very dangerous because by the time the symptoms are apparent, there is little that can be done to save the plant. Wilting occurs when the vascular tissue of the plants has been damaged, preventing the normal flow of food and water from the root. Normally, symptoms become apparent after flowering begins. If the development of the disease is slow, the tomato plant sometimes produces side roots from the lower stem, to try and compensate from the damage (this can also occur due to other symptoms such as waterlogging). Fusarium wilt (Fusarium oxysporum) and Verticillium wilt (Verticillium spp.) are two common fungal wilts while bacterial wilt is caused by Pseudomonas solanacearum. Fusarium wilt is a warm weather disease while verticillium wilt is a cooler weather problem. All these diseases are aided by damage to the roots through cultivation and insect or
nematode damage. Bacterial wilt can be distinguished from the fungal wilts by putting a diseased section of clean stem in water. If it is bacterial wilt, a white, milky stream emerges from the cut end.

**Control**

- Consider not planting tomatoes if the field has a history of this disease.
- Maintain good plant nutrition and avoid over-fertilizing with nitrogen.
- Carry out good soil preparation, keep pH regulated and retain organic material in the soil (fusarium wilt prefers acidic, sandy soils).
- Maintain good weed control.
- Avoid over-watering and ensure good drainage - standing water favors the disease.
- Avoid root damage - control insects and nematodes and take care with manual weeding.
- Use preventive fungicides can be used.
- Don’t bring soil preparation equipment or stakes from affected areas if they haven’t been disinfected.
- Pull out the infected plants and apply lime to the hole and to the surrounding plants. Apply a Previcur N (Propamocarb) + Bavistan 50 DF/Goldazim 500 SC (Carbendazim) drench to the same treatment area as the lime.
2.3.6 Bacterial leaf spot (\textit{Xanthomonas campestris} pv. \textit{vesicatoria}) \& bacterial leaf speck (\textit{Pseudomonas syringae} pv. \textit{tomato})

Bacterial spot and bacterial speck are important diseases that can cause a total loss of the crop. They attack foliage, fruit and stems. As the names suggest, these diseases form spots or specks that can join together to form large necrotic areas on the leaves. The spots look water-soaked under humid conditions and there is a yellow halo around the spot or speck. One of the problems of controlling this disease is that it is highly virulent which triggers the plant to protect itself by losing all the infected foliage, flowers and fruit (the a premature aging using ethylene).

Septoria is a fungal disease that is often mistaken for bacterial spot/speck, but there are differences between these diseases. Generally, septoria is found in association with alternaria and it starts from the older leaves, moving to newer ones. The bacterial leaf diseases on the other hand do not usually associate with alternaria (although they could) and they tend to start with the new leaves and spread rapidly from there. If you find spots in the new leaves or inside the foliage, it is very probable that you are dealing with bacterial spot/speck.

The lesions initially affect the foliage (early \& late symptoms), but they also affect the stem, fruit petiole and fruit.

**Control**
- Use certified seeds
- Produce seedlings that are free of the disease
- Use resistant varieties
- Maintain good weed control and begin this control before planting. Make sure there are no solanaceous crop residues in the field at planting. Crop rotation helps this.
- Produce healthy plants with a good nutrition program – focus on the correct N:K ratio (2.2 to 1.9 during the vegetative stage and 1.6 to 1.4 during the harvest).
- Avoid the use of overhead irrigation. If there is no alternative, irrigate in the mornings.
- Salicylic acid and phosphonate applications stimulate the plants to defend themselves (systemically acquired resistance).
- Use a systemic bactericide in conjunction with a contact bactericide and always apply three times.
- Do not move around an infected crop if conditions are wet – this will speed up the spread of the disease.
Many of the diseases described above are a problem every season. For this reason, many farmers begin a preventative, calendarized spray program from early in the crop’s development. These programs should only be initiated if there is a history of the disease and if climatic conditions are or have been right for the disease’s development. If not, it is a wasteful exercise that leads to unnecessary exposure to fungicides.

One example of a calendarized spraying program is to alternate a copper-based fungicide with one that has mancozeb, mefenoxam or chlorothalonil as an active ingredient. The copper fungicides are effective against both fungal and bacterial diseases. The other group of fungicides is better than the copper fungicides at controlling fungal diseases. Therefore, by rotating these two groups at a 7 to 10 day interval, you are protecting the crop against most diseases. For a fuller list of fungicides, refer to the table below.

List of diseases and their chemical control

<table>
<thead>
<tr>
<th>Common name</th>
<th>Technical name</th>
<th>Plant parts affected</th>
<th>Chemical control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virus</td>
<td>various</td>
<td>Entire plant</td>
<td>None – vector control and clean seeds</td>
</tr>
<tr>
<td>Early blight (Alternaria)</td>
<td><em>Alternaria solani</em></td>
<td>Leaves</td>
<td>Amistar 250 SC, Ortiva SC (Azoxystrobin) Score 250 EC (Difenoconazole) Rovral Aquaflo 500, Iprodione 50% SC (Iprodione) Bravo 500 SC, Daconil 75 WP (Chlorothalonil) Flint WG 50 (Trifloxystrobin)</td>
</tr>
<tr>
<td>Late Blight</td>
<td><em>Phytophthora infestans</em></td>
<td>Leaves, stem and fruit</td>
<td>Acrobat MZ (Dimethomorph+Mancozeb) Ridomil Gold MZ (Metalaxyl+Mancozeb) Koicide 101 (Copper hydroxide) Bravo 500 SC, Daconil 75 WP (Chlorothalonil) Previcur N (Propamocarb HCL) Aliette 80 WP, Fosotive 80 WP (Fosetyl-Al)</td>
</tr>
<tr>
<td>Powdery Mildew</td>
<td><em>Leveillula taurica</em></td>
<td>Leaves</td>
<td>Amistar 250 SC, Ortiva SC (Azoxystrobin) Score 250 EC (Difenoconazole) Flint WG 50 (Trifloxystrobin) Bravo 500 SC, Daconil 75 WP (Chlorothalonil)</td>
</tr>
<tr>
<td>Wilting</td>
<td>Fungal and Bacterial</td>
<td>Stem and Roots</td>
<td>Lime Previcur N (Propamocarb HCL) + Bavistan 50 DF/Goldazim 500 SC (Carbendazim) Cultural controls Control mechanical damage to roots</td>
</tr>
<tr>
<td>Bacterial spot &amp; speck</td>
<td><em>Xanthomonas campestris pv. vesicatoria &amp; Pseudomonas syringae pv. tomato</em></td>
<td>Leaves, flowers, stem and fruit</td>
<td>Koicide 101 (Copper hydroxide) Penncozeb 80 WP, Sancozeb 80% WP, Dithane M-45 (Mancozeb 80% W/W)</td>
</tr>
</tbody>
</table>

12.4 Application of pesticides
Poor pesticide control is often a result of bad pesticide choice, careless preparation and poor application practices. By choosing the correct pesticides and by following the correct methods, not
only will control be more effective but there will also be fewer negative impacts on human health and the environment. Below are some key points to follow:

- Follow all directions on the pesticide label – especially the information on safety precautions
- Choose the right pesticide (need correct pest/disease identification and knowledge of its biology). Remember, viral diseases cannot be treated using fungicides
- If more than one pesticide is used, these mix in the following order: wettable powders (W, WP); water-dispersible granules (WDG, DG); emulsifiable concentrates (E, EC); and then water-soluble liquids (S, SL, SE).
- Make sure that the pesticide gets to where the pest is – most of the time pests are found under the leaves. Backpack sprayers and mist blowers have the required pressure needed to deliver the pesticide even with a dense vegetation crop like tomato.
- Add spreader/stickers & penetrants to the pesticide mix to improve coverage, delivery and residual activity (see photo below)
- Make sure that the pH of the water is between 4-6 to prevent deactivation of the pesticide.
- Do not use a sprayer that previously contained a hormone-type herbicide like 2,4-D—tomatoes are very sensitive to these chemicals. Rinsing with water will not remove these chemicals.

Left-hand photo: Water drop with a spreader/sticker added. Right-hand photo: water drop without the spreader/sticker – this will run off the plant taking the pesticide with it
13. **HARVEST**

Extreme care should be taken during harvest, since the effort of raising quality crops can be easily be undone through careless harvest and postharvest practices.

**Harvesting will not improve crop quality – it can either preserve it or spoil it.**

Tomatoes are usually harvested 2½ to 3 months after harvest, depending on the zone and the time of year. The maturity of the harvested tomatoes will depend on the market demands. Maturity at harvest ranges from fully developed, green fruit, through to red, vine-ripened tomatoes. Supermarkets will often ask for tomatoes that were harvested at the color break stage - that is when the fruit have begun the turn to a pinkish-red. These tomatoes are physiologically mature but are still some time from full ripening. This time can be used to get them to market with minimal damage.

The length of harvest will depend on crop type (determinate or indeterminate), crop health and productivity. There can be up to 10 cuts or harvests in one determinate tomato crop if it is a healthy, productive crop. 24 to 30 people are required for each cut per hectare each week. The fruit are placed into buckets or field crates and then sorted in the field. Field selection eliminates the transport of non-commercial tomatoes from the field. All sorting and selecting in the field should be done in the shade and protected from the rain. Apart from physical damage, unnecessary exposure to heat is the biggest factor leading to postharvest losses. In larger operations, tomatoes are taken to refrigerated rooms to take the field heat out of the fruit.

---

**SCHEMATIC TOMATO COLOUR CHART**

<table>
<thead>
<tr>
<th>Color break</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Color Break 1" /></td>
</tr>
<tr>
<td><img src="image5" alt="Color Break 5" /></td>
</tr>
</tbody>
</table>
Key points to harvesting:
- Have your production and harvest dates planned out beforehand
- Communicate regularly with your buyers – there should be no surprises
- Coordinate your harvesting teams and the transporting agents
- Maintain good field supervision of the harvest

14. POSTHARVEST

14.1 Selection
Field classification focuses on size, quality and degree of ripeness. Some causes for rejection in the selection process are given on the next page.

14.2 Packing & transport
Packing into crates or boxes can happen at the same time as classification. The minimum infrastructure needed for a field packing shed is a roof and sorting tables (to keep the fruit off the ground). Workers should be encouraged to work fast, work carefully and take precautions against food safety risks. Packing crates or boxes should not be over-filled and they can be lined with a sponge or any other protective lining – keep them below the height of the container. Transport of the tomatoes should be in covered, ventilated trucks.

14.3 Storage
Storage will depend on the maturity stage of the tomatoes. Two key considerations are:

Temperature
- Mature, green tomatoes - 12½ - 15°C for up to 15 days
- Color break tomatoes – 10 - 12½°C for 8 to 10 days
- Firm, red tomatoes – 7 - 10°C for 3 to 5 days

Relative humidity
- Should be kept between 90-95% to prevent water loss and reduction in quality.
Causes for rejecting tomatoes

- Insect damage
- Late blight damage
- Rots
- Deformations
- Sun burn
- Cat facing
- Blossom-end rot
- Environmental damage
- Bruising
- Spray deposits
- Radial cracking (water issues)
- Field contamination