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U.S.-PAKISTAN PARTNERSHIP FOR AGRICULTURAL MARKET DEVELOPMENT



# CHILI PRODUCTION MANUAL

Chili Production, Harvest & Post-Harvest Management



## DATA PAGE

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## Acronyms

GAP	Good Agricultural Practices
GSP	Good Storage Practices
GPP	Good Post-Harvest Practice
CAC	Codex Alimentarius Commission
PSQCA	Pakistan Standard Quality Control Authority
EU	European Union
FAO	Food and Agriculture Organization
USAID	United States Agency for International Development
CNFA	Creating New Frontiers for Agriculture
HACCP	Hazard Analysis Critical Control Points
Hrs	Hrs.Hours
HVOSV	High Value, Off-Season Vegetable
PE	Economic Threshold Level
ELISA	Enzyme- Linked Immuno Sorbent Assay
LU	Learning Unit
AMD	Agricultural Market Development



## Introduction

The U.S.-Pakistan Partnership for Agricultural Market Development (AMD) was a USAID funded, four-year project. AMD aimed at increasing the efficiency, quality and profitability of the four targeted product lines through strengthening related supply chains, improving market linkages and developing the institutional capacity of catalytic actors throughout these supply chains. AMD collaborated with stakeholders to plan and execute interventions after a thorough sectorial and cost-benefit analysis of the livestock, HVOSV, citrus and mango sectors with focus on farmers, abattoirs, fruit and vegetable processors, and exporters. The project implemented assistance with competitively selected businesses (farmers and processors/exporters) through introduction of new technologies by upgrading infrastructure and equipment through matching grant funds, advanced farm practices (capacity building through technical assistance and tailored trainings) and sustainable market linkages. AMD facilitated collaboration and synergies between producers and processors/exporters with stakeholders from the government, academic and private sectors to make targeted product lines more efficient and competitive (i.e. increased capacity for high-end domestic and export markets and value addition). AMD largely focused product lines upgradation and infrastructure development through matching grant fund mechanism to enhance efficiency or new product development for improved and sustainable supply chain.

## Project Objectives

- ▶ Increase the efficiency, quality and profitability of selected product lines through the adoption of best practices in production, marketing and business organization management which will make the supply chains more competitive. The project will also facilitate an increased demand for Pakistani agricultural products and support supply-demand synergies between producers and buyers;
- ▶ Improve the market linkages within targeted product lines and develop the institutional capacity of catalytic actors within these value chains. AMD works with processors, traders, retailers and ancillary services providers that support the targeted value chains.

## Traditional Red Chili Varieties

Pakistan's traditional round chili variety, which is locally known as either "Longi" or "Dandicut", is praised for its unique taste, flavor and pungency. Sindh province is the leading chili producer in Pakistan, with most of the production centered in District Umerkot and parts of neighboring Districts Mirpurkhas and Badin.

The round chili varieties are mainly open pollinated. Farmers select a few exceptional chilis at harvest, save them over the winter, then extract the seed from these pods to use as seed for the next crop. This has been the common practice for many decades. However, this practice has led to loss of varietal purity, increased disease susceptibility and declining yields. For instance, in the 1980's, the yield of Dandicut variety averaged around 2 tons/acre, but current yields are just under 1 ton/acre and chili production is no longer profitable. Some commercial seed companies are currently working to develop a hybrid variety of the Dandicut chili in order to overcome these problems.

The Dandicut chili pods and powder are not only liked by the consumers for their domestic cooking but are also the preferred raw material for the very well-established spice industry of Pakistan. Hundreds of recipes are prepared using this red chili as the base ingredient and are exported all over the world.

## Traditional Red Chili Cultivation

Of the high value crops, red chili is one of the most important vegetables due to good demand and the

potential for both domestic and export sales. District Umerkot Sindh has been famous for the cultivation of red chili for more than sixty years. At one time the Kunri wholesale market was considered Asia's largest red chili trading market.

Historically chili production started in this area due to favorable agro-ecological conditions. The sandy soils in this area provide adequate water holding capacity while allowing suitable internal drainage. The sandy soil in this area is suitable for field drying of chilis and labor is available.

### **The Challenges Within the Chili Industry**

The declining yields of traditional varieties and absence of good agricultural practices (GAP) provided space for the introduction of hybrid "finger-shaped" varieties with yields averaging three to four times the yield of "Dandicut". Although they are more pungent, these hybrid varieties lack the aroma and taste of the traditional "Dandicut" variety. As reported by all the major red chili processors in Pakistan, the powder of these varieties does not possess the physical qualities of "Dandicut", and it turns to a blackish color within a few weeks after the chili is ground into powder.

Therefore, the industry has determined that there is a need to save the "Dandicut" traditional variety and a major step in reaching that goal is to purify and improve the quality of seed.

### **Objectives for AMD**

Based on the scenario described above, AMD has provided support and coordination to the key players within this important vegetable sector to:

- ▶ Purify and improve the quality of the traditional "Dandicut" variety
- ▶ Increase production (yield/acre) by using GAPs
- ▶ Improve marketing by introduction of grading & sorting prior to marketing
- ▶ Increase farm income
- ▶ Reverse declining cultivation of traditional chili varieties
- ▶ Support the processing industry by increasing quality and quantity of traditional varieties

### **Benefits for the Industry**

Chili processors will have increased availability of the preferred "Dandicut" chilies rather than relying on the less desirable hybrid, finger-shaped varieties

The more desirable traditional variety will be able to target high value export markets

### **Benefits to farmers:**

- ▶ Improved seed and adoption of GAPs will lead to a yield increase of 25%-100%
- ▶ Increased vigor will reduce expenses for pest control
- ▶ Farmers will achieve higher income due to increased quality and quantity

# CHAPTER 1

## CHILI VARIETIES & SAVING SEED

The chili varieties grown in Pakistan are characterized according to shape and type of pollination. For example, some varieties are called “round”, “diamond” or “bullet” shaped. Others may be called “finger” shaped. Pollination types are either “open pollinated” or “hybrid”. Generally, varieties fit into one of these three categories, which combine shape and pollination type, as follows:

- ▶ Round shaped, open pollinated varieties
- ▶ Finger shaped, open pollinated varieties
- ▶ Finger shaped, hybrid varieties

There is another important characteristic, peculiar to the Dandicut variety which is a round shaped, open pollinated variety. When harvested at maturity, the stem remains attached to the plant, rather than releasing from the plant and being harvested with the fruit as is the case with other varieties. This provides a harvesting and processing advantage over the other varieties. It also provides a higher quality chili powder for consumers since the stems are not ground into chili powder as happens with the other varieties.

The Dandicut variety, over the years, has developed into several subtypes.

### Subtypes of chili variety “Dandicut”

#### Kunri 1 subtype

This subtype was introduced by the Chili Research Institute at Kunri. The pod is sharp tipped and shiny and fully filled with the seed. The powder of this variety has dark red color. The average yield potential of dried chili of this variety is around 1600 to 2000 kg per acre.



### **Nagina subtype**

This subtype was also introduced by the Chili Research Institute at Kunri. The chili pod size is a bit smaller than Kunri 1. The pod is also fully filled with the seed. It has a yield potential of 1400 to 1600 kg of dried red chili per acre. Its powder is dark red in color. This variety is up to 70% resistant against root rot.



### **Maxi subtype**

This is a very old subtype. The size of its chili pod is quite large, but it contains a smaller number of seed. After drying it becomes very light in weight. The potential average yield per acre of Maxi dried red chili is around 1000 to 1200 kg per acre.



### **Tall Round subtype**

Tall Round is also an old subtype. The plants grow taller. The pods are round, and it matures a bit late. The average potential per acre yield of dried red chili is around 1000 to 1120 kg per acre.





## Tall Pointed subtype

Tall Pointed pods are sharp-tipped, and the plants grow taller than other subtypes. Its average yield potential is 1000 to 1120 kg per acre of the dried red chili.



## Non-Hybrid Finger-Shaped Varieties

### Talhari variety (non-hybrid long)

A local traditional variety, Talhari, is a very old variety from Sindh. During the winter months, it is sown in the southern areas of Sindh province. Talhari has utility as both green (fresh) and red (dried) chili with farmers deciding on selling in the green or red market based on market conditions.

The average potential production of green chili ranges between 3300 to 5000 kg, and for dried chili, 1000 to 1500 kg per acre.



### Ghotki variety

Ghotki is also an old variety which is mainly grown in northern Sindh. This variety is preferred in pickles and curries. Its average production potential per acre ranges from 2400 to 2800 kg fresh green chili, and 800 to 930 kg for dried chili.



### **Sanam variety**

This variety originated from India. Pods average around 3 inches in length and are well-filled with seed. Its whole red chilis and powder are preferred for curries and other dishes. Average yields of Sanam range from 1600 to 2000 kg dried chili, and 5300 to 6600 kg fresh green chilis per acre.



### **Hybrid Chili Varieties**

#### **P-6 variety**

This variety was introduced by Syngenta. The chili pod is finger-shaped and longer in size. It is dark green in color and mainly used as a green chili. The pod has fewer seed and is mainly used in salads and pickles. Average yield of this variety is around 6600 to 8800 kg fresh green chili, and 2200 to 2660 kg dried red chili per ac



### Sky Red variety

Sky Red originates from South Korea. The pods grow upside down in bunches and the pod is filled with seed. Sky Red is used both in the form of green chili as well as dried red chili. Fresh fruit production ranges from 8000 kg to 10,000 kg, and dried chili production ranges from 2400 to 3000 kg per acre.



### Hot Pepper variety

Hot Pepper also originates from South Korea. Average yield of fresh fruit averages 8000 to 10,000 kg, and dried red chili averages 2400 to 3000 kg per acre.



### Saving Seed for Planting Next Crop

The use of high-quality seed is critical for successful crop production, and chili production is no exception. Using high quality seed results in higher germination percentage which means fewer seed are required per acre. High quality seed result in more vigorous seedlings which are better able to tolerate and resist problems such as pest attacks and environmental stresses. Plants from high quality seed also results in higher yields and better-quality produce. Purchasing fresh, high quality seed is preferred to saving one's own seed. Commercial companies have the equipment, facilities and expertise to harvest, clean, store and treat seed that will produce the highest yields. However, economics sometimes dictate the use of farm-saved seed. Be sure that only seed from open-pollinated varieties are saved. Seed from hybrid varieties will not be "true" to the plants from which they are saved. For those who desire to save their own seed, the following section offers important best management practices.

## Saving Seed Instructions for Farmers

When the crop is nearing maturity, go through the field to identify and tag large, uniform (size, shape, and color), high quality pods.

Allow selected pods to stay on the plants until they become fully ripe and start to wrinkle. Harvest the selected pods from the field. Discard any pods that are off-colored, show signs of disease, etc. Save only the largest and most perfect pods.

Place selected pods into large jute or burlap bags and tie the bags closed. These bags should be loosely woven in order to allow air movement which will reduce mold and improve drying speed.



Bags should be protected from moisture. Do not lay them on the ground but hang them off the ground. Should storms threaten, move the bags into a protected area. Keep night time dew off the bags by placing a cover over them or placing the bags under shelter at night.

Move or shake the bags daily to insure pods are not sticking to each other, and to encourage air movement.

Allow pods to dry for a minimum of 2 weeks. If you have access to a moisture meter, continue drying until moisture is no more than 10%.

Once all the pods are thoroughly dried, it is time to break the pods to release the seed.

Using wooden sticks, beat the sacks thoroughly until all the pods are broken into small pieces.

The use of screens or sieves can be particularly useful at this stage to remove larger pieces of pods and trash.

The seed can then be separated from the smaller pieces of pods, dust and trash using the natural wind or air blown from an electric fan. Care must be taken at this stage in order to avoid seed loss.

Continue screening through moving air in order to select the heaviest seed possible. These are the seed to save for the next crop.

Once the seeds are sorted, check that moisture is not greater than 10%. Place seed in the sun for a few days if there is any doubt.

Once the seeds are thoroughly dry, they can be placed in clean, new cloth bags. Commercial silica-gel desiccant packets can be placed into the bags to collect any residual moisture. An alternative is to use dry milk powder as a desiccant. Place powdered milk into a small bag, the size of a fist, made of cloth, and place a few into a large seed bag. The powdered milk desiccant pack will collect residual moisture for 6 months.



Seed bags should be stored off the ground. Small bags can be hung inside of buildings. Large bags can be stored on a pallet. This allows for air circulation and prevents condensation moisture from ruining seed.

Seed should be stored in areas protected from insects, rodents or domestic livestock.



## Commercial Seed Companies Seed Saving Instructions

The same selection criteria are used as described in the previous section.

### ***Option 1. Drying Pods in Baskets or Bags***

Pods can dry in the sun, in either loose-woven baskets, or in jute or burlap bags.

Once dry, the pods are secured bags so they can be beaten with sticks in order to break open the pods and loosen the seed.

The use of an adjustable flow electric fan can then allow for the separation of dust, seed and pod debris, but care must be taken.

Screens or sieves can help complete the task with workers providing close inspection of the seed in this process.

### ***Option 2. Drying Pods on the Ground on Fabric or Hard Surfaces***

Pods can also be dried on the ground, specifically on geotextile fabric placed on raised soil, higher ground, or concrete floors (under roof or open).

Place the geotextile sheets in areas that are protected from rain, dust and excessive moisture. Pay attention to water drainage in case of rainfall.

Provide adequate space for workers to walk around the edges of the geotextile sheets in order to avoid damaging the pods.

Pods should be spread out on the geotextile sheets. not exceed 3 inches in depth in order to facilitate air movement and drying.

Pods should be turned every day with soft materials such as brooms. The use of metal tools or sharp objects is discouraged since they are likely to wound the pod and increase the opportunity for attack by disease.

During the drying process, remove any sub-standard pods.

## **Final Processing**

Commercial operations may utilize seed processing machinery and should follow the manufacturer's recommendations.

Some commercial operations may have enough labor that they find it more cost-effective to use hand labor to break pods and separate the seed, using a process similar to that described for farmer seed-saving process, above.

Commercial processors, regardless of the method they utilize for drying and separating seed from pods, can generally clean and sort seed better than an on-farm operation. They will usually have the ability to apply seed treatments. The purpose of any seed treatment is to improve seed performance in one or more of the following ways: 1) eradicate seedborne pathogens or protect from soilborne pathogens by treating seed with chemical fungicides, 2) protect seedlings from insect attack, and/or provide systemic insecticidal activity following germination, 3) optimize ease of handling and accuracy of planting (reduce gaps in stand or the need for thinning of seedlings, particularly when mechanical planters are used), and 4) improve germination rates.

Commercial operations generally have improved packaging materials which provide extended protection from seed degradation, as well as improved storage facilities. These capabilities frequently allow commercial seed processors to provide superior seed to farmers. Many growers consider this expense to be a wise investment in their crop.

## **Germination Test**

Knowing the germination percentage of any lot of seed is critical to planting a crop. By having this information, farmers can adjust seeding rates to achieve optimal plant populations. Calculation of the germination percentage can be done by conducting a simple germination test.

The following process describes an easy seed germination test method.

- ▶ Conduct the germination test in a clean area with clean hands.
- ▶ In order to test a representative sample, you should replicate the following process 3 times.
- ▶ Randomly select one hundred seed from the lot to be tested. Count and discard shriveled, broken and discolored seed to identify percentage of pure seed in the sample.



Take a paper towel of a size that can hold 100 seed when placed 2 inches apart, in rows that are 3 inches apart.

Moisten the towel with clean water to the level that the towel is damp, but not saturated.

Cover the seed with another layer of paper towels, insuring that the paper towel is damp but not saturated. The paper towels can now be gently rolled or folded in order to save space and placed into a clean plastic bag.

Place the bags in a place having temperatures from 24 °C to 27 °C. It would be useful to have a minimum-maximum thermometer to track temperatures for the duration of the germination test.

At six, ten and fourteen days after starting the test, remove the paper towels from the bag, unroll or unfold them gently in order to avoid disturbing the seed, and count the number that have germinated, as well as the number that have become moldy. Remove germinated and any moldy seed at each counting. After fourteen days average the three replications. For example, if 91, 88 and 83 seed are germinated in each sample, it would make  $91 + 88 + 83 = 262/3 = 87.6\%$  germination.

This assessment will also help understand seed vigor. Seed which germinated within 10 days are vigorous. The seed which does not germinate in 14 days are not viable. However, keeping seed at lower temperatures may require 21 days or longer to germinate.

If either of the three paper towels is ruined by fungus or mold, discard it from the test and rely on the counts from the remaining two towels. If two of the towels are ruined one should repeat the test with more clean preparation. Generally, germination tests don't require this step, but if two towels out of three are ruined, the test can be repeated by paying attention to cleanliness, or even dipping the seed in a mild bleach solution, such as 10 ml of bleach in 1 liter of water, for 15-30 seconds. This will reduce mold-causing organisms.

### **Aflatoxin Contamination**

Aflatoxins are a family of naturally-occurring mycotoxins produced by fungi in the genus *Aspergillus*. These fungi live naturally in soil, as well as in dead and decaying plant material in fields. Aflatoxins are highly carcinogenic and mutagenic, having the ability to cause liver cancer, damage the immune system

and decrease growth and productivity in both humans and livestock. These toxins are found all over the world. In hot and humid agricultural regions there can be a serious loss to the value of crops from aflatoxin contamination.

Aflatoxins are regularly found in improperly stored staple commodities such as chili peppers, cassava, maize, cotton seed, millet, peanuts, rice, sesame seed, sorghum, sunflower seed, tree nuts, wheat, and a variety of spices. When contaminated food is processed, aflatoxins enter the general food supply where they contaminate both human and livestock foods. Animals fed contaminated food can pass aflatoxin transformation products into eggs, milk products, and meat.

Most strains of *Aspergillus parasiticus* can produce the group of four mycotoxins: B1, B2, G1, and G2, while *Aspergillus flavus* usually only produces B1 and B2. Aflatoxin occurs due to the colonization and contamination by the fungus. This can occur in crop plants in the field, at harvest, during post-harvest activities or in storage. The fungus *Aspergillus flavus* is green in color, but aflatoxin contamination is not always visible. Aflatoxin contamination can be determined through laboratory tests. The degree of aflatoxin contamination depends on temperature, humidity and storage conditions. The most effective way to control aflatoxin contamination in susceptible crops is controlling the growth of the causative fungi. Traditionally, this can be achieved by adopting GAPs, and good harvesting, drying and storage practices. Pest management is also important since insects and diseases expose susceptible plant tissues to colonization of the fungi.

Farmers and processors selling aflatoxin contaminated products are generally penalized with a much lower price than those selling uncontaminated goods. In developed countries where phyto-sanitary standards are strictly implemented, consignments with harmful levels are rejected and at times the suppliers are blacklisted or fined.

Different countries have established limits for the aflatoxin contamination on the products which they import. For example, the European Union allows no more than 10 parts per billion (ppb) of all aflatoxins, except B1 which has a maximum limit of 5 ppb. The US has a maximum allowable limit of 20 ppb of all aflatoxins, combined.

### **Best Weather and Soils for Chili Cultivation**

Hot and humid weather is very suitable for the cultivation chili. Cool, wet weather reduces growth and the plants become more susceptible to disease attack. Temperature should be in the range of 22 °C to 35 °C for good chili production.

The sandy loam, loam and clay loam soils are good for chili cultivation. The soil should be well drained and aerated as it gives a better yield. Highly alkaline or acidic soils are not recommended for chili cultivation.

Chili seed can also be grown in seed sowing trays using peat moss instead of soil. The trays can be placed on clean, dry ground. They should be raised above the surrounding soil in order to drain any excessive moisture. Watering can be done using hand held sprinklers.



## CHAPTER 2

### SITE SELECTION & LAND PREPARATION, PLANTING SEED FOR GROWING CHILIS, INSECT AND DISEASE MANAGEMENT IN SEEDLING NURSERY & IRRIGATION

#### Field Selection & Land Preparation

Chilis grow best in sandy, sandy loam, loam and clay loam soils which are well aerated. Saline, water logged, and clay soils are not recommended for chili cultivation. Chilis are particularly susceptible to seedling diseases. Growers should practice crop rotation and avoid fields which have recently been planted to tomato, brinjal, peppers or white potatoes

Soil should be plowed to the depth of the expected root zone and clods crushed. Normally, soil preparation of 12 to 18 inches deep is considered optimal. Residues of the previous crop should be thoroughly mixed up in the soil through ploughing as it will also increase the organic matter in the soil. This tillage will provide optimum soil structure to produce vigorous seedlings, support plant growth and produce higher yields.

Laser-levelling is a modern technique that uses lasers and highly sophisticated equipment to move soil throughout a field to result in a level field that facilitates the even distribution of water. By using laser levelers, farmers can level fields ranging up to 10 acres.

A level field optimizes water and nutrition application and movement through the field. Uneven soil will result in over-irrigation in some areas and under-irrigation in others, resulting in uneven yields. Uneven water movement also affects fertilizer movement. If water and fertilizer is not optimum, yields will not be optimum.



*Fig. 1. Laser levelling a field*



*Fig. 2. Field after thorough ploughing, laser-leveling, rotary cultivation and ridge formation.  
Notice the uniformity of the soil texture, furrows and rows (beds).*

## Fertilization and Irrigation Planning

Before planting the crop, the soil and water should be tested. Soil and water samples should be collected as per the recommended procedure. Many reputable fertilizer companies and government agencies offer agricultural soil and water analysis at discounted rates.

It is generally recommended to mix a portion of the fertilizer requirement into the soil during the time ridges are formed. A later application of fertilizer at the beginning of the peak fruiting period may be beneficial.

## Ridge Formation

The chili crop is mainly grown through direct seeding or planting seedling transplants on ridges (also called beds) with row to row distance of 3 feet. Furrows between the rows serve as irrigation channels and ridges prevent water-logging of the root zone since the ridge tops are above the zone that is watered. Preventing water-logged ridges will help to prevent seedling diseases. Drip irrigation is an option for highly efficient irrigation, with efficiencies exceeding 90%, and it can easily be established on ridges.



*Fig. 3. Ridges (beds) formed in well-tilled soil, ridge spacing is 3 feet, from center to center.*

### Three Methods of Growing Chili Plants

- ▶ Growing seedlings in raised bed nurseries for transplanting to the field
- ▶ Growing seedlings in seedling trays, and using sterilized growing medium
- ▶ Planting seed directly in field ridges

These methods are discussed in more detail below:

#### Growing seedlings in raised bed nursery

In open fields, seedling nurseries can be established by developing raised beds of 1.5 to 2 feet above the ground. Nurseries can vary in size, but a reasonable size might be 4 x 6 feet, or a larger nursery might be 8 x 12 feet.

Developing seed nurseries flat with the ground should be avoided. Nursery beds should be close to a water source and the bed should be tilled thoroughly so the soil has no clods. The benefit of the raised seed bed is that the excessive moisture drains away from the tender roots. Excess moisture tends to encourage the development of seedling diseases. The seedlings grown on the raised beds will also have better root development, increasing resistance to seedling diseases. A small amount of a complete fertilizer (for example 0.5 to 1 kg) should be applied to the nursery bed in order to help the seedlings get a good start.

After the seedling bed is developed growers can use a string, measuring ruler, stick or a metal rod to create small, straight furrows in which seed should be placed side by side in the rows, approximately 2-3 inches apart. After that cover the seed with ash or straw etc. and apply water through a hand sprinkler. Apply the water gently in order to avoid washing the seed away or covering them with too much water.



*Fig. 4. Watering seedling transplant beds gently with sprinkler cans*





*Fig. 5. Raised bed seedling nursery*

### **Growing seedlings in seedling trays**

An alternative method of growing seedlings is to grow them in seedling trays. These are made of plastic or natural materials such as compressed peat moss. The trays contain a number of individual cells where seedlings can be grown, separated from other seedlings. The advantage is that roots of the seedlings don't become entangled with adjoining seedlings, allowing them to be removed from the trays without tearing roots. Additionally, the seedlings can be removed with soil attached to the small root ball and transplanted with less stress.

Growers often use sterilized soil or a commercially-available growing medium when using seedling trays. The sterilization process kills fungi that cause seedling disease, helping the plant get off to a better start. Growers can make their own sterilized soil for growing transplants by mixing one-part loamy soil, one-part shredded peat moss, and one-part sand. Mix thoroughly and sterilize this soil-peat-sand mix by baking it in an oven for about 1 hour at 100°C.

Seedling trays can be placed on raised beds in the field or in any suitable location. Whether grown in raised beds or in plastic trays, seedling damage by insects can be reduced using fine mesh netting as a cover over the nursery.



*Fig. 6. Seedlings growing in plastic nursery in trays. Roots do not become entangled with roots of other plants, reducing transplant shock when the seedlings are removed*



Apply water regularly to the nursery, as needed, to prevent the seedlings from experiencing drought stress. When the seedlings are 25-35 days old, they should be ready to be transplanted to the field. Water the beds, or seedling trays, thoroughly a few hours before removing the seedlings from the nursery. This will soften the soil and cause less damage when the seedlings are removed. Avoid simply pulling them from the nursery bed because this will cause the loss of the very fine, almost invisible, root hairs. Use a small spade or trowel to help remove the seedlings. Seedlings grown in trays can be removed by gently pulling the plants out, gently bending or twisting the tray. Discard weak or diseased seedlings.

The seedlings should be treated with a liquid NPK fertilizer with zinc and appropriate insecticides and fungicides at time of transplanting. These are usually mixed, according to label directions, and the plant roots are dipped into the solution at the time of planting, or some of the solution is poured into the hole formed for the individual seedlings. Follow label recommendations for the products you select.

A few hours before transplanting, water the field in order to have moisture available for the tender seedlings. The seedlings can be transplanted manually or with a mechanical transplanter.

### **Direct seeding in the field**

Another option is to sow seed directly in the field in well-tilled, leveled ridges (beds). After forming the ridges, apply water and let the ridges settle for a few days. If using furrow irrigation, seed should be sown at the level where the irrigation water moisture level ends in order to insure seed can receive adequate moisture for germination and seedling growth, without danger of being water-logged. Water regularly to avoid drought stress to tender seedlings.

Seed can be planted manually or with a mechanical planter.

### **Insect Pests and Diseases in The Nursery**

#### **Insects with Soft Bodies and Sucking Mouthparts**

##### **Whitefly**

Adults are moth-like and covered with white, waxy powder. Adult female whiteflies are about 1/16 of an inch in length. They are found in groups and easily disturbed, flying in small white clouds quickly if disturbed. A whitefly population can reach very high numbers, quickly, particularly at high temperatures. They are very destructive to many crops, including chilis.

Adult and immature whiteflies feed exclusively on leaves, nearly always occurring on the undersurface. They suck juices from the plants and excrete large quantities of honeydew in which sooty mold grows.



*Fig. 7. Whiteflies on underside of a leaf*



*Fig. 8. Adult whitefly, highly magnified*

### **Control:**

Yellow sticky traps, placed in the nursery can be helpful in monitoring the presence of whiteflies, and can reduce populations in nurseries or greenhouses.

If insecticide applications become necessary, consult with your Extension Agent or farm retail outlet for current recommendations. Follow label directions for use.

### **Thrips**

Adult chili thrips have pale bodies with dark wings and are typically are less than 2 mm in length. They are pale yellow or nearly white in color. Chili thrips feed on young leaves, terminals & developing flower buds with a piercing and sucking mouthpart. The resulting damage causes the leaves to become curled, bronzed & distorted. Their attack reduces plant growth, vigor and yield. Detecting chili thrips is difficult because they are very small in size. Yellow or blue sticky traps can help with detection, as can careful scouting procedures.



*Fig. 9. Pepper leaves curled and distorted due to thrips attack*





*Fig. 10. Adult thrips, seen from above, highly magnified*



*Fig. 11. Thrips damage seen on underside of leaf*

If insecticide applications become necessary, consult with your Extension Agent or farm retail outlet for current recommendations. Follow label directions for use.



Fig. 12. Example of yellow sticky trap



Fig. 13. Blue sticky traps, most effective for thrips, although thrips are also attracted to yellow.



Fig. 14. Predatory mite (right) attacking immature thrips.  
University of California Statewide IPM Project





Fig. 15. Fine mesh netting protects seedlings from some insect damage, depending on size of the mesh.

Some plants naturally repel insects. Marigolds are an example.

Other repellent plants include onions, shallots, lemongrass, garlic and basil

## Bud Mite

The chili bud mite is a highly destructive pest of chilis, particularly in Sindh. It is shiny white, very, very small (0.2 mm in length) and is most commonly found in hot, dry weather. While technically not an “insect”, we’ll consider them as such for the purpose of our discussions.



Fig. 16. Photographs of a female chili mite on the surface of a chili leaf, highly magnified with electron microscope (photos on left), and chili mite damage to chili bud causing tissue proliferation, photo on right. Photos by J. Pena, University of Florida  
[https://entnemdept.ifas.ufl.edu/creatures/orn/broad\\_mite.htm](https://entnemdept.ifas.ufl.edu/creatures/orn/broad_mite.htm)

This destructive pest causes terminal leaves and buds to become malformed. The mite's toxic saliva causes twisted, hardened and distorted growth in the terminal of the plant. Mites are usually seen on the newest leaves and small fruit. Leaves turn downward and turn coppery or purplish. In older plants, the blooms abort and plant growth is stunted when large populations are present.

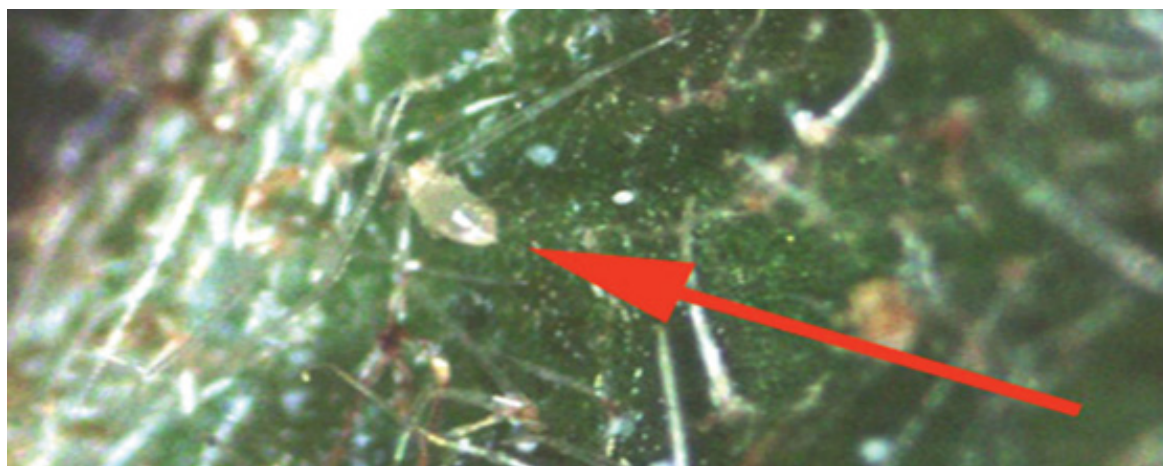
Options for management include sanitation, miticides and biological control. Remove plants that are attacked, and adjoining plants, from the nursery bed.

Conservation or enhancement of biological control agents, such as the predatory mite *Euseius ovalis*, or other predatory mites, can help to reduce chili mite populations.

If insecticide applications become necessary, consult with your Extension Agent or farm retail outlet for current recommendations. Follow label directions for use.



*Fig. 17. Deformed leaves with mosaic (light and dark green), virus-like, symptoms on chili caused by the chili mite.*  
[http://www.pestnet.org/fact\\_sheets/capsicum\\_broad\\_mite\\_049.htm](http://www.pestnet.org/fact_sheets/capsicum_broad_mite_049.htm)



*Fig. 18. Bud mite, highly magnified, on leaf.*  
<http://www.omafr.gov.on.ca/english/crops/facts/14-013.htm>





*Fig. 19. Chili mite damage to chili fruit.*

<https://site.extension.uga.edu/colquittag/2014/10/broad-mites-in-pepper/>

## Aphids

Aphids are very small (2-4 mm in length) insects that are most commonly found on the underside of leaves. They can be green, brown, black or yellow in color and can be most easily recognized by their pear-shaped body and the presence of 2 prominent “tubes” from the rear of the body. Aphids reproduce rapidly and are usually found in large colonies, hidden under leaves away from view. Both winged and wingless forms are found. They move slowly when disturbed. Their mouthparts are like a drinking straw and they only feed on plant juices that they suck out of the plant, causing the leaves to curl, become stunted and often turn yellowish in color. They excrete a liquid waste, called honeydew, that accumulates on the plants. The honeydew supports the growth of several fungi that give the honeydew its characteristic dark, “sooty” appearance.

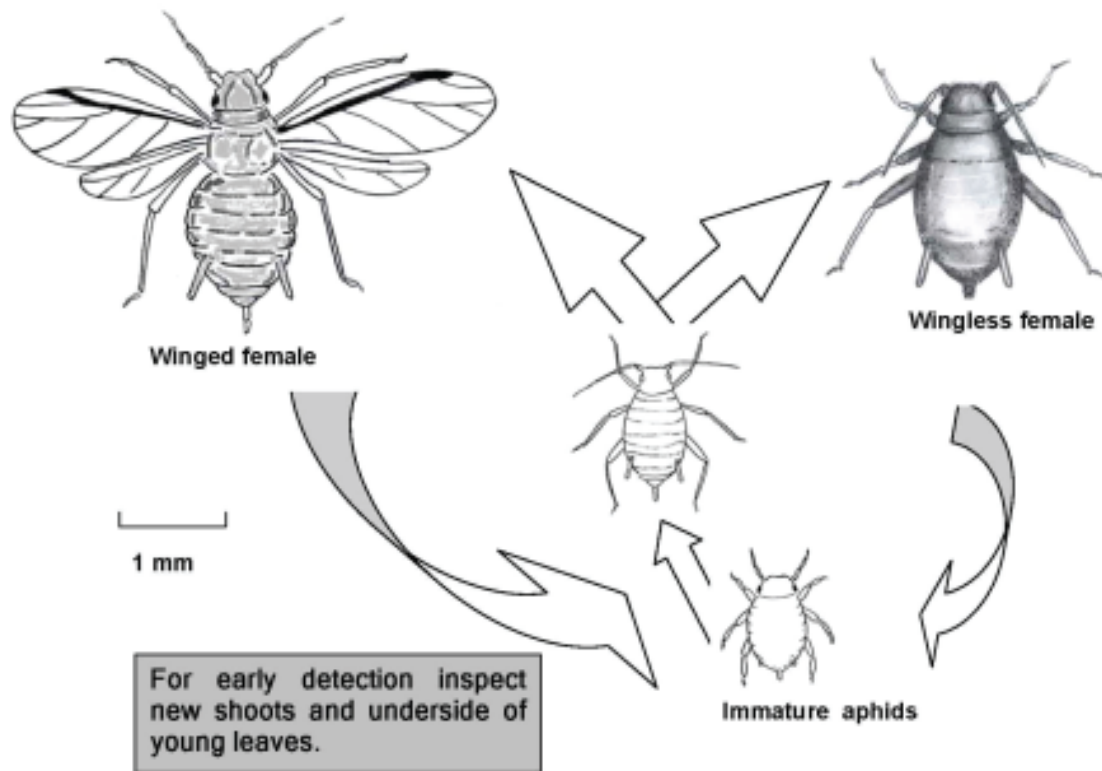


Fig. 20. Typical aphid lifecycle.

<https://www.infonet-biovision.org/PlantHealth/Pests/Aphids>



Fig. 21. Aphids on underside of leaf, highly magnified





*Fig. 22. Aphids on underside of bean leaf.*  
<http://urban-ipm.blogspot.com/2013/>

### **Control Methods for Thrips, Aphids, Whiteflies and Bud Mites in Seedlings and Transplant Nursery**

Chemical insecticides are frequently viewed as the only viable alternative to insect pest management. Over the last several decades, significant progress has been made in the field of Integrated Pest Management, where numerous alternative methods of insect management have become more developed and popular.

Aphids, whiteflies, thrips and bud mites are frequently referred to as “soft-bodied insects” which describes the general characteristic of their exterior. The soft bodies are a weakness that farmers can use to their advantage. Soaps, insecticidal soaps and horticultural oils can be useful in controlling a moderate infestation of these soft-bodied insects. These can be particularly useful in nurseries.

Horticultural oils are usually a type of highly-refined petroleum oil but can also be plant-based. Horticultural oils kill insects by suffocating them. The oil blocks the pores through which insects breathe. They also act on insect eggs. In other insects, horticultural oils inhibit the insect's ability to feed, causing them to starve to death.

Spraying the underside of leaves with a mild solution of water and a few drops of dish soap can also be useful. This soapy water solution should be applied every 2-3 days for 2 weeks. The soap dissolves the waxy protective coating from these soft-bodied insects, causing dehydration and death.

Maintaining weed-free fields and reducing vegetation around the edges of fields can also be useful because some of these insects on weeds, especially grasses, before moving to chili plants.

Aphids, especially, dislike the organic compounds which give onions and garlic their signature aroma. Grow these and other alliums, such as scallion, shallot, leek or chives around the chili field to discourage aphids from taking up residence.

If insecticide applications become necessary, consult with your Extension Agent or farm retail outlet for current recommendations. Follow label directions for use.

## **Insects with Chewing Mouthparts**

### **Cutworms**

Cutworms are the larval form of several different night-flying moths. The adult moths are harmless to plants, but the larvae can be very destructive, especially to young seedlings whether in the seedling nursery or after being transplanted to the field. Cutworms generally feed at night at the soil line, some feed just below the soil, and some climb into the plant. A cutworm curls its body around the stem and feeds on it, cutting it off at the soil surface. During the day, cutworms hide in plant debris and wait until night to start feeding again. As plants age, the stems become tougher and less susceptible to cutworm damage. Cutworm problems vary greatly from one year to the next.



*Fig. 23. Cutworm larva*

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*Fig. 24. Cutworm moth*

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Cutworm moths are attracted to vegetation and crop residues, so eliminate the weed population and old crop residue to make the area less attractive. Plow the old crop residue into the soil thoroughly. Maintain clean field margins by mowing, grazing or plowing. Birds and fireflies are predators of cutworm larvae.

Insecticide applications are seldom required, or effective. Cutworms occur sporadically, usually even within fields they generally attack portions of it, rather than the whole field.

If insecticide applications become necessary, consult with your Extension Agent or farm retail outlet for current recommendations. Follow label directions for use.

### Termite or White Ant

Fortunately, termites or white ants, are not a significant pest of chilis in Pakistan, but they can be an occasional pest. Termites, or white ants, are light brownish in color. These insects live in colonies and prefer sandy and loam soils. They attack the chili plants from the roots, tunneling upward into the stem, causing the plant to die.

Insecticides are not very effective because it is difficult to get the insecticide to the termites. Bait formulations of insecticides, including insect growth regulators, can be more effective because the termites will take these products into the underground colony where it can affect all the termites.

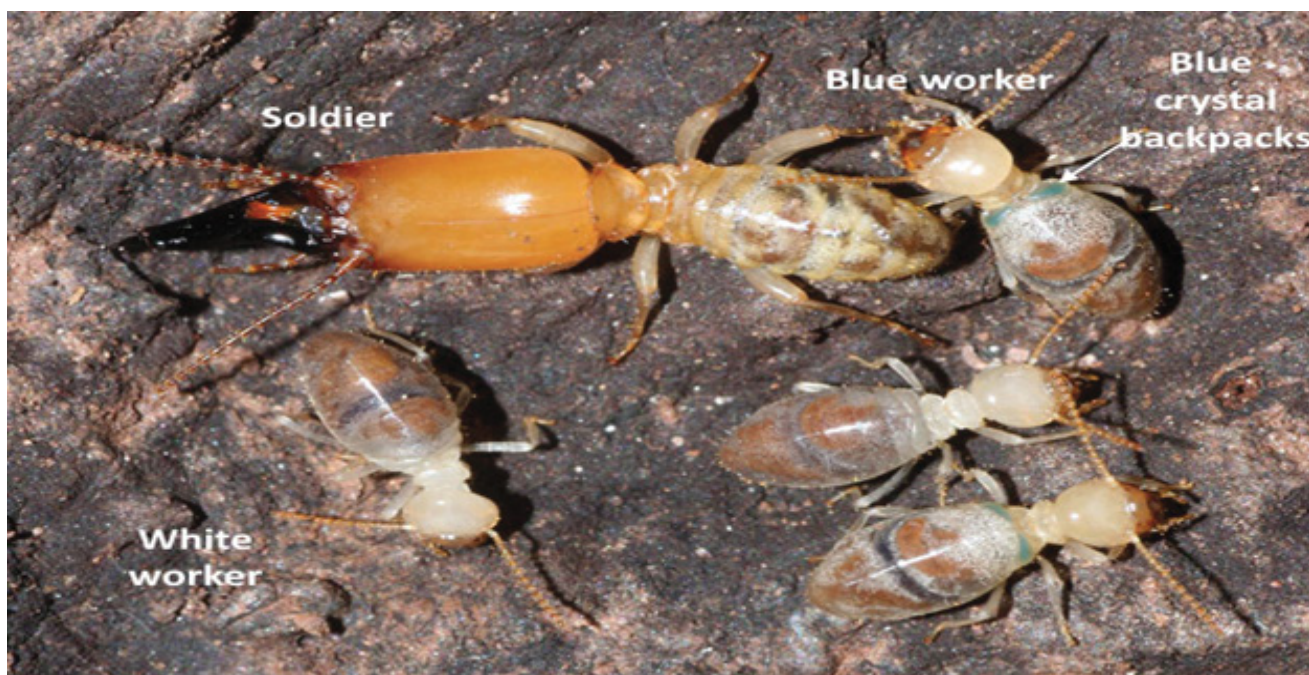


Fig. 25. White ants, or termites



Fig. 26. White ants or termites

If insecticide applications become necessary, consult with your Extension Agent or farm retail outlet for current recommendations. Follow label directions for use.

## Irrigation

### Understanding irrigation water quality

Water quality is of critical importance in irrigation for crop production, including chilis.

Irrigation water quality can be impacted by chemical, physical and biological characteristics, with chemical characteristics being the most important and usually, the most difficult to manage. Very briefly, the chemical characteristics of irrigation water refer to the types and quantity of salts in the water, as well as the effects resulting from the composition of salts in the water, such as EC/TDS (Electrical Conductivity/ Total Dissolved Solids), SAR (Sodium Adsorption Ratio) alkalinity and hardness.

**Salinity** - The main problem related to irrigation water quality is the water salinity. Water salinity refers to the total amount of salts dissolved in the water, but it does not indicate which salts are present. The primary natural source of salts in irrigation water is mineral weathering of rocks and minerals. Secondary sources include atmospheric deposition of oceanic salts (salts in rain water), saline water from rising groundwater and the intrusion of sea water into groundwater aquifers. Fertilizers, which leach to water sources, may also affect the irrigation water quality. Some salts in the irrigation water are more detrimental than other salts in their impact on plant growth. High level of salts in the irrigation water reduces water availability to the crop (because of osmotic pressure) and causes yield reduction. Crops vary in their tolerance to salinity and therefore have different thresholds for damage and yield reduction rates.

TDS ppm or mg/L	EC dS/m	Salinity hazard
<500	<0.8	Low
500 - 1000	0.8 - 1.6	Medium
1000 - 2000	1.6 - 3	High
> 2000	> 3	Very high

*Fig. 27. General crop salinity hazard ratings. Based on electrical conductivity (EC) and total dissolved solids (TDS). [www.smart-fertilizer.com/articles/irrigation-water-quality](http://www.smart-fertilizer.com/articles/irrigation-water-quality)*

Determining the levels of Total Dissolved Solids (TDS) and/or Electrical Conductivity (EC) will allow farmers to provide the quality of irrigation water that will insure healthy plant growth. In general, chilis respond best to low or medium salinity hazard (TDS less than 1000 ppm, or EC less than 1.6dS/m). By knowing the salinity hazard of irrigation water sources (which can change throughout the year), farmers might be able to blend water sources, for example, mix subsurface (well) water with surface “river or lake” water. The only way to determine the salinity hazard of available irrigation water is to have it tested.

### Testing irrigation water

Water testing facilities are offered by the government and private laboratories working in the chili growing areas in Pakistan. Consult the testing lab for recommended sampling procedures, or the lab may send out one of their staff members to collect the water samples.

Individuals can purchase very basic water testing devices, such as pH and TDS or EC meters. TDS (total dissolved solids) can serve as an estimate, but not always an accurate measurement, of EC (electrical



conductivity). For this reason, agronomists and irrigation specialists generally rely on laboratories to test for EC in order to have a more accurate assessment.

A pH meter measures the hydrogen ion activity in water-based solutions and indicates its alkalinity or acidity as “pH”. pH measurements are expressed on a scale from 0 to 14 where 7 is considered neutral. Below 7.0 is known as acidic, and above 7.0 is called alkaline.



*Fig. 28. Portable 3-in-1 Digital Water Test Meter for TDS and EC.*

*[www.doctorponic.com](http://www.doctorponic.com)*

## **Irrigation efficiency**

Water is a precious resource. With an increasing population, water demands are exceeding supplies in many nations, including Pakistan. Demands for domestic, industrial and agricultural water are increasing annually. Farmers in many nations pay for irrigation water and have been forced to adopt more efficient methods of irrigation. Farmers in Pakistan will be wise to consider irrigation efficiency as they move into the future.

### Example of Typical Irrigation Efficiencies

Surface application (flood, furrow)	60%
Sprinkler	75%
Drip	90%

<http://www.fao.org/3/t7202E/t7202e08.htm>

Flood irrigation is the predominate irrigation method in Pakistan. Losses in irrigation canals usually result from leakage, seepage or evaporation, with seepage accounting for most losses. Of course, leaks can account for a tremendous, or total loss, depending on the severity of the leak.

Level fields improve efficiency of irrigation water. Irrigation specialists recommend that flood irrigated plots do not exceed 0.25 acre. This allows the farmer to better control the irrigation water. Thus, if a farmer has 1 acre devoted to chilis, he should divide the field into 4 individual plots, which allows for individual field irrigation.

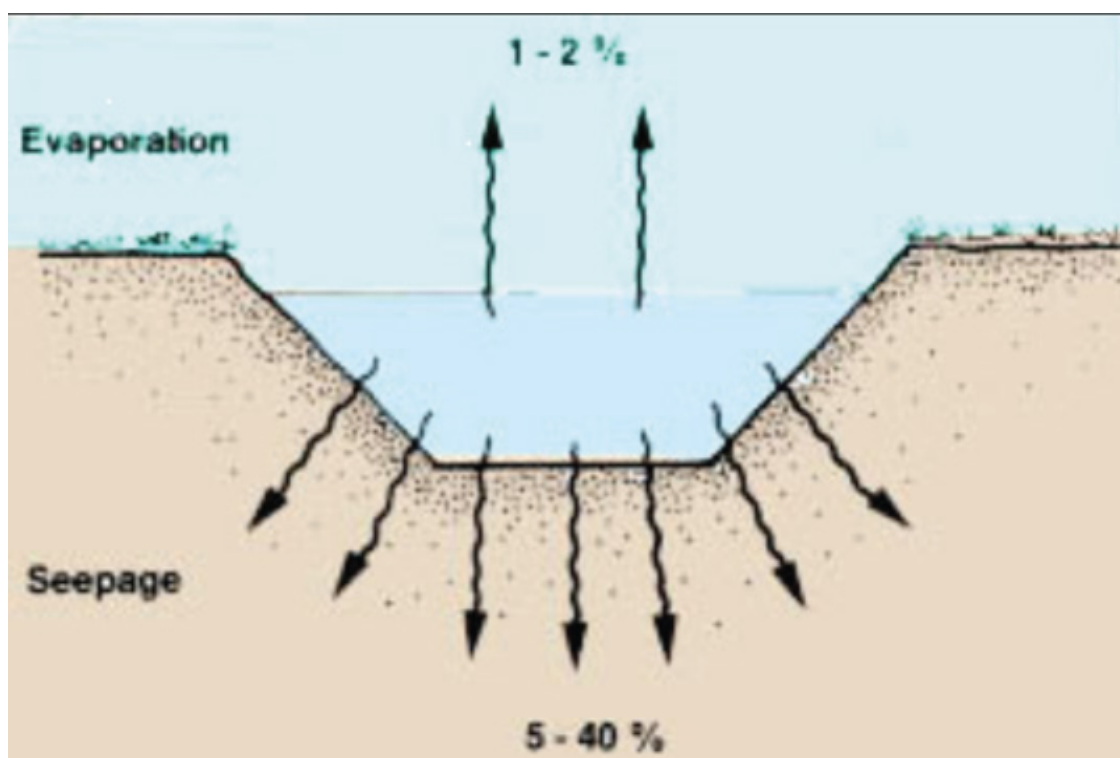


Fig. 29. Water losses in unlined canals or field furrows.

[http://www.fao.org/tempref/Fl/CDrom/FAO\\_Training/FAO\\_Training/General/x6708e/x6708e08.htm](http://www.fao.org/tempref/Fl/CDrom/FAO_Training/FAO_Training/General/x6708e/x6708e08.htm)

### Lining of irrigation canals

Lining water canals with bricks or concrete can greatly reduce leaks and seepage, thereby increasing irrigation efficiency. Evaporation is generally a minor source of water loss.



*Fig. 30. Concrete irrigation canal*

### Siphon System

Furrow irrigation efficiency can be improved with the use of a siphon system. This allows water to be moved from the main canal to the individual furrows through a pipe, which reduces soil erosion and canal deterioration. In a level field, the use of a siphon system also reduces labor.



*Fig. 31. Siphon irrigation method of furrow or flood irrigation*

### Sprinkler irrigation system

Sprinkler irrigation systems are gaining in popularity but aren't usually recommended for use in high value crops due to the potential for spreading, increasing or prolonging disease incidence.

Water not only plays a role in dispersing waterborne pathogens but can provide the moisture that favors the infection and disease development of airborne pathogens. Three conditions must be met for a disease to occur: 1) a susceptible host, 2) a virulent pathogen and, 3) favorable environmental conditions. Sprinkler irrigation water provides moisture and leaf wetness so that if spores of a pathogen land on



a host plant, an irrigation event allows the infection process to begin. As the disease progresses, overhead irrigation can splash pathogens from infected plants to nearby healthy plants, allowing the epidemic to continue to develop in the field.



*Fig. 32. Sprinkler irrigation*

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### **Drip irrigation System**

Drip irrigation is the most efficient irrigation method, with efficiencies exceeding 90%. Drip irrigation uses plastic tubing which is engineered and manufactured with precision water emitters spaced at regular distances along the length of the tubing. The emitters are engineered to release a specific amount of water across a range of water pressures. The drip irrigation tubing is expensive but will last for several years if handled according to manufacturer instructions. This is particularly cost effective in locations where water is not free. Fertilizers can also be applied through this system, placing the nutrients precisely in the root zone. Water for drip irrigation systems must be free of solid particles which can clog the emitters. Thus, filtering systems are recommended.



*Fig. 33. Drip irrigation showing in onions.*

[www.canr.msu.edu/news/irrigation\\_and\\_disease\\_development\\_in\\_michigan\\_vegetables](http://www.canr.msu.edu/news/irrigation_and_disease_development_in_michigan_vegetables)

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The use of plastic mulch in high value crop production is another option for chili production. The plastic, used to cover the plant row, decreases water evaporation, increases irrigation efficiency, increases yield, significantly reduces weed infestation, produces an earlier and higher-quality crop. Plastic mulch can be used with furrow irrigation to achieve both an increase in yield and increased irrigation efficiency.

Plastic mulch, combined with drip irrigation, is considered the current “state of the art” in irrigation for high value crop production. It can be used with, or without drip irrigation, but the combination is one of the most efficient and productive systems for maximizing both yield and irrigation efficiency.



*Fig. 34. Drip irrigation combined with black plastic mulch*

## Managing irrigation intervals as per crop requirement

Chilis grow best in soils with good drainage. Soils that stay wet for extended periods lead to root diseases. Irrigation water should not come in contact with the stems.

Irrigation should be applied on an “as needed” basis only. Applying water too frequently, or infrequently, both lead to reduced yields. Fields should be checked regularly for soil moisture. This can be accomplished using one’s hand, or a small spade to dig into the root zone. Moisture can be checked visually and by feel. Advances in technology also allow someone to measure soil moisture with a variety of devices. Consult your agronomist, irrigation specialist, Extension worker or farm retail outlet for assistance.

Shallow watering should be done to the crop with enough moisture to reach the root zone. Irrigation water should not touch the plant stem.



*Fig. 35. Drip irrigation in a raised-bed, furrow-irrigated field.*

## CHAPTER 3

### WEED MANAGEMENT

A common definition of “weed” is “any plant which is growing where it shouldn’t be growing”. Under this definition a maize, cotton, khabal grass, tomato, cucumber, nutsedge or tomato plant is a weed if it is growing in a chili field. Weeds are undesirable because they compete with chilis for water, space, sunlight and nutrients, thereby decreasing chili yields. Weeds can also serve as a refuge for insects or diseases.

#### Types of weeds

In general, the main weeds impacting chili yields in Pakistan are:



Fig. 36. Wild oat (*Avena fatua*). Local name: Jangli jai





*Fig. 37. Bermuda grass (Cynodon dactylon). Local name: Khabal grass or dhab*

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*Fig. 38. Jungle rice (Echinochloa colona). Local name: Dhela*

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Fig. 39. *Lambsquarter (Chenopodium albus)*. Local name: *Bathu*



Fig. 40. *Horse purslane (Trianthema portulacastrum)*. Local name: *Itsit*





*Fig. 41. Annual beardgrass, annual rabbitsfoot grass (Polopogon monspeliensis).*  
*Local name: Dumb grass, ghooian*

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*Fig. 42. Local name: Laran*

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*Fig. 43. Bokhara clover, white sweet clover (Melilotus albus). Local name: Sanji safeed*



*Fig. 44. Jungle rice (Echinochloa colonum)*





*Fig. 45. Purple nutsedge (Cyperus rotundus)*



*Fig. 46. Toothed dock or Aegean dock (Rumex dentatis)*



Fig. 47. Toothed bur clover, burr medic (*Medicago denticulata*). Local name: maina

Figures 36-47 photo and name credits to Identification of Weeds Presented by M. Anees Khan, Department of Entomology, Faculty of Agricultural Sciences & Technology Bahauddin Zakariya University Multan.

### Importance of weed removal at proper timing

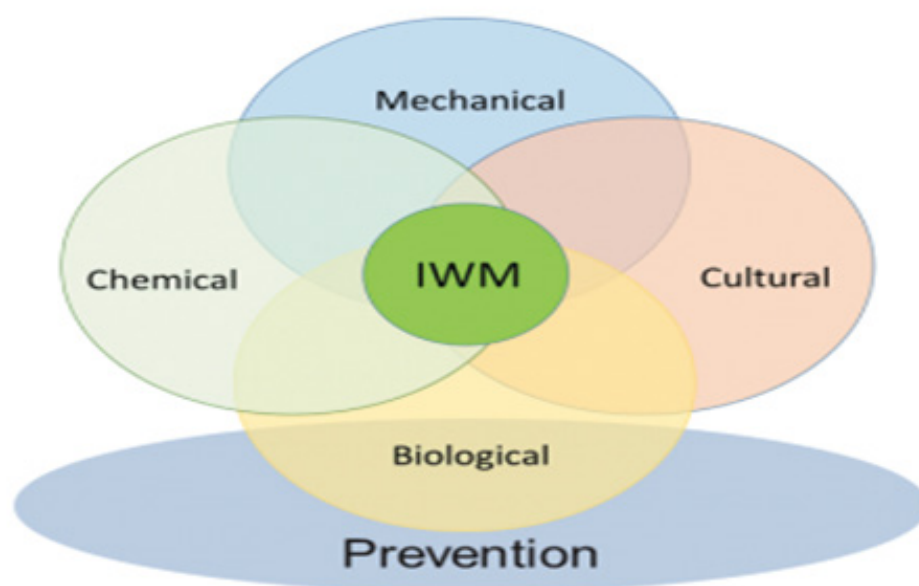
Chilis are tender summer annual crops that require warm temperatures and an adequate supply of nutrients throughout the season to support good growth and yields. Newly emerged seedlings are highly vulnerable to weed competition. Once established, these crops become more tolerant of weed pressure, but early season competition is very detrimental to chili yield. Research shows that the minimum weed-free period for chilis is 8–10 weeks. Again, competition from weeds during this critical period will result in decreased yields.

Chili nurseries should be weed free when transplants are set in the field, or before direct seeding. This can be accomplished with the use of cultivation (ploughing) or herbicides. Irrigation softens the ground and makes cultivation easy at this stage.

### Integrated weed management practices

Weed management is most effective when it integrates a combination of strategies, based on what works best for achieving a specific management goal, while maintaining economic and environmental stability. Common methods span a range of practices, including prevention and cultural, chemical, mechanical, and biological strategies.





**The 5 types of management tactics that can be used in integrated weed management.**

**Illustration: Annie Klodd**

*Fig. 48. Integrated Weed Management.*

<http://integratedweedmanagement.org/index.php/iwm-toolbox/what-is-integrated-weed-management/>

Integrated weed management is not an alternative to herbicides in conventional crops, that is, IWM's goal is not to displace herbicides, but to use them as part of a total weed management strategy. For many decades, herbicides have been the primary means of weed management in conventional crops due to their ease of use, effectiveness and affordability. IWM is about using all options available to best solve the problem – in many cases in conventional crops, herbicides are part of this solution.

## **Prevention**

Preventing weeds is the preferred method of weed management. Weed seed can be brought onto farms in organic fertilizers, manure, seed, soil or irrigation water. Farmers should take care and avoid bringing weed seed onto the farm. Tractors and equipment traveling between farms can easily transport weed seed in soil that travels on the equipment. It's easier to prevent the problem than to solve the problem.

## **Chemical**

Herbicides are a key part of IWM in conventional and some organic systems. As is true with other classes of pesticides, it is important that farmers rotate between different modes of action in order to avoid the development of herbicide resistance. Herbicides should be rotated within a growing season, as well as using different herbicides each year, as possible.

## **Mechanical**

Common mechanical methods to disrupt weed growth and survival include cultivation, tillage, ploughing, burning, and hand-weeding. Mechanical approaches to IWM should be integrated when appropriate as part of a larger weed management program. No-till and reduced tillage farmers can also take advantage of mechanical weed management approaches.



*Fig. 49. Tractor-mounted Rotovator, a type of rotary cultivator, for thorough soil and seedbed preparation*



*Fig. 50. Manual tools for weed removal*



## Biological Control of Weeds



A less common IWM strategy is the use of living organisms, including livestock, insects, nematodes, fungi, and bacteria, to attack weeds. Many biological agents target specific weed species, while livestock are relatively more generalist in weed consumption and may avoid eating certain weeds.

### Cultural control

Cultural tactics are crop management decisions that help the crop be more competitive against weeds and help optimize the effectiveness of herbicide applications. Common examples include timely scouting, using the best row and plant spacing to allow the crop to shade out weeds later in the season, crop rotation, crop variety selection, timing of planting, and cover cropping. The use of plastic mulch is also a very effective cultural control method, particularly when black plastic is used. Clear plastic allows sunlight to penetrate and promotes weed growth, black plastic does not.

### Chemical Control of Weeds with the Safe Use of Herbicides

For many farmers, herbicides are the backbone of their weed management program. Herbicides are valuable tools and it's the farmer's duty to use them in a responsible manner. This means following label directions, avoiding environmental pollution, protecting people, livestock and all non-target organisms, and practicing safety in mixing, application and disposal.

Always follow label directions when using herbicides. Safety is your responsibility! Labels are legal documents and strict penalties can result from misuse.



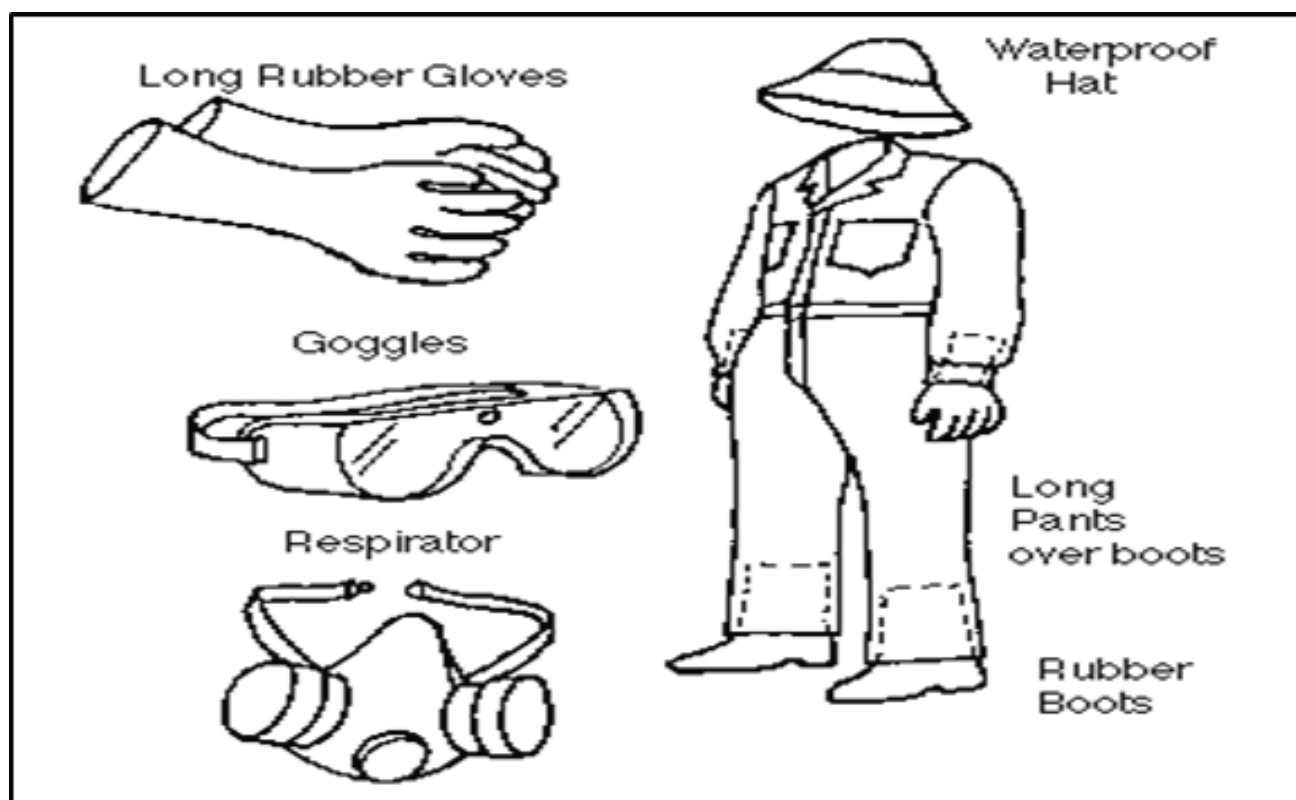


Fig. 51. Typical Personal Protective Equipment (PPE) for pesticide mixing and application

Herbicides are divided into several different categories. Understanding these is important to making wise selections, using the herbicide properly and achieving maximum weed control.

#### ► Definitions describing the placement of herbicide applications

**Soil applied:** Herbicides applied to the soil that come into contact with germinating or emerging weeds, or into contact with the roots of emerged weeds

**Foliar applied:** Herbicides that are applied directly to the plants

**Broadcast:** The application of herbicides evenly across an entire area

**Banded:** The application of herbicides over a portion of the total treatable area (for example, in strips on top of a seedling)

**Directed:** The application of herbicides that are targeted at a very specific area (for example, at the base of a crop plant). In certain situations, this might be referred to as a lay-by application

#### ► Definitions describing the timing of herbicide applications

**Pre-plant (PP):** Herbicides applied prior to planting. Often, this may refer to herbicides that are applied well in advance of crop planting in order to treat existing vegetation

**Pre-plant incorporated (PPI):** Herbicides that are applied prior to planting and that are incorporated into the soil

**Pre-emergence (PRE):** Herbicides that are applied prior to crop and/or weed emergence. The herbicides that are considered PRE may also be referred to as 'residual' herbicides meaning that they are applied to the soil where they provide 'extended' control of germinating or emerged weeds

Post-emergence (POST): May also be referred to as 'topical' or 'over-the-top' herbicides. Herbicides that are applied after crop and weed emergence

#### ► Definitions related to herbicide selectivity

Non-selective: Synonymous with 'broad-spectrum'; a herbicide that controls many different types of plant species

Selective: A herbicide that is effective at controlling some species but not others (for example, mostly broadleaves or mostly grasses)

#### ► Definitions related to herbicide activity

Contact: Herbicides that affect only the plant tissues that they contact

Systemic: Herbicides that are translocated, or moved, throughout a plant

(Source: L.M. Sosnoskie, Ph. D, University of California)

Farmers should be sure to purchase herbicides, and all pesticides, from reputable companies and always follow label directions.

### Types of Herbicide Sprayers

Selection of the right equipment for herbicide applications is very important. As mentioned above, there are many different types of herbicides. Each application may require particular equipment to achieve maximum weed control. For instance, a soil-applied pre-emergence herbicide will have different application requirements than a foliar-applied herbicide. Using the wrong equipment can lead to herbicide failure.

Common sprayers types used are:

Knapsack sprayer: They are usually carried with a strap over the shoulder, or on the back. They usually operate by pressure created from a hand-operated pump.

Electric Sprayer: Small battery-operated sprayers are now very common. These use an electric battery and electric pump to create pressure to spray the herbicide.



Fig. 52. Hand operated and battery-operated knapsack sprayers



*Fig. 53. Small tractor-mounted sprayer. The sprayer is operated by a PTO-driven pump*

### Key factors for consideration during herbicide application

1. The amount of chemical
2. The desired uniformity
3. The coverage of the target surface
4. The potential for herbicide

### Types of nozzles

There are several types of agricultural spray nozzles, or spray tips, available in the market. The most common types are:

1. Flat fan
2. Hollow cone
3. Flood



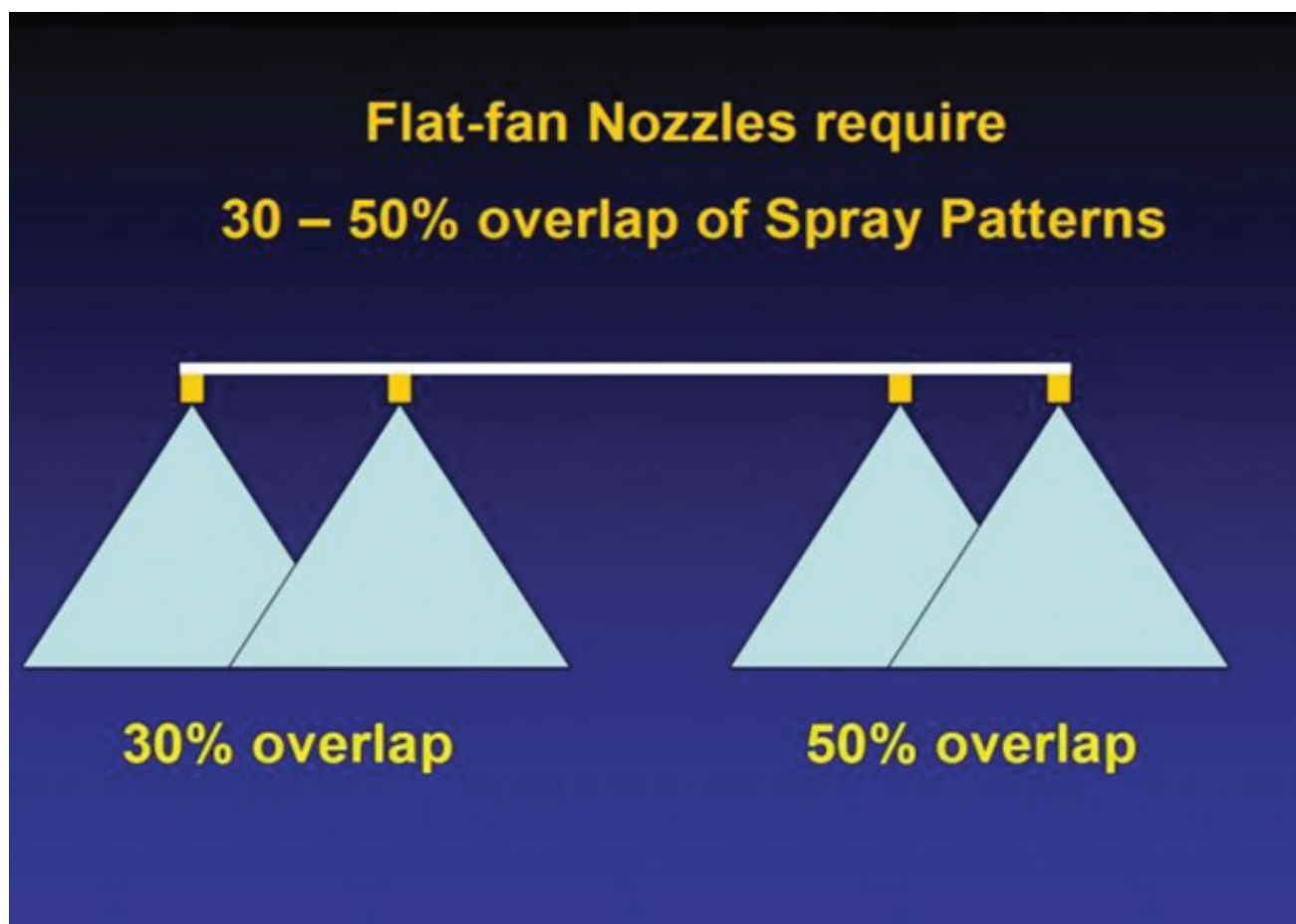


Fig. 54. Flat fan nozzle

Flat-fan nozzles are widely used for broadcast spraying of herbicides. These nozzles produce a tapered-edge, flat-fan spray pattern. These nozzles have several subtypes, such as standard flat-fan, even flat-fan, low pressure flat-fan, extended-range flat-fan, and some special types such as off-center flat-fans and twin-orifice flat-fans. The spray from this tip forms a narrow, elliptical, inverted V pattern which is referred as a tapered spray. The deposition is heaviest at the center of the pattern and dissipates towards the outer edge. Hence a uniform distribution pattern is achieved across the boom when the nozzle height and spacing are optimized.



Fig. 55. Hollow cone type spray nozzle



*Fig. 56. Flood type spray nozzle*

Flood type spray nozzles are often used for pre-emergence herbicides which are applied to the soil surface. Droplets from these nozzles are usually much larger than those from hollow-cone or flat-fan nozzles.

Nozzle selection is a key factor in determining Droplet size, which is determined by the pesticide being applied

- ▶ When coverage is critical, such as in post-emergence contact applications, nozzles with finer droplets are recommended because of the excellent coverage on leaf surfaces.
- ▶ Nozzles producing mid-range droplets are most commonly used for application of contact and systemic herbicides, insecticides and fungicides.
- ▶ Nozzles producing coarser droplets are typically used for systemic herbicides and pre-emergence soil applied herbicides while minimizing drift.

Remember, droplet size can vary based on pressure. The same nozzle can produce medium droplets at low pressures and fine droplets at higher pressures.

### **Calibration of knapsack sprayer**

Sprayer calibration is very important. Under application will result in a reduced rate of the pesticide being applied to the field, resulting in reduced efficacy. Over application could damage the crop.

How do we insure that we know how much we are spraying on a per-acre basis? And, how much of the pesticide do we mix with the water in the sprayer? Since every sprayer has a different capacity, with

different nozzles with higher or lower output, and each operator who works at a different speed, and pumps at a higher or lower pressure, calibration is the only answer. Here is one simple way to calibrate a knapsack sprayer:

- ▶ Measure out a square that is 18.5 ft. x 18.5 ft. (340 sq. ft.). Ideally, this will be on concrete, or dry ground without vegetation. Pay attention to your speed, however, as you may walk faster on the hard surface compared to walking in a soft field. You want to walk with the same speed you would use as you spray the field.
- ▶ Fill the spray tank about half full of water, stand still next to another person and operate the sprayer just like you did in step 1. Have the person next to you carefully measure the time (seconds or minutes, just as long as they measure it accurately) that it takes you to spray the entire 18.5 ft. x 18.5 ft. area. Be sure to keep the spray tank pressure constant throughout calibration and your nozzle at a consistent height where you would typically operate it.
- ▶ Spray the nozzle into the measuring container and collect all the water that comes out of the nozzle, for the same amount of time as it took to spray the 18.5 ft. x 18.5 ft. area.
- ▶ Repeat steps 2 and 3 to make sure your speed and nozzle outflow are consistent. Measure the amount of water sprayed out of the nozzle each time. Average those numbers together to get a representative sample.
- ▶ Whatever amount is collected in the container, measured in ounces, is the amount of water you are spraying, in gallons per acre. For instance, if you collected 40 fl. oz. in your measuring container, this means you are applying 40 gallons of water per acre through the sprayer, when operating at the speed and pressure you used. As another example, if you collected an average of 25 ounces, that means you are applying an average of 25 gallons per acre.

Now that we have calibrated the sprayer (and operator), we now need to know how much pesticide must be added to the tank to make sure the proper rate is being applied. To do this, first locate the rate on the pesticide label. For example, we will use a herbicide that is to be applied at 1 quart per acre. We calibrated our sprayer and find that we are applying 30 GPA, and our spray tank can hold 3 gallons of liquid. Because backpack sprayers are not typically used to cover large areas like an acre and because the spray tanks are quite small, we need to convert the rate from quarts to a much smaller value like fluid ounces. To do this, we plug our numbers into the following formula:

$$\frac{\text{spray tank size (gallons)}}{\text{GPA}} \times \text{pesticide rate per acre} = \text{amount of pesticide required in sprayer}$$

Plugging in our numbers we get the following:

$$\frac{3}{30} = 0.1 \times 1 \text{ quart} = 0.1 \text{ quarts}$$

Because most measuring containers use fl. oz., we can then convert this number into fl. oz. by multiplying by 32 fl. oz. in a quart: 0.1 quarts x 32 = 3.2 fl. Oz



# CHAPTER 4

## SOIL PROPERTIES & FERTILIZER

### Soil Properties

Chilis prefer a well-drained, sandy loam soil, but a few other soil types can be used with satisfactory results. Drainage is critical, so fields with high clay content soil should not be selected. Sandy, sandy loam, loam and clay loam soils can be satisfactory with proper management. Fields selected for chili production should not have been cropped with pepper, potato, tomato or brinjal during the previous two seasons due to the potential for disease.

Soil provides more than just an anchor for plants, it provides most of the plant's habitat. The soil that sustains our lives is quite complex. Soil scientists study the properties of soil, which can be divided into these categories: 1) physical properties, 2) chemical properties, and 3) biological properties. These three soil properties, taken together, determine the productivity of the soil. A fertile and nutrient-rich soil provides essential nutrients to the plants. It has internal space for water and air, allows roots to develop, and has a healthy population of microorganisms.

Of the three soil properties, only the physical properties can be readily observed in the field. Some biological organisms, or their remains, can be observed in a field, but most are too small to see with the eye. Chemical properties can only be identified with laboratory testing. We will focus on soil fertility in this section, but in order to understand this chemical property, we need to understand something of the other two properties.

### Physical Properties of Soils

The particles that make up soil are categorized into three groups according to size – sand, silt, and clay. Sand particles are the largest and clay particles are the smallest. Sand, silt and clay are also known as “solid” portion of soils.

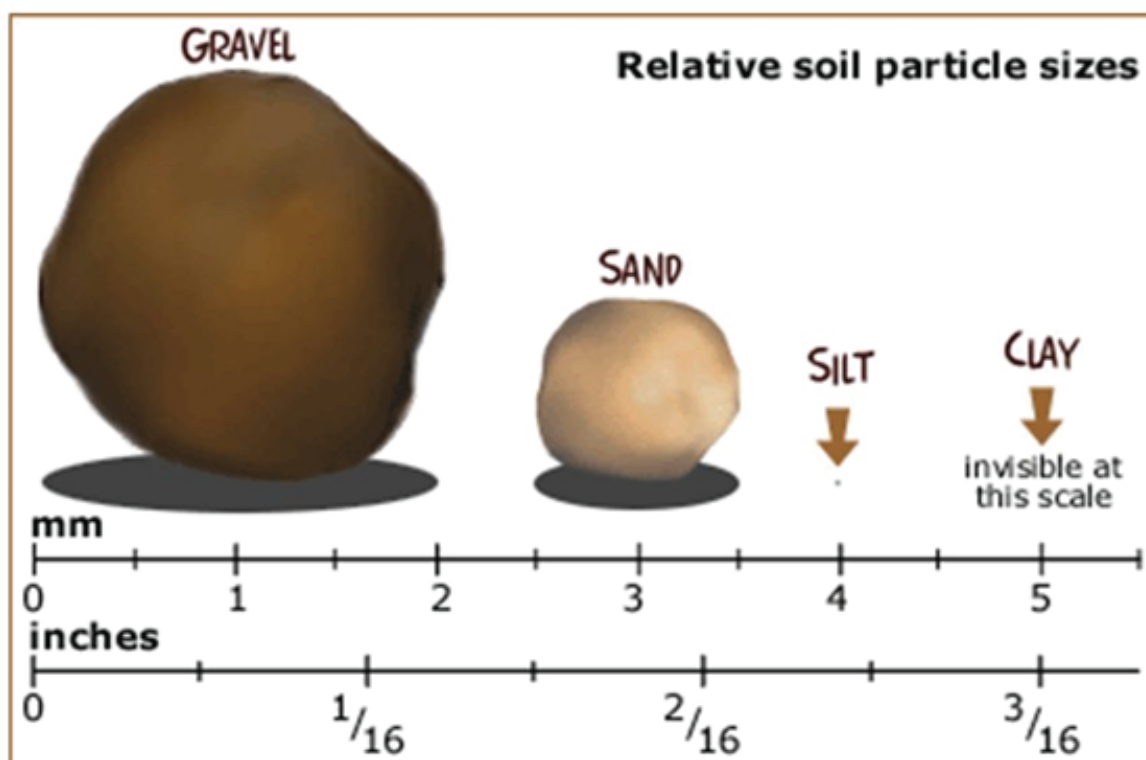
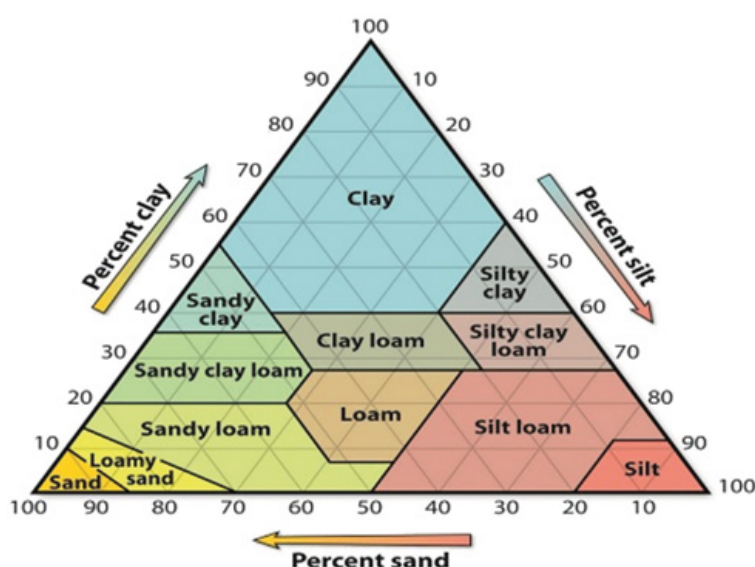


Fig. 57. Comparison of sizes of the three soil particles, Sand, Silt & Clay.

Gravel is not considered an agricultural soil particle

The relative percentages of sand, silt, and clay are what gives soil its “texture”, the way it feels in your hands when you work it. Soil scientists can study a soil in a laboratory and determine the exact percentages of the three soil particles. They have developed the following diagram to show how they determine the “soil texture”, based on the amount of sand, silt and clay.



This is the textural triangle. If you know the percent clay (flat line) and percent sand or silt, you can draw lines into the triangle to figure out what textural category the soil belongs too.

Fig. 58. Soil texture triangle used to determine the soil texture name.

Source: <https://www.soils4teachers.org/physical-properties>

Soil texture can be measured precisely in a laboratory, but it's possible to determine the soil texture in the field with a high degree of accuracy.

A method of determining soil texture by feel is described as follows:

## Assessing soil texture

Carry out this ribbon test on a sample from each layer identified in the soil profile.

1. Take a small handful of soil.



2. Add enough water to make a ball. If you can't make a ball, the soil is very sandy.



3. Feel the ball with your fingers to find out if it is gritty (sand), silky (silt) or plastic/sticky (clay).



4. Reroll the ball and with your thumb gently press it out over your forefinger to make a hanging ribbon.



5. If you can make a short ribbon, your soil texture is loamy, a mixture of sand and clay.



6. The longer the ribbon, the more clay is in your soil.



Do this several times for confirmation and compare the average ribbon length with those in Table 1.

Table 1. Soils textures using the ribboning technique

### SAND

Coherence nil to very slight, cannot be moulded; single grains adhere to fingers; nil to slight turbidity when puddled.

### LOAMY SAND

Will form a ribbon to 5 mm. Slight coherence; definite turbidity when puddled in palm of hand

### CLAYEY SAND

Will form a ribbon 5 to 15 mm. Slight coherence, sticky when wet, many sand grains stick to fingers, discolours fingers with clay stain.

### SANDY LOAM

Will form a ribbon of 15 to 20 mm. Bolus just coherent and very sandy to touch; sand grains visible.

### LIGHT SANDY CLAY LOAM

Will form a ribbon of 20 to 25 mm. Bolus moderately coherent but sandy to touch; sand grains easily visible.

### LOAM

Will form a ribbon of about 25 mm. Bolus coherent and spongy; smooth feel and no obvious sandiness; may be somewhat greasy, as organic matter is usually present.



**SANDY CLAY LOAM**

Will form a ribbon 25 to 40 mm. Bolus strongly coherent, sandy to touch; sand grains visible.

**CLAY LOAM**

Will form a ribbon 40 to 50 mm. Bolus strongly coherent and plastic; smooth to manipulate.

**SANDY CLAY and LIGHT CLAY**

Will form a ribbon 50 to 75 mm. Plastic bolus, slight resistance to shearing. sandy clay - can see, feel and hear sand grains. light clay - smooth to touch.

**LIGHT MEDIUM CLAY**

Will form a ribbon 75 to 85 mm. Plastic bolus smooth to touch; moderate resistance to shearing between thumb and forefinger.

**MEDIUM CLAY**

Will form a ribbon 85 to 100 mm. Smooth plastic bolus; handles like plasticine and can be moulded into rods, moderate resistance to ribboning.

**HEAVY CLAY**

Will easily form a ribbon over 100 mm. Smooth plastic bolus; handles like stiff plasticine; can be moulded into rods without fracture; has firm resistance to ribboning shear.

Each soil texture is classified within a ribbon length range (for example, sandy clay loam ribbon length is 25 to 40 mm long). Therefore, once a consistent ribbon length is being produced, you can be reasonably sure that the correct soil texture has been identified.

*Fig. 59. Determining soil texture using the ribboning technique. Department of Primary Industries.*

*Government of New South Wales.*

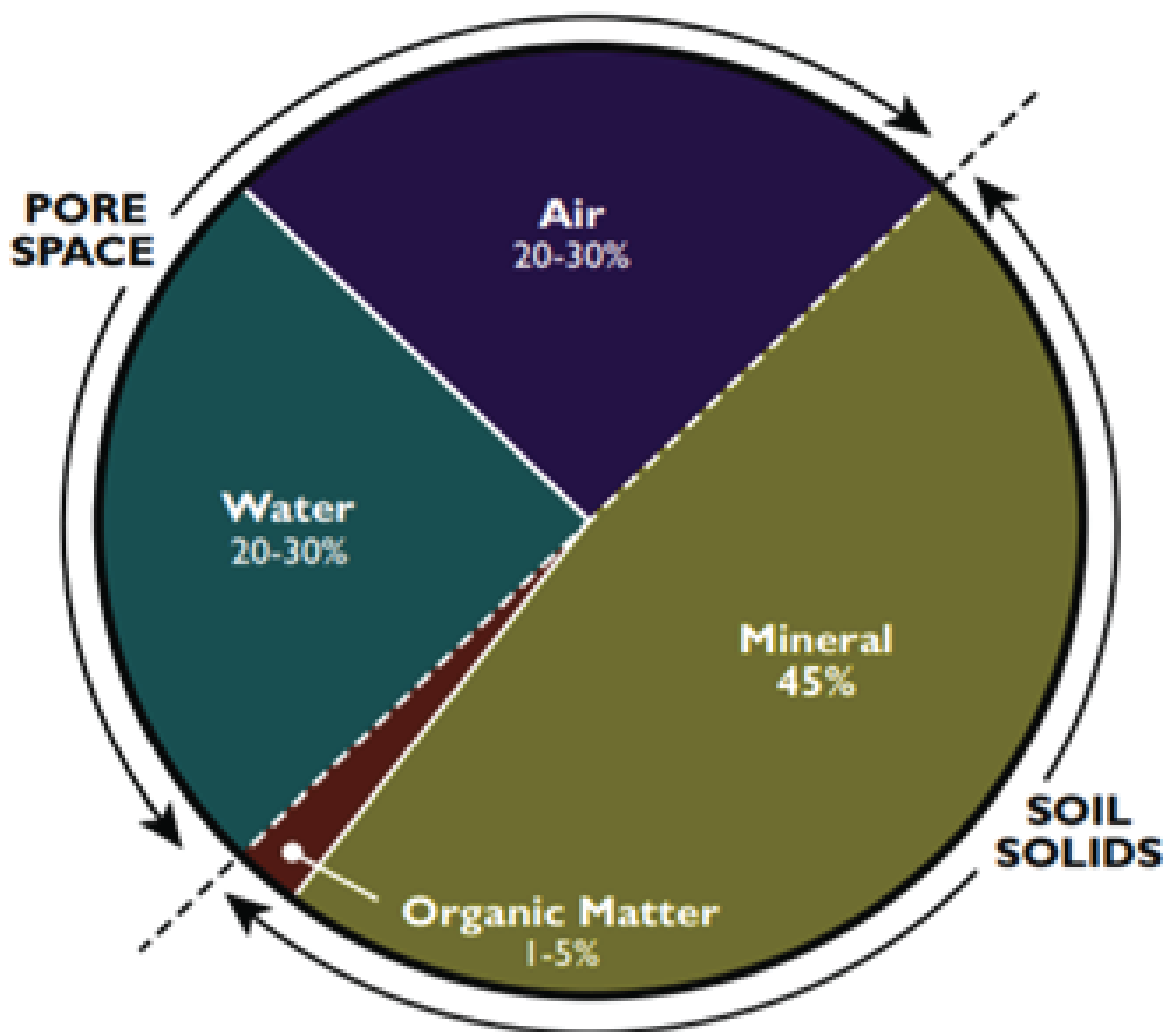
[https://www.dpi.nsw.gov.au/\\_data/assets/pdf\\_file/0005/164615/determining\\_soil\\_texture\\_using\\_-ribboning\\_technique.pdf](https://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/164615/determining_soil_texture_using_-ribboning_technique.pdf)

Size, shape, and arrangement of the primary soil particles (sand, silt and clay) are physical properties of soil, but there are other important physical properties, such as the size and shape of the spaces between the particles. These spaces, known as “pore space” effect the movement of air and water in the soil, which determines the ability of the soil to supply nutrients to plants, and the amount of water available to the plant.

In addition to the soil particles and pore space, we find another component in soil, and that is “organic matter” which can be defined as any living organism, or the remains of a once-living organism that are part of the soil. The residues from a previous crop, now dead and decaying, is organic matter. Living or dead microorganisms, found in the soil, are also organic matter. Organic matter:

- ▶ increases the nutrient-holding capacity of soil
- ▶ provides a supply of nutrients for plants
- ▶ binds nutrients, preventing them from becoming permanently unavailable to plants
- ▶ provides food for soil organisms
- ▶ improves water infiltration in the soil
- ▶ decreases water evaporation
- ▶ increases water holding capacity of the soil
- ▶ reduces crusting, especially in fine-textured soils
- ▶ encourages root development
- ▶ prevents soil compaction

Together, sand, silt, clay and organic matter make up the “solid” portion of soils. Air and water occur in the “pore space” of soils. Thus, soil is composed of all these components, shown below:



*Fig. 60. The four components of soil. Minerals and soil organic matter make up the solid fraction, whereas air and water comprise the pore space fraction. A typical agricultural soil is usually around 50% solid particles and 50% pores. (Adapted from Brady and Weil, 2002)*

The proportions of the four major components of soils can vary greatly from place to place. The amount of water and air in a soil can also change from season to season. However, the physical characteristics of the solid components, inorganic and organic particles, are essentially unchanging.

### Biological Properties of Soils

The biological properties of soils are dictated by the microorganisms within the soil. Good physical and chemical properties supply the right environment and enough nutrients to the organisms. This in turn improves the soil physical and chemical properties through improved structure and nutrient cycling.

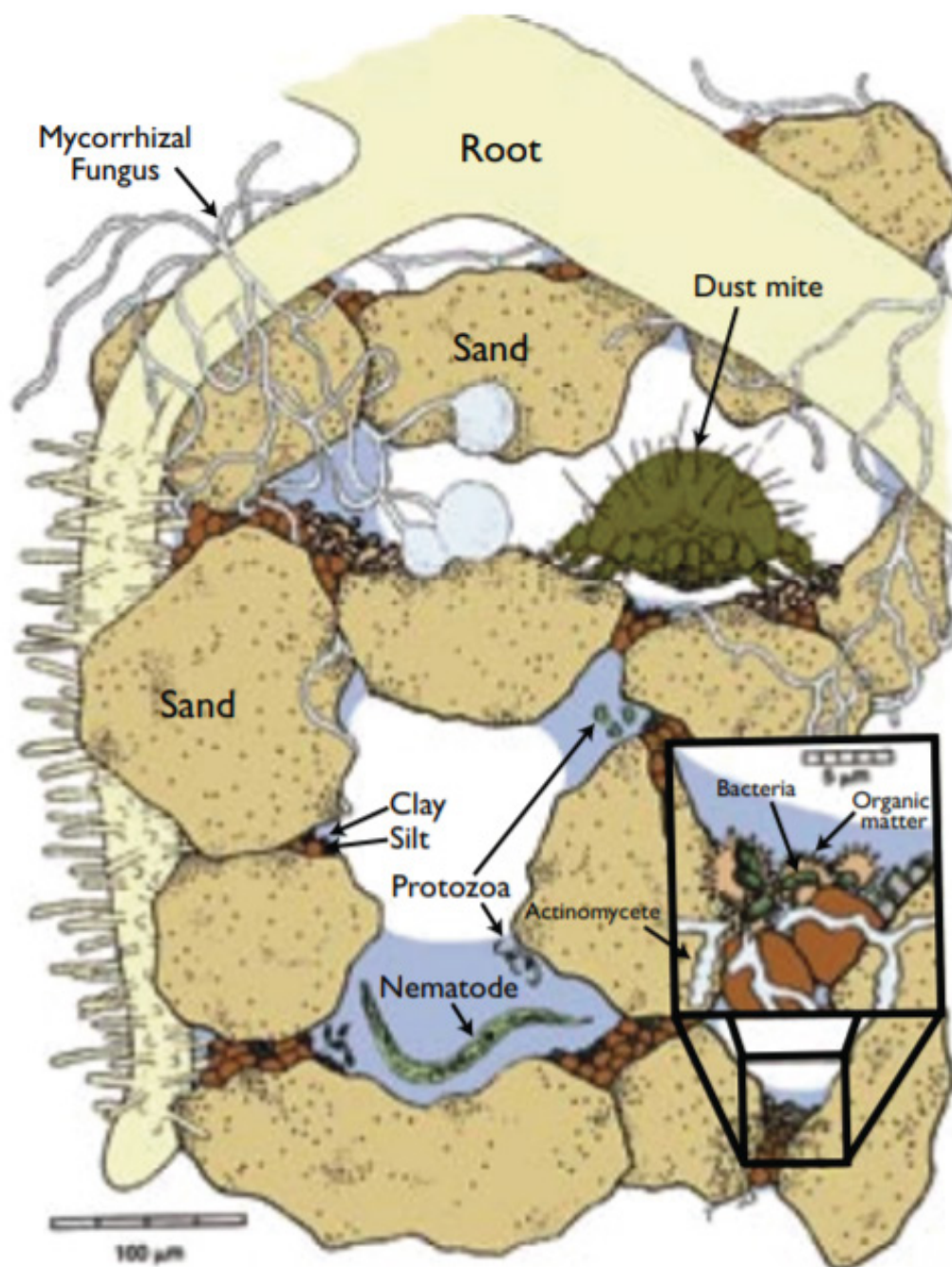


Fig. 61. Soil organisms and their environment. (From Sylvia et. al, 1998)

Plants create space within soils. Root channels from dead roots can remain open for some time after the root decomposes, allowing an avenue for water and air movement. Decaying plants provide organic matter.

Soil microbes are invisible to the naked eye and represent the largest and most diverse biotic group in soil, with an estimated one million to one billion microorganisms per one gram of agricultural top soil. Microbes aid soil structure by physically surrounding particles and 'gluing' them together through the secretion of organic compounds. This contributes to the formation of granular structure in the topsoil where microbial populations are greatest.



## Chemical properties of soils

There are strong relationships between soil physical properties and soil chemical properties. For example, surface area of soil particles is directly related to chemical activity.

### Cation Exchange Capacity (CEC)

The negative ends of two magnets repel each other. The negative end of one magnet attracts the positive end of another magnet. This same principle affects the holding ability of plant nutrients in soil. Some plant nutrients are cations, which have a positive charge, and some are anions, which have a negative charge. Just like the opposite poles on magnets, cations will be attracted to anions.

Soil particles are like a magnet, attracting and holding oppositely charged ions and holding them against the downward movement of water through the soil. The nutrients held by the soil in this manner are called “exchangeable cations” and can be displaced or exchanged only by other cations that take their place. Thus, the negative charge on a soil is called the cation exchange capacity (CEC). Soils with high CEC not only hold more nutrients, they are better able to buffer or avoid rapid changes in the soil solution levels of these nutrients. A soil test will tell you the CEC number of your soil. Soils high in clay, silt, or organic matter will have a CEC number of 10 or greater, and no soil treatment or soil amendment is required. Sandy soils will have a CEC number between 1 and 5. Adding organic matter to these soils will help increase the CEC, but it will be difficult to increase the CEC significantly.

### Soil pH

The soil pH is a chemical measure of soil acidity or alkalinity. Scientists measure pH in the laboratory, or farmers can use small test devices in the field. The pH is measured on a numeric scale from 0 to 14, with values below 7 being known as “acidic”, and values above 7 being known as “alkaline “. Soils usually range from 4 to 10. The pH is one of the most important properties involved in plant growth, as well as understanding how rapidly reactions occur in the soil. For example, the element iron becomes less available to plants as the pH increases. This creates iron deficiency problems. Crops usually prefer pH values between 5.5-8, but the value depends on the crop. Humans can add things to soils to change them to help plant growth. Soil pH also affects microorganisms in the soil.

### Salt-Affected Soils

The presence and concentration of salts in soil can have adverse effects on soil function and make management more difficult. Salt-affected soils are most common in arid and semiarid regions where evaporation exceeds precipitation and dissolved salts are left behind to accumulate, or in areas where vegetation or irrigation changes have caused salts to leach and accumulate in low-lying places (saline seeps).

The three main types of salt-affected soils are:

- ▶ Saline soils: contain a high amount of soluble salts, primarily calcium, magnesium, and potassium
- ▶ Sodic soils: contain high amounts of sodium
- ▶ Saline-sodic: soils have both high calcium, magnesium, potassium and sodium content

Salts in soil can affect structure, porosity and plant/water relations that can ultimately lead to decreased productivity. Managing salt-affected soils can be very difficult.

Calcareous soils are dominated by calcium and magnesium carbonates and generally occur in areas where precipitation is too low to leach the minerals from the soil. Carbonates can be found throughout a soil profile or concentrated in the lower horizons due to downward leaching. Calcareous soils can be distinguished in the field by an effervescence (fizz) reaction that occurs when a drop of strong vinegar is applied. The presence of carbonates in soil can affect soil productivity by influencing soil pH, structure, water holding capacity and water flow. Carbonates can alter soil structure by affecting texture and promoting aggregation.

## **Summary**

Soil physical, biological and chemical properties affect many processes in the soil that make it suitable for agricultural practices and other purposes.

Physical properties such as texture, structure, and pore space influence the movement and retention of water, air and minerals in the soil, which subsequently affect plant growth and organism activity.

Biological properties in soil contribute to soil aggregation, structure and pore space, as well as organic matter decomposition. Organism activity is controlled by various soil conditions and may be altered by management practices.

Chemical properties affect nutrient availability, growing conditions, and in some cases, soil physical properties.

Understanding and recognizing soil properties and their connections with one another is important for making sound decisions regarding soil use and management.

## **Plant Nutrition and Fertilizers**

Plants require eighteen elements found in nature to properly grow and develop. Some of these elements are utilized within the physical plant structure, namely carbon (C), hydrogen (H), and oxygen (O). These elements, obtained from the air and water, are the basis for carbohydrates such as sugars and starch, which provide the strength of cell walls, stems, and leaves, and are also sources of energy for the plant and organisms that consume the plant.

Elements used in large quantities by the plant are termed macronutrients, which can be further defined as primary or secondary. The primary nutrients include nitrogen (N), phosphorus (P), and potassium (K). These elements contribute to plant nutrient content, function of plant enzymes and biochemical processes, and integrity of plant cells. Deficiency of these nutrients contributes to reduced plant growth, health, and yield; thus, they are the three most important nutrients supplied by fertilizers. The secondary nutrients include calcium (Ca), magnesium (Mg), and sulfur (S).

The final essential elements are used in small quantities by the plant, but nevertheless are necessary for plant survival. These micronutrients include iron (Fe), boron (B), copper (Cu), chlorine (Cl), Manganese (Mn), molybdenum (Mo), zinc (Zn), cobalt (Co), and nickel (Ni).

Nutrient	Macro/micro	Uptake form	Mobility in Plant	Mobility in Soil
Carbon	Macro	CO <sub>2</sub> , H <sub>2</sub> CO <sub>3</sub>		
Hydrogen	Macro	H <sup>+</sup> , OH <sup>-</sup> , H <sub>2</sub> O		
Oxygen	Macro	O <sub>2</sub>		
Nitrogen	Macro	NO <sub>3</sub> <sup>-</sup> , NH <sub>4</sub> <sup>+</sup>	Mobile	Mobile as NO <sub>3</sub> <sup>-</sup> ; immobile as NH <sub>4</sub> <sup>+</sup>
Phosphorus	Macro	HPO <sub>4</sub> <sup>2-</sup> , H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	Somewhat mobile	Immobile
Potassium	Macro	K <sup>+</sup>	Very mobile	Somewhat mobile
Calcium	Macro	Ca <sup>2+</sup>	Immobile	Somewhat mobile
Magnesium	Macro	Mg <sup>2+</sup>	Somewhat mobile	Immobile
Sulfur	Macro	SO <sub>4</sub> <sup>-</sup>	Mobile	Mobile
Boron	Micro	H <sub>3</sub> BO <sub>3</sub> , BO <sub>3</sub> <sup>-</sup>	Immobile	Very mobile
Copper	Micro	Cu <sup>2+</sup>	Immobile	Immobile
Iron	Micro	Fe <sup>2+</sup> , Fe <sup>3+</sup>	Immobile	Immobile
Manganese	Micro	Mn <sup>2+</sup>	Immobile	Mobile
Zinc	Micro	Zn <sup>2+</sup>	Immobile	Immobile
Molybdenum	Micro	MoO <sub>4</sub> <sup>-</sup>	Immobile	Somewhat mobile
Chlorine	Micro	Cl <sup>-</sup>	Mobile	Mobile
Cobalt	Micro	Co <sup>2+</sup>	Immobile	Somewhat mobile
Nickel	Micro	Ni <sup>2+</sup>	Mobile	Somewhat mobile

Fig. 62. List of essential plant nutrients and their status as macro- or micronutrients, their uptake forms, and their plant mobility.

Source: [https://nrcca.cals.cornell.edu/soilFertilityCA/CA1/CA1\\_print.html](https://nrcca.cals.cornell.edu/soilFertilityCA/CA1/CA1_print.html)

In order to meet the plant's needs, farmers must apply unavailable nutrients in the form of "fertilizer". Fertilizers are supplied to the soil as amendments which can be from mineral or organic material.

The primary and secondary plant nutrients are typically provided to a crop through fertilizer applications. The micronutrients, required in very small amounts, can be applied through fertilizer, as well. Some can be effectively applied through foliar spray applications. The soil test lab should be able to provide recommendations for micronutrients. Soils in Pakistan are noted for zinc deficiency, and a reputable soil testing laboratory should be testing for zinc, and other micronutrients.

To determine the kind and amount of a fertilizer which is needed in a field, farmers must have a representative sample of the field soil tested in a laboratory. The test kits that are sold in markets are not reliable and should be avoided. Reputable laboratories can test the soil and determine the amount of nutrients available in the soil. Reputable laboratories will provide accurate testing, which allows farmers to make wise fertilizer decisions. By comparing reliable information to the known nutrient requirements of a crop, the laboratory can make a fertilizer recommendation to the farmer.

## Planning and Taking the Soil Samples

Farmers should draw maps of their farm for permanent records. Maps should show field boundaries and any areas within fields that are different from other areas in the same field. Assign a permanent name or number to each field, including a different name or number for different areas in the same field. These permanent field identifiers will help keep records of the soil treatments applied and the crop yields obtained from each area. These identifiers will be used when submitting the soil samples.



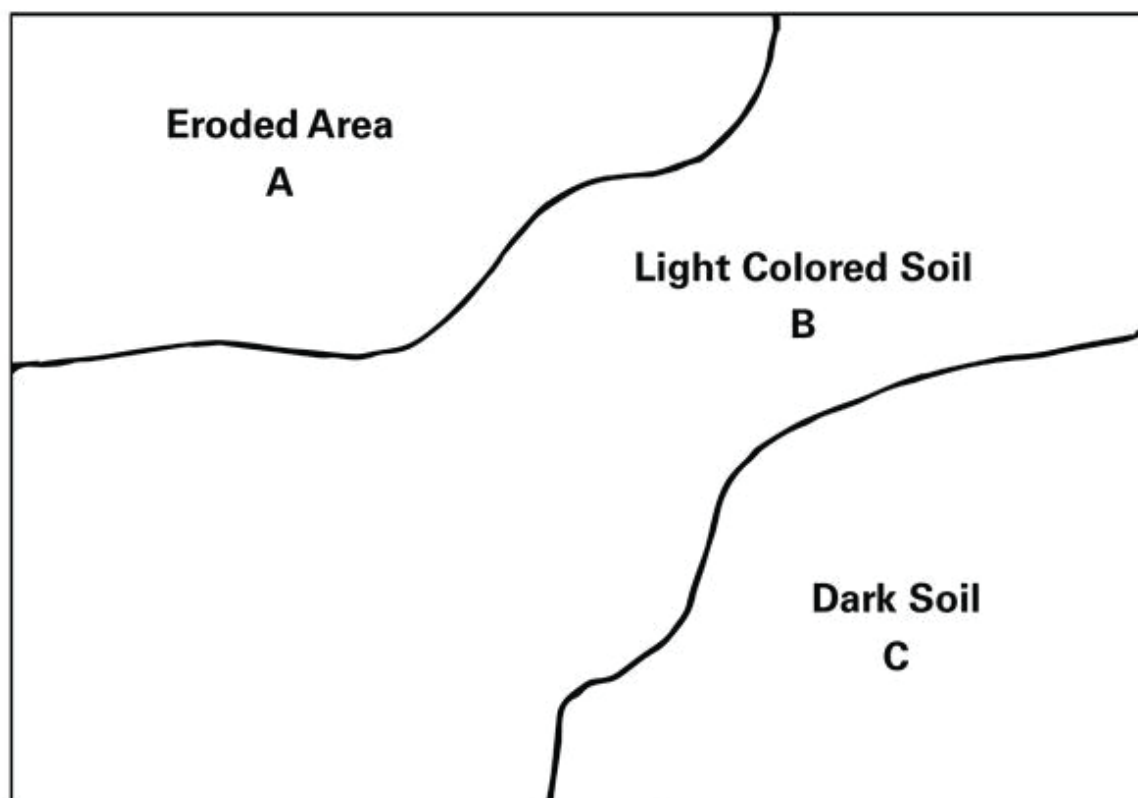


Fig. 63. Field map. If the soil is not uniform across the field, identify the different soil types and take soil samples from those different areas.

Collect soil samples with stainless steel or chrome-plated sampling tools and plastic buckets to avoid contaminating the samples with traces of chemical elements (micronutrients) from the sampling tools. Avoid brass, bronze, or galvanized tools as these can cause contamination and change the test results.

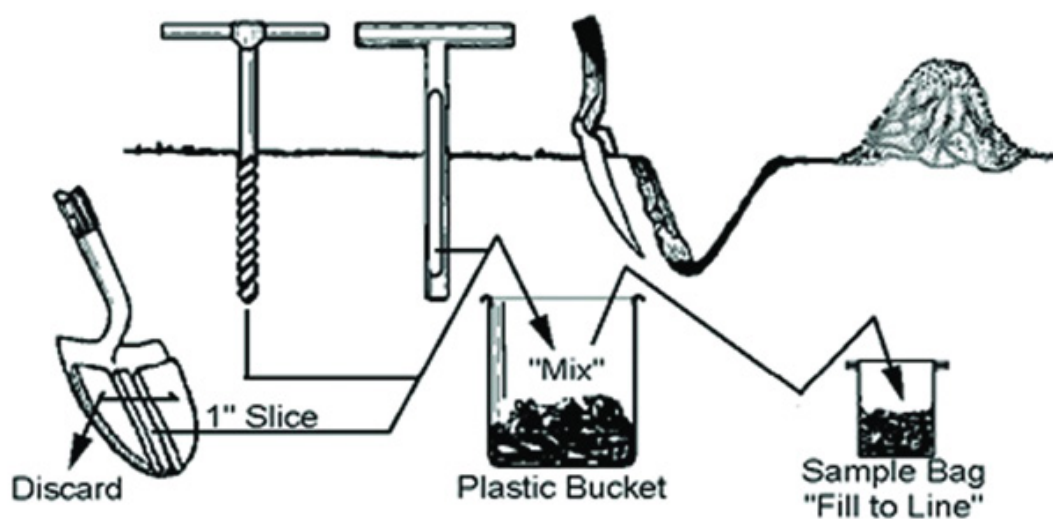


Fig. 64. Diagram instructions for taking soil sample. You can use a shovel, auger or soil test probe to draw the soil samples. Sample 15-20 locations in each field or soil type area. In a field to be planted to chilis, samples should be taken 6-8 inches deep.

Mix those samples thoroughly in a plastic bucket.

After the soil is mixed thoroughly, take about 2 cups of soil and place in a clean plastic bag.

Mark the bag to identify the field, or field area, from which the sample was taken.

This is the soil sample that will go to the soil testing laboratory.

Every soil sample you submit to the soil test laboratory should consist of about 15 to 20 individual samples, or sub-samples, taken at random locations throughout the field. This provides the most representative sample and the laboratory will be able to make the best fertilizer recommendation.

### Samples collected randomly

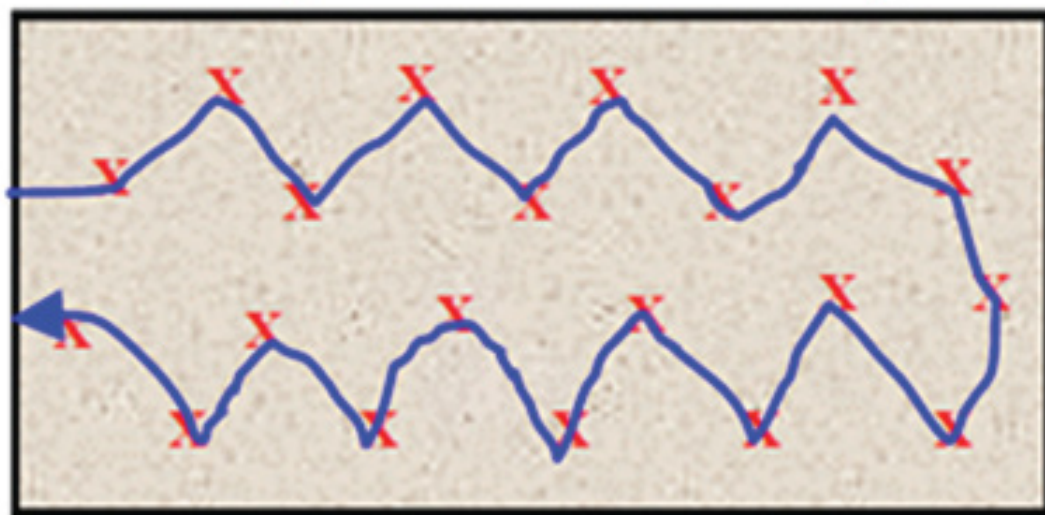


Fig. 65. Pull soil samples from random areas within the field

When collecting samples, avoid small areas where the soil conditions are obviously different from those in the rest of the field—for example, wet spots, old manure and urine spots, places where wood piles have been burned, severely eroded areas, or old building sites. Samples taken from these locations would not be typical of the soil in the rest of the field and including them could produce misleading results.

Collect samples three to six months before planting time, if possible. You will then have the test report in time to plan your fertilization program before the busy planting season.

Do not collect samples when the soil is too wet because it will be difficult to mix the soil. As a rule, if the soil is too wet to plough, it is too wet to sample.

Test the soil every two to four years.

Make sure that the buckets and sampling tools are clean and free of manure and fertilizer residues. Even a small amount transferred from the sampling tools to the soil can contaminate the sample and produce inaccurate results.

For areas in which field crops are grown, collect samples to the same depth that the field is ploughed (usually about 6-8 inches) because this is the zone in which lime and fertilizer have been incorporated.

Remove large pieces of organic material, such as roots, stalks, and leaves, from the sample.

Place about a pint of the composite sample for each area sampled in a plastic bag and label with the field name or number.

Complete the laboratory's soil test form which indicates information such as farmer's name and location, date samples were taken and crop to be grown.



Fig. 66. Soil samples, well mixed and placed in clean bags with clear labels indicating the field, or field area, from which they were taken

Once the soil samples have been delivered to the soil testing laboratory the technicians there will take several days to prepare and analyze the soil. This process requires careful handling and several different individual tests before the overall soil nutrition status can be determined. Once the testing is complete, the technicians will issue a report, usually in the form of a table. It must be noted that there is no “standard” soil test method for all tests. Testing methods may vary from one laboratory to another. Likewise, reporting methods vary from one laboratory to another. For this reason, soil test reports can be difficult to interpret, and therefore difficult to determine fertilizer recommendations needed to meet nutritional deficiencies. It’s important that farmers insure that the testing laboratory will provide interpretation and fertilizer recommendations.

The figures below show two soil test reports from different laboratories.

SAMPLE ID	LAB NUMBER	Organic Matter		Phosphorus		Potassium	Magnesium	Calcium	Sodium	pH		Hydrogen	Cation Exchange Capacity	PERCENT CATION SATURATION (COMPUTED)					
		* % Rating	** ENR lbs/A	P1 (Weak Bray)	NaHCO <sub>3</sub> -P (Olsen Method)	K	Mg	Ca	Na	Soil pH	Buffer Index	H meq/100g	C.E.C. meq/100g	K %	Mg %	Ca %	H %	Na %	
				***	****	*****	*****	*****	*****										*****
				ppm	ppm	ppm	ppm	ppm	ppm										ppm
130-1	55931	4.0H	110	23M	14**	110L	460M	992VL	104L	4.7	6.2	9.7	19.1	1.5	19.8	25.9	50.5	2.4	
130-2	55932	1.5L	60	27H	6**	41VL	569M	1154VL	185M	4.6	5.9	13.3	24.7	0.4	19.0	23.3	54.0	3.3	
12-1	55933	3.5M	100	12L	11**	64L	471VH	841VL	87L	5.2	6.5	4.5	13.1	1.2	29.5	31.9	34.5	2.9	
12-2	55934	2.8M	86	8VL	9**	29L	553VH	665VL	89M	5.3	6.6	3.7	12.1	0.6	37.7	27.5	31.0	3.2	
** NaHCO <sub>3</sub> -P unreliable at this soil pH																			
SAMPLE NUMBER	Nitrogen NO <sub>3</sub> -N ppm	Sulfur SO <sub>4</sub> -S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Excess Lime Rating	Soluble Salts mmhos/cm	Chloride Cl ppm	PARTICLE SIZE ANALYSIS				SOIL TEXTURE				
											SAND %	SILT %	CLAY %						
130-1	5L	5L	0.3VL	3M	53VH	0.2VL	0.1VL	L	0.3L		44	25	31	CLAY LOAM					
130-2	3VL	41VH	0.1VL	1VL	14M	0.2VL	0.1VL	L	0.6L		60	16	25	SANDY CLAY LOAM					
12-1	2VL	5L	0.1VL	2L	50VH	0.1VL	0.3VL	L	0.2VL		42	36	23	LOAM					
12-2	2VL	4L	0.1VL	1VL	53VH	0.1VL	0.2VL	L	0.1VL		40	35	25	LOAM					

\* CODE TO RATING: VERY LOW (VL), LOW (L), MEDIUM (M), HIGH (H), AND VERY HIGH (VH).

\*\* ENR - ESTIMATED NITROGEN RELEASE

\*\*\* MULTIPLY THE RESULTS IN ppm BY 2 TO CONVERT TO LBS. PER ACRE OF THE ELEMENTAL FORM.

\*\*\*\* MULTIPLY THE RESULTS IN ppm BY 4.6 TO CONVERT TO LBS. PER ACRE P<sub>2</sub>O<sub>5</sub>.

\*\*\*\*\* MULTIPLY THE RESULTS IN ppm BY 2.4 TO CONVERT TO LBS. PER ACRE K<sub>2</sub>O.

MOST SOILS WEIGH TWO (2) MILLION POUNDS (DRY WEIGHT) FOR AN ACRE OF SOIL 6-23 INCHES DEEP.

This report applies only to the sample(s) tested. Samples are retained a maximum of thirty days after test.

Fig. 67. Example of soil sample test report.

This report provides the results from four individual fields which are presented in the form of a data table



Notice that some of the numerical values are followed by letters (L, M, H, VL) indicating relative level of the corresponding nutrient. However, there are no recommendations given to inform the farmer of the quantity of various fertilizers needed to meet the nutrition need of the crop.

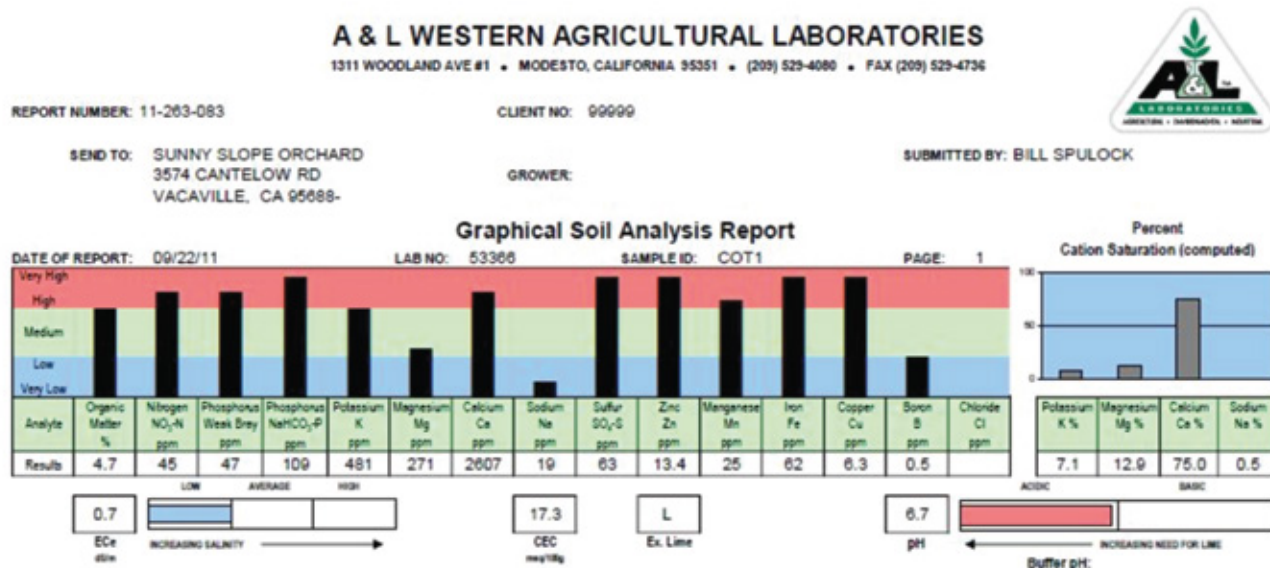


Fig. 68. Example of soil sample test report.  
Data is from one field and is presented in a graphic form

Notice that the nutritional status of the field is shown in graph form, and easy to see the relative nutritional status of the field. However, there are no recommendations given to inform the farmer of the quantity of various fertilizers needed to meet the nutrition need of the crop.

### Obtaining Selected Fertilizer and Other Inputs from Reliable Sources

In Pakistan there are reports of many substandard fertilizer and pesticide products being marketed. Farmers are strongly cautioned to purchase fertilizer, and all farm inputs, only from reputable dealers.

Many farmers receive crop inputs from commission agents who provide farm inputs in the form of a loan. It is reported that some commission agents provide crop inputs which are substandard. As a result, crop yields suffer, income is less, and the crop is uneconomical for the farmer.

It is therefore very important for the farmers to purchase all the crop inputs including seed, pesticides, fertilizers, etc. from reputable suppliers.

### Major Types of Fertilizer for Crop Production

Fertilizers are also sometimes classified as organic or inorganic. Organic fertilizers come from plant or animal sources and include manure, bone meal, blood meal, cottonseed meal, urine, sugar cane by-products, fish emulsion and green manure crops. But not all plant or animal products are acceptable for making organic fertilizer. Many organic sources can change soil pH, contain chemicals that are toxic to other plants, do not readily release fertilizer elements to the plant, or carry disease organisms. Some organic fertilizers provide readily-available fertilizer elements to the crop, other organic fertilizers should go through the composting (natural decomposition) process for the nutritional elements to be available to the crop.

YES				NO			
							
Fruit Peels/ Rinds	Tea Bags	Vegetable Scraps	Plant Trimmings	Weeds with Set Seeds	Meat	Large Wood Pieces	Cat Litter
							
Dried Leaves	Egg Shells	Coffee Grinds	Shredded paper	Coal/ Ash	Fish	Dairy Products	Sawdust
							
Straw/ Small Branches	Cardboard	Animal Manure	Natural Fibres	Walnuts	Citrus Fruit Insides	Fruit Stones	Non-Biodegradable Products

Fig. 69. Example of acceptable and non-acceptable organic materials

Source	%	% Dry Weight			% Wet Weight			
		Dry Matter	Total N	Total P <sub>2</sub> O <sub>5</sub>	Total K <sub>2</sub> O	Total N	Total P <sub>2</sub> O <sub>5</sub>	Total K <sub>2</sub> O
Dairy	15-25		0.6-2.1	0.7-1.1	2.4-3.6	0.1-0.5	0.1-0.3	0.4-0.9
Feedlot	20-40		1.0-2.5	0.9-1.6	2.4-3.6	0.2-1.0	0.2-0.6	0.5-1.4
Horse	16-25		1.7-3.0	0.7-1.2	1.2-2.2	0.3-0.8	0.1-0.3	0.2-0.6
Poultry	20-30		2.0-4.5	4.5-5.0	1.2-2.4	0.4-1.4	0.9-1.5	0.2-0.7
Sheep	25-35		3.0-4.0	1.2-1.6	3.0-4.0	0.8-1.4	0.3-0.6	0.8-1.4
Swine	20-30		3.0-4.0	0.4-0.6	0.5-1.0	0.6-1.2	0.1-0.2	0.1-0.3

\*To determine actual amounts of nutrients, however, it is necessary to have the manure tested. **Source:** Knott's Handbook for Vegetable Growers. 1997. John Wiley & Sons.

Fig. 70. Examples of nitrogen, phosphate and potash concentrations in different animal manures, on basis of %dry weight and % wet weight



Fig. 70. Compost, well-decomposed and ready to be used as organic fertilizer

Inorganic fertilizers are also known as chemical fertilizers or synthetic fertilizers and are made through industrial processes or mined from deposits in the earth. These industrial processes allow for the precision manufacture of fertilizers that are uniform in physical size and chemical composition. Inorganic fertilizers can be produced as granules, prills or liquids. They are classified according to whether they provide a single nutrient, such as nitrogen, phosphorous or potassium, in which case they are classified as "straight fertilizers." "Multi-nutrient fertilizers", or "complex fertilizers", provide two or more nutrients, for example nitrogen and phosphorous, together.

In general, nutrients in synthetic fertilizers are more rapidly available to plants because they are more water-soluble or in a form plants can use. The disadvantage is that it may be easier to overapply a synthetic fertilizer than a natural one, which may result in fertilizer burn. In addition, synthetic fertilizers may not support beneficial microbial populations to the same extent as natural fertilizers.



*Fig. 71. Modern synthetic fertilizer production facility*



Fertilizer Sources	Frequently Used Abbreviations	% N	% P <sub>2</sub> O <sub>5</sub>	% K <sub>2</sub> O
Anhydrous Ammonia	AA	82	-	-
Ammonium nitrate	AN	34	-	-
Urea-ammonium nitrate	UAN	28-32	-	-
Monoammonium phosphate	MAP	11-13	48-62	-
Diammonium phosphate	DAP	18-21	46-54	-
Potassium chloride	KCl	-	-	60
Urea	UR	46	-	-

Fig. 72. Common names and concentrations of nitrogen, phosphate and potash found in common inorganic, or synthetic fertilizers

Organic fertilizers, generally applied as manures or composted manures, can be very beneficial to crops and soils. Most soils in Pakistan are low in organic matter, which as discussed previously, helps the soil structure and properties in several different ways. Thus, manures can be a good choice for meeting all, or part, of your crop's nutritional need.

#### Advantages and Disadvantages of Commercial Fertilizers and Organic Manure Fertilizers

##### Commercial Fertilizers Advantages

- ▶ Contain a precise amount of N, P, K
- ▶ Available in a range of nutrient levels (especially when blended) to provide the producer what is needed for the crop
- ▶ Uniform material for ease of transport and application
- ▶ Known properties of the material with predictable effect on crops
- ▶ Widely available

##### Commercial Fertilizers Disadvantages

Costs vary and change during the year, and are currently at record highs

Often have higher chance for nutrient runoff or leaching, because of high solubility

## Manure Advantages

- ▶ Often free (except for transport/application)
- ▶ Adds organic matter (OM) to the soil which improves structure, increases water holding capacity, increases CEC and reduces erosion
- ▶ Provides both available and 'slow-release' N, P, K and micro-nutrients to crops

## Manure Disadvantages

- ▶ Nutrients can be easily leached through the soil profile or volatilized if left on the surface
- ▶ Nutrient content is very low and highly variable
- ▶ May introduce human pathogenic bacteria such as fecal coliform or E. coli
- ▶ May introduce weed seeds
- ▶ Weight and bulk of transporting and applying wet manures to fields

## Calculating the Fertilizer Dosage Requirement Based on Soil Analysis Report

Complete (or complex or multi-nutrient) fertilizers are labeled with at least three numbers which are: nitrogen, phosphorous and potash content commonly known as N P and K. These numbers list the percentages of nitrogen (N), phosphate (P<sub>2</sub>O<sub>5</sub>) and water-soluble potash (K<sub>2</sub>O).

For example, a 50 kg bag of fertilizer labeled 18-46-0, it contains 9 kg nitrogen, 23 kg phosphate and 0 kg of potash.

Therefore, once a farmer knows the nutritional status of his soil (based on the results of the soil test), and the nutritional requirement of chilis (based on university or industry research), he can calculate the amount of the different fertilizers needed to supply his chili crop with optimum nutrition.

Here's a useful formula for calculating fertilizer rate needed to meet the need as identified by the soil testing laboratory:

Recommended amount of the fertilizer element per acre × Area in acres = Total fertilizer content of the specified nutrient in the fertilizer, as a decimal needed

### Example 1:

The field of chilis at your farm is 1 acre in size. The local fertilizer store sells DAP which contains 18-46-0 (18% nitrogen, 46% phosphate and 0 potash). The soil test lab recommends 45 kg of phosphate per acre. Calculate the amount of 18-46-0 that you need to apply in order to meet the phosphate requirement.

45 kg phosphate per acre × 1 ac = 45 kg of 18-46-0 will meet the phosphate requirement

0.46 phosphate content

### Example 2:

The field of chilis at your farm is 0.7 acres in size. The local fertilizer store sells MAP which contains 12-61-0 NPK. Your fertilizer test states that your field needs 54 kg/ac of phosphate. How much MAP should be applied per acre?

Since MAP also contains nitrogen, how do we calculate the amount of nitrogen applied to the field, and meet the additional nitrogen requirement?

We applied 62 kg in the 0.7 acre field, which is equal to 89 kg/acre (to make the next calculation easier).

89 kg/ac of 12-61-0 applied x 0.12 nitrogen content = 11 kg/acre of nitrogen applied through the application of MAP. The soil test laboratory states that chilis require 65 kg/ac of nitrogen to make an optimum crop. How much more nitrogen is needed?

65 kg/acre needed – 11 kg/acre applied = 54 kg/acre additional nitrogen is needed

How do we provide the additional nitrogen by using ammonium nitrate that is 32% nitrogen?

54 kg/acre needed x 0.7 ac field size = 118 kg ammonium nitrate in 0.7 acre field

0.32 nitrogen content

If in doubt, consult your fertilizer dealer or Extension worker for assistance.

#### Calculation for Applying Organic Fertilizer

In the previous example of commercial, inorganic fertilizers, we calculated that a field would require 98 kg of DAP/acre would provide 45 kg/acre of phosphate. How does that compare to an organic fertilizer, such as chicken manure?

Unless we had the chicken manure tested at a laboratory, we would not know the exact nutrient content. However, prior research has shown that chicken manure, on average, contains in the range of 4.6 – 6.0 percent phosphate. If we assume that the chicken manure contains 6% phosphate, how much would be needed to provide 45 kg/acre of phosphate?

45 kg recommended per acre = 750 kg/acre of chicken manure needed

0.06 (phosphate content expressed as a decimal)

Thus, the phosphate requirement can be met by using manure, but it will require much more (over 7 times more) manure as compared to the synthetic fertilizer. Cow manure is much lower in fertilizer value as compared to chicken manure, so using cow manure would require several times more to achieve the same fertilizer amount. Another option is to use both manure and commercial fertilizer to meet the nutrient requirements. Growers must consider availability, cost, transportation and labor in order to make good decisions.

## Useful Tips for Planning Fertilizer Programs

### Methods of Fertilizer Application and Placement

Preplant fertilizer is applied to the soil in accordance with soil test requirements prior to planting the crop. It may be broadcast over the soil surface and mixed with the soil, applied in a strip and mixed with the soil in the row, or applied in a band beside the seed or transplant line.

Broadcasting is a good method for applying large quantities of fertilizer without plant damage or when speed of application is important. A broadcast application can be plowed or disked in during soil preparation. Broadcasting is generally an inefficient method for widely spaced crops (such as watermelon), or for application of large amounts of nitrogen on sandy soil (due to loss through leaching) or phosphorus (due to potential to be tied up by soil).



Band application near the seed or plant is an efficient placement method because it delivers the fertilizer close to the plant root zone. The usual method is applying the fertilizer in a line 2 to 3 inches beside and 2 to 3 inches below the seed or transplant. The amount of fertilizer that can be placed in a band is limited due to the possibility of injury to seedlings. This is particularly true for nitrogen and potassium. A general rule to follow is the total nitrogen and potash in a band should not exceed 45 kg/acre when using a row spacing of 3 ft. In a band application, be sure to place fertilizer band so that the irrigation water will reach it and help to make it available to the plant roots.

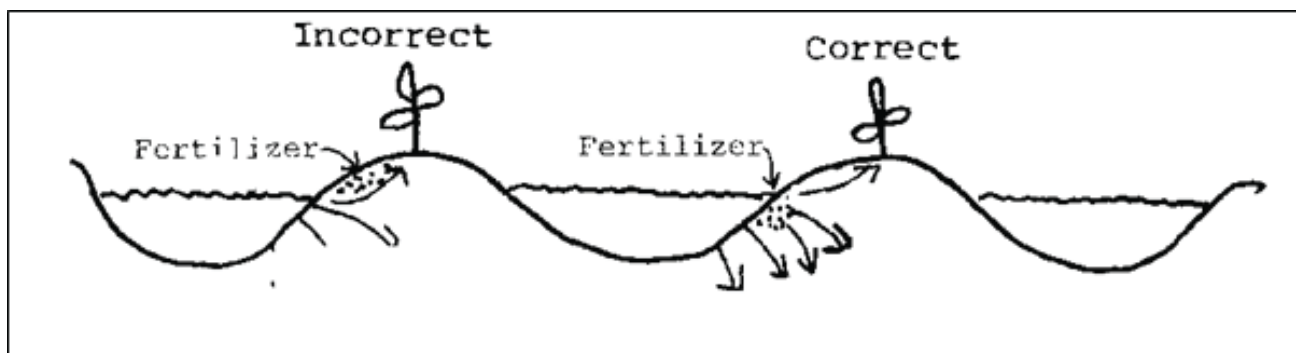


Fig. 73. Proper placement of fertilizer on ridge when using furrow irrigation

### Timing Fertilizer Applications

Nitrogen, phosphate and potash are soluble and mobile in the soil. Knowing this allows a farmer to time application for maximum efficiency.

Nitrogen, phosphate and potash are all soluble in water, but they're not equal in their solubility. Nitrogen is the most soluble and most likely to 'move' through the soil. Therefore, is generally recommended that nitrogen applications be split through the season. By applying it all at once, much of it will be gone before the plants can benefit. Phosphate is the least mobile of the three major nutrients, and potash is intermediate. Since phosphate and potash aren't highly mobile in the soil, they are frequently applied prior to ridge or bed formation and planting.

Nitrogen should be split with part applied (for example, 30% of the total N) as a broadcast at time of bed formation. Then beginning two weeks after planting apply 45 percent of the N spread out over the four or five weeks until the first fruit begin to swell. The final 25 percent is a maintenance level and should be spread out and applied on a weekly basis until two weeks prior to last harvest. This approach will develop enough plant prior to fruit set that will allow the plant to continue to flower and make fruit.

### Applying Fertilizer Through Drip Irrigation

An emerging trend in plant nutrition is the use of "fertigation" which is the application of fertilizer through the irrigation water. It is the use of irrigation equipment to apply fertilizers. The combination of high-quality, highly-soluble liquid fertilizers and drip irrigation is becoming very popular in high value crop production, such as chilis and other fruits and vegetables.

The advantages of using drip irrigation for chemical fertilizer application include:

- ▶ Ability to apply precise amount of fertilizer to plant root zone
- ▶ Ability to split applications precisely, and apply as often as needed
- ▶ Highly soluble fertilizer is instantly available to plants

However, there are disadvantages to drip irrigation fertigation.

- Requires skilled labor to operate and maintain application equipment
- Additional costs of highly soluble fertilizer, injector equipment and filters



*Fig. 74. Drip irrigation in a field, applying water soluble fertilizer to young plants.*

## CHAPTER 5

### CHILI PEST MANAGEMENT

#### What is a pest?

A pest can be a plant or an animal which can cause harm to the interest of humans. This includes damage to fruits and vegetables, crops, livestock and forestry. In a broader sense, a pest is a competitor of human beings. Pests, whether insects, diseases, weeds or nematodes compete with humans by feeding on their crops, thereby reducing the food supply of humans. In general, pest populations are affected by environmental conditions and tend to increase as temperature and humidity increases.

Other than pests, different types of problems can occur and are sometimes confused with pest-related problems. Examples are drought (water deficit), excessive watering (water-logging/flooding), extreme temperatures (cold, frost and heat), salinity and mineral toxicity.

#### Integrated Pest Management in Chili

Chilis are attacked by a number of pests such as weeds, insects, diseases and nematodes. Pests can cause significant crop losses. Depending on the severity of the attack, losses can range from minor to total.

Farmers must be constantly alert to pest attacks in order to protect their chili crop. Some pests are expected from year to year. For instance, farmers can usually expect the same weed to show up from one year to the next. Fields with nematode populations will usually continue to harbor nematodes. In these regards, farmers can plan ahead and adopt appropriate management tactics to minimize the impact of those pests that are expected to occur.

Insect and disease pests are often predictable, but some can occur unexpectedly. Environmental conditions influence insect and disease prevalence. Changing climatic conditions, even shifting winds, can bring in unexpected disease or insects.

Regardless of the historical pattern or prevalence of pests, it is wise for a farmer to develop a plan to protect his crop from pests in order to insure the maximum yield and income from his chili crop.

Just as farming techniques have developed over the generations, so have pest control strategies. The current best management practices for pest management encourage the use of what is commonly known as Integrated Pest Management, or IPM. IPM can be defined as the practice of preventing or suppressing damaging populations of pests by application of the comprehensive and coordinated integration of multiple control tactics. Tactics are the various control methodologies, e.g., chemical, biological, cultural and mechanical.



The tactics used in IPM include one or a combination of the following:

- **Cultural control**

- Crop rotation, for instance chilis should not be planted in a field that has tomato, brinjal, potato or peppers for the previous 2 years
- Use of locally adapted or pest resistant/tolerant varieties that have shown tolerance to a disease or other pest
- Sanitation, or removing plants or trash that can harbor pests. Destroying crop residue from the previous crop, removing weeds, keeping field edges grazed short
- Manipulating planting/harvest dates to avoid pests, if possible

- **Biological control**

- Protect, enhance or import natural enemies of pests. If good insects are present, avoid killing them so they can continue to kill the bad insects

- **Mechanical control**

- Cultivation, trapping, pest exclusion

- **Chemical control**

- Chemical pesticides, biological pesticides, insect growth regulators, pheromones are products that kill pests, prevent them from completing their life cycle or change their behavior in order to prevent them from damaging the crop

Why should farmers use Integrated Pest Management?

- **Save money:**

- IPM can allow growers to save unnecessary pesticide applications, which reduces expense and increases profit

- **Pesticides aren't always effective:**

- Frequent exposure to some pesticides has allowed "pesticide resistance" to develop. Pesticides that were once effective, are no longer effective. Pakistan ranks 4th in the world in the number of reports of pesticide resistance.

- **IPM isn't difficult:**

- Although some of the terms and ideas may be new to you, practicing IPM is not difficult. Believe it or not, you will have done much of the "work" for an IPM approach if you've figured out the problem (the pest), determined the extent of the damage, and decided on the action to take. These steps are the same ones used in IPM.

- **Keep a balanced ecosystem:**

- Every ecosystem, made up of living things and their non-living environment, has a balance; the actions of one creature in the ecosystem usually affect other organisms. The introduction of chemicals into the ecosystem can change this balance, destroying certain species and allowing other species (sometimes pests themselves) to dominate. Beneficial insects such as the ladybird

beetle and lacewing larvae, both of which consume pests, can be killed by pesticides, leaving few natural mechanisms of pest control.



*Fig. 75. Scouting a vegetable crop.*

*The colored sheet on the ground offers a contrasting color that makes insects more visible.*

## IPM Decision-Making

There is a 6-step process to decision-making in IPM:

- **Identify the problem or pest**

- Unless the pest is identified, a control tactic can't be selected
- A farm retail outlet or Extension Agent can help with identification

- **Determine the severity of the problem (scouting, traps, history)**

- The presence of a pest doesn't mean that it has to be controlled
- We can only make good decisions if we know the severity of the potential problem. We can do this best by using a standardized 'scouting' method and comparing results to research-based Economic Threshold, or Action Threshold

- **Assess the management options (cultural, biological, mechanical, chemical control)**

Once we have identified the pest, and the severity of the problem, we can evaluate the different tactics that offer control

- **Select and apply one or more tactics**

- Which tactic can protect the crop from damage

- **Measure the success of options employed**

- How do we know if the tactic was successful

- **Record the results**

- Keeping records helps us make better decisions in the future

Questions to Ask Before Pest Management Decisions Are Made:

- What pests are present, in what numbers and stages of development?
- What conditions exist that may increase or decrease pest problems?
- What natural enemies of the pests, such as parasites, predators, and diseases, are present that may play an important role in control?
- What amount and type of damage is being caused or may soon be caused by pests?
- What is the stage of development, condition, and value of the crop?
- What is the potential for economical injury? How much damage is tolerable? Has the economic threshold been reached?
- What pest management options are available, and how do the advantages and disadvantages of each apply to the situation?
- If alternatives are not available, is a pesticide treatment justified for the situation? If so, what is the material of choice?
- If a pesticide is not justified, what approaches, if any, should be taken?

Operationally, IPM relies on good data collected from the field and compared to research-established findings. The first step in the decision-making process is collecting data. In IPM, the collection of field data is called “field scouting” and can be defined as: “A regularly scheduled, standard method of examining the crop, pests, and any beneficial insects in each field.” The second step is comparing the field scouting data to established “economic thresholds” which are defined as: “the pest population point at which the cost of a control measure for the pest is offset by the yield increase expected from that control measure.”

A foundation of IPM is the use of the Economic Threshold, also known as the Economic Threshold Level, or Action Threshold. This is defined as “The point at which the cost of control is offset by the cost of the control action.” For example, if the cost of the control action is \$8 per acre, we can only justify the control action if it will provide a yield benefit of greater than \$8 per acre. Researchers use a lot of crop and economic data to develop Economic Thresholds. This process usually takes a few years of research. Your Extension Agent or local farm retail outlet should be knowledgeable about Economic Thresholds. The Ministry of Agriculture in some provinces has established special Integrated Pest Management teams that should have this information. In the absence of such information, we can use the Economic Thresholds from neighboring countries. This is not ideal, but when at least it gives us a starting point that can be adjusted as experience is gained.



## Most common insect pests of chilis

Chilis are attacked by various insect pests, and scientists commonly describe insects in broad terms, based on the type of feeding damage they inflict on the plants. For insects attacking chilis, the insects are normally divided into those with 1) sucking mouthparts, or 2) chewing mouthparts.

Those with sucking mouthparts insert their mouthparts into the plant tissue and simply suck the plant juices out of the leaves, reducing plant vigor and reducing growth and production. This group includes some small insects, such as thrips, mites, aphids and whiteflies.

The insects with chewing mouthparts damage plants and fruit by chewing the plant leaves, stems or fruit. Some, like cutworms or fruit borers, consume large amounts of plant tissue. Their damage varies from completely cutting the plant stem to eating leaves or fruit. Those that chew on the fruit cause terrible damage. Even if the chewing damage doesn't destroy the fruit, the subsequent attack by bacteria and fungi will lead to rapid fruit rot, destroying the fruit. Weevils have chewing mouthparts, but usually only chew small holes into which they lay eggs. While the chewing damage is minimal, the resulting larva then chews the interior of the fruit, which also leads to massive infection and fruit loss.

Another type of insect which has chewing mouthparts is a leafminer which, in the immature stage, lives inside a leaf between the upper and lower surface of a leaf. It eats the tissue inside the leaf, reducing the plants ability to produce energy. Finally, in Sindh a termite, known locally as a 'white ant', is occasionally found attacking chilis.

## Insects with Sucking Type Mouthparts

### Whitefly

Whiteflies (both immature and adult stages) are white or yellow in color, with a dusty appearance, and very small in size (2-3 mm). They are most often found under the leaves at the top of the plant. They are very active and fly if disturbed. In heavy infestations, disturbing the plant will result in a small white cloud of whitefly adults taking flight. They damage the plant through sucking the sap from the leaves. Heavily-infected plants will be easily visible due to leaves wilting. Significant yield losses can occur.





*Fig. 76. Adult (upper photo) and immature (lower photo) whiteflies on underside of leaf (top), adult whitefly, highly magnified*

## Control alternatives

### • Cultural

- Whiteflies prefer cotton, melons and cole crops. Plant peppers away from these crops
- Maintain good sanitation in areas of winter and spring host crops and weeds by destroying and removing all crop residues as soon as possible. Control weeds in non-crop areas including head rows and fallow fields

### • Biological

- Some beneficial insects such as big-eyed bugs, lacewing (*Chrysoperla*, available through IPM programs in Pakistan) larvae and lady bird beetles prey on whiteflies, but they seldom offer acceptable control, and are almost always killed with the first insecticide application

### • Mechanical

- There are no effective mechanical methods of control

### • Chemical

- There are several insecticides that offer partial control. Whiteflies are very difficult to control because they can develop resistance to insecticides quickly, particularly if those insecticides are overused
- Consult your farm retail outlet or Extension Agent for the best local recommendations for whitefly management. Always consider resistance management
- The reported Economic Threshold for whiteflies on chili, in India, is 2 whiteflies per leaf



## Thrips

Chili thrips feed on young leaves, stem terminals & developing flower buds with a sucking mouthpart. This causes leaf to become curled, bronzed & distorted. Severe infestation reduces plant growth and crop yield. Detecting chili thrips is difficult because they are very small in size (< 2 mm in length). The best method for scouting for thrips is to lay a sheet of light-colored cloth or paper on the ground next to chili plants and gently shake the plant over the paper. The chili thrips will fall onto the paper and be visible. A hand lens will be helpful due to their small size.



Fig. 77. Dorsal view of adult chili thrips, *Scirothrips dorsalis*.

Photograph by Lance Osborne, Entomology and Nematology Department, University of Florida



Fig. 78. Deformed pepper fruit (no economic value) after damage from an infestation of the chili thrips.

Photograph by Vivek Kumar, Entomology and Nematology Department, University of Florida.





*Fig. 79. Chili plant exhibiting leaf curl from thrips damage.*

*Notice that the curl is "upward" a characteristic sign of thrips damage. [http://agritech.tnau.ac.in/crop\\_protection/chili/chili\\_1.html](http://agritech.tnau.ac.in/crop_protection/chili/chili_1.html)*

## Control alternatives

### • Cultural

- ▶ Because this thrips can overwinter as adults in leaf litter or weeds, cleaning up debris from infested plants and removing weeds are important activities to reduce the overwinter population. This is especially critical for nurseries that have had chili thrips infestations in the past
- ▶ Sticky traps can be helpful in monitoring for thrips infestation but do not provide acceptable control in a field situation
- ▶ Detergent spray mixtures can also provide suppression, or even control in low populations

### • Biological

- ▶ Big-eyed bugs have been reported to provide acceptable control of chili thrips in fields and nurseries
- ▶ When used alone, the fungal pathogen *Beauveria bassiana* is not effective in controlling chili thrips adults or larvae but produced better result when used in combination with an experimental product consisting of borax, orange oil and biodegradable surfactants (Kumar, unpublished data, University of Florida) [https://entnemdept.ufl.edu/creatures/orn/thrips/chili\\_thrips.htm](https://entnemdept.ufl.edu/creatures/orn/thrips/chili_thrips.htm).
- ▶ Research is underway to identify control with chrysoperla (lacewing) and other beneficial insects, and some predatory mites

## • Mechanical

- ▶ Sticky traps are helpful in monitoring for thrips
- ▶ Fine mesh row covers can provide a barrier to thrips and would be practical for use in a chili nursery

## • Chemical

- ▶ There are several insecticides that offer acceptable control.
- ▶ Some biological, or biochemical insecticides that have shown promise include neem oil, horticultural oil and the fungi, *Beauveria bassiana*. Some commercial products based on *Beauveria bassiana* may be available in Pakistan
- ▶ Consult your farm retail outlet or Extension Agent for the best local recommendations for thrips management. Always consider resistance management
- ▶ The reported Economic Threshold for thrips on chili, in India, is 8-10 nymphs or adults per leaf



Fig. 80. Yellow or blue sticky traps can be helpful in monitoring for some insects, but seldom provide acceptable control in a field. Blue is particularly attractive to thrips. Yellow also attracts thrips, as well as aphids and whiteflies

## Aphids

Aphids are very small (2-5 mm) insects which are usually found on the underside of leaves, near the top of the plants. They can appear as various shades of green, black or yellow. Adult aphids can be found with or without wings. They move slowly and can cause significant damage to chilis. They suck the sap from the leaf, resulting in plants in low vigor with reduced yield. They secrete a waste product from their body, known as 'honeydew' which falls on the leaves under their feeding site. It's not uncommon to find a black-colored mold, known as 'sooty mold' growing on the honeydew.

## Control alternatives

### • Cultural

- ▶ Because aphids can overwinter as adults in leaf litter or weeds, cleaning up debris from infested plants and removing weeds are important activities to reduce the overwinter population.
- ▶ Because many vegetables are susceptible to serious aphid damage primarily during the seedling stage, reduce losses by growing seedlings under fine mesh covers in the nursery
- ▶ Sticky traps can be helpful in monitoring for aphid infestation but do not provide acceptable control in a field situation
- ▶ Detergent spray mixtures can also provide suppression, or even control in low populations

### • Biological

- ▶ Natural enemies can often provide acceptable control of chili aphids in fields and nurseries that haven't been treated with broad-spectrum insecticides
- ▶ Chrysoperla larvae, often available from the government, are effective predators of aphids
 

Parasitic wasps attack aphids, laying eggs into the aphids, and the developing wasp larva eats the inside of the aphid. These parasitized aphids appear golden brown and swollen, and usually don't move
- ▶ Pirate bugs are good predators

### • Mechanical

- ▶ Sticky traps are helpful in monitoring for aphids
- ▶ Fine mesh row covers can provide a barrier to aphids and would be practical for use in a chili nursery

### • Chemical

- ▶ There are several insecticides that offer acceptable control.
 

Some biological, or biochemical insecticides that have shown promise include neem oil, horticultural oil and the fungi, *Beauveria bassiana*. Some commercial products based on *Beauveria bassiana* may be available in Pakistan
- ▶ Consult your farm retail outlet or Extension Agent for the best local recommendations for thrips management. Always consider resistance management
- ▶ The reported Economic Threshold for aphids on chili, in India, is 5 whiteflies per leaf





Fig. 81. Green peach aphid, *Myzus persicae*, a common pest of numerous crops in Pakistan



Fig. 82. Green peach aphid on underside of bean leaf

### Bud mite

Bud mite, or broad mite, is a very serious pest of the chili crop, particularly in Sindh. It is shiny, white, very small (0.2 mm) insect pest. It is barely visible by the naked eye but can be seen through a magnifying glass or microscope.

Bud mite damage consists of malformation and distortion of the above-ground growth of the plant. The mites show a preference for young, developing plant tissue, like the growing tips, young leaves and flower buds. Leaf feeding is mainly concentrated on the leaf underside near the leaf stalk, which tends

to cause the leaf to turn brown and curl up. A typical indication of an attack of bud mite is the appearance of dark brown edges at the base of young leaves. Like whitefly and aphids, the bud mite mainly attacks during warm and dry weather conditions.



*Fig. 83. Broad mite feeding damage to chili.*  
<https://site.extension.uga.edu/colquittag/2014/10/broad-mites-in-pepper/>

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*Fig. 84. Bud (or broad) mite injury to greenhouse chili, Photo by L. Pundt.*  
<http://ipm.uconn.edu/documents/raw2/html/473.php?display=print>

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*Fig. 85. Bud mite feeding damage to chili fruit.*

<https://site.extension.uga.edu/colquittag/2014/10/broad-mites-in-pepper/>

## Control alternatives

### • Cultural

- ▶ Because this mite can overwinter in leaf litter or weeds, cleaning up debris from infested plants and removing weeds can reduce the overwinter population that attacks the first crops of the growing season. This is especially critical for nurseries that have had mite infestations in the past
- ▶ Detergent spray mixtures can also provide suppression, or even control in low populations

### • Biological

- ▶ While several insecticides/miticides are labeled for control of this pest, insecticidal oils (lightweight horticultural oils) or soaps are usually just as effective and less toxic to the environment



- Predatory mites, such as *Amblyseius ovalis* can be effective in both nursery and field

- **Mechanical**

- There are no recommended mechanical controls

- **Chemical**

- There are several insecticides/miticides that are effective.
  - Insecticidal oils or soaps, and neem oil are effective. Thorough coverage is necessary, requiring spraying the underside of leaves
  - Consult your farm retail outlet or Extension Agent for the best local recommendations for bud mite management. Always consider resistance management



Fig. 86. Bud mite feeding damage to chili fruit.  
<https://site.extension.uga.edu/colquittag/2014/10/broad-mites-in-pepper/>



*Fig. 87. Predatory mite attacking a two-spotted spider mite.*  
<https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=16763>

## Insects with Chewing Type Mouthparts

### Cutworm

Cutworms generally damage seedlings and young plants. The larvae chew the stem, frequently cutting the stem entirely through. They feed at night and spend the night just under the soil surface.



*Fig. 88. Young potato plant damaged by cutworm. Plant stem has been chewed through, completely.*  
<https://extension.umn.edu/yard-and-garden-insects/cutworms>





*Fig. 89. Cutworm larva. They are often described as appearing “greasy”*

## Control alternatives

### • Cultural

- Destroy plant residues by ploughing deeply, at least 2 weeks before planting
- Manage weeds surrounding the field before planting. Kill and till under or remove weeds as cutworms will shelter in living and dead weeds.

### • Biological

- There are no recommendations for effective biological control

### • Mechanical

- Exclusion can be effective. On small scale, plants can be protected by wrapping the stems with thick paper, aluminum foil, etc.

### • Chemical

- Insecticides are effective, but applying them so they contact the larvae is impractical
- Consult your farm retail outlet or Extension Agent for the best local recommendations for cutworm management.
- The reported Economic Threshold for cutworms on chili, in India, is 10% of the chili seedlings killed



## Fruit borer

The fruit borer, *Helicoverpa armigera*, is also known as the cotton bollworm, Old World bollworm, African bollworm, tomato fruitworm, and several other common names. The larva is yellowish to greenish in color, and it damages the crop by eating a hole in the fruit and entering the fruit to feed. It completes its larval stage inside the fruit and drops to the ground to pupate. It emerges from the ground and becomes an adult.

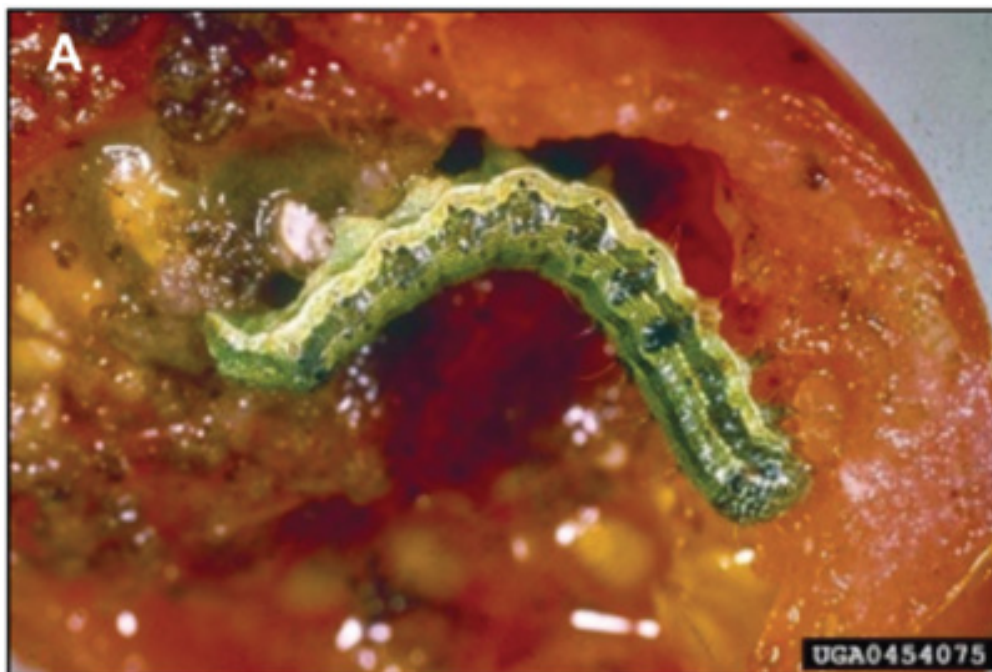


Fig. 90. *Helicoverpa armigera*, the chili fruit borer, also known as the cotton bollworm, African bollworm, Old World bollworm. Photo shows larva on tomato fruit. This insect species attacks over 200 different plant species and is one of the most destructive pests of chili. <http://download.ceris.purdue.edu/file/3616>





Fig. 91. Chili fruit worm, moth (top) and larvae (bottom).  
<http://agropedia.iitk.ac.in/content/chili-fruit-borer>

## Control alternatives

### • Cultural

- ▶ Pepper fields should not be planted near or adjacent to post-silking maize fields
- ▶ Cull fruit from infested fields should be disposed of as far from production fields as possible
- ▶ Pepper, tomato, brinjal and potato fields which have been harvested can be a reservoir of migrating adults and, therefore, should be destroyed immediately after final harvest by deep ploughing to destroy infested fruit and pupating larvae
- ▶ Volunteer plants and weed hosts should be destroyed during the growing season

### • Biological

- ▶ Natural enemies do not usually cause high enough mortality of fruit worm to prevent crop injury. Nevertheless, the parasitic wasp, *Trichogramma pretiosum*, attacks eggs and can account for 40 to 80% parasitism
- ▶ Eggs and young larvae are attacked by generalist predators, including lacewings (*Chrysoperla*), big-eyed bugs, damsel bugs) and minute pirate bugs
- ▶ Natural enemies can be conserved by avoiding broad spectrum pyrethroid, organophosphate and carbamate insecticides. Fewer insecticide applications and applications of new, reduced risk insecticides can also enhance biological control

## • Mechanical

- ▶ Exclusion can be effective. Greenhouse netting is adequate to exclude fruit borer moths and could be used as a row cover

## • Chemical

- ▶ Insecticides should be timed to control eggs and hatching larvae. Once larvae enter fruit, they are less accessible to insecticides and are more difficult to control
- ▶ Pheromone traps can be useful for monitoring the presence of fruit borer moths and alert growers to increased egg laying
- ▶ There are several insecticides that offer acceptable control.
- ▶ Consult your farm retail outlet or Extension Agent for the best local recommendations for fruit borer management. Always consider resistance management
- ▶ The reported Economic Threshold for fruitworms on chili, in India, is 5% of the pods attacked by fruitworms

## Leafminer

Leafminer adults are small, shiny black flies with a bright yellow triangular spot on the upper thorax, but few people will notice them flying in a field. Eggs are white and oval and laid within the leaf, between the upper and lower leaf surfaces. Larvae feed between leaf surfaces, creating meandering tunnels. Mature larvae leave the mine and drop to the ground to pupate. The life cycle takes only 2 weeks in warm weather; there can be many generations a year. Leaves injured by leafminers drop prematurely; heavily infested plants may lose most of their leaves.

Areas mined by insects die and dry out. Although injuries produced by leafmining insects can be unattractive, it is rare for them to significantly affect plant health or yield. Control measures are typically not recommended for leafminers.



*Fig. 92. Leafminer damage to pepper leaf.*

<https://content.ces.ncsu.edu/extension-gardener-handbook/4-insects>



## Termite or White Ant

Termites, also known as white ants, are social insects that have a single queen that is the only female capable of laying fertile eggs. They are light brownish or white in color. These insects live in underground colonies and prefer sandy and loam soils. They attack chilis from the roots and move upwards, which is typical of termite behavior. Termites bore into the plant stem destroying the plants vascular system and leading to plant death. Termites require humid conditions and can't survive long outside of their protected soil or within a plant.

Some insecticides can be effective but must be applied in a manner that gets the insecticide into the colony. Even if termites near the surface are killed, there are many more developing underground. They'll simply attack the crop as they develop. It is better to use an insecticide that contain some attractant for the termites and may also has cascading effect, thus the entire colony there may be killed. Insecticides with this characteristic are known as 'baits'.

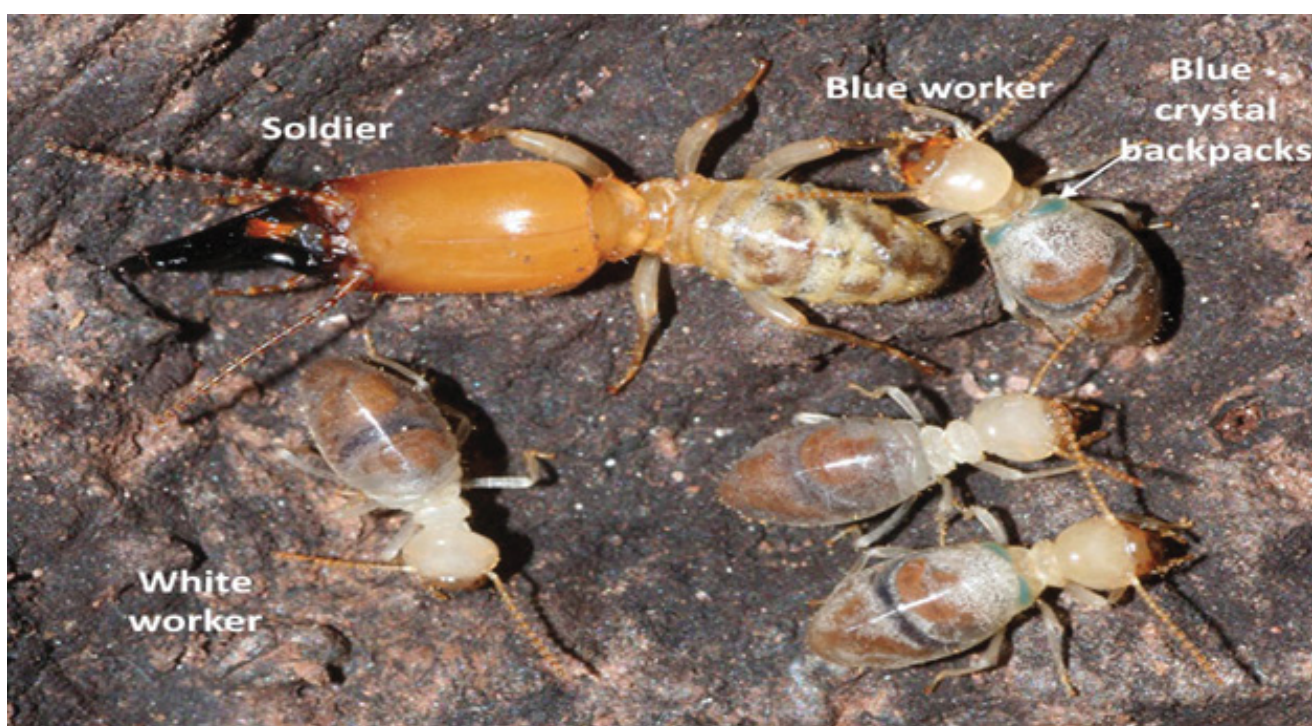


Fig. 93. White ants, or termites



## Pictorial Guide to Common Parasites and Predators

Predators are insects that hunt and attack the insects that damage our crops. Parasites hunt the bad insects and lay their eggs inside the bad insect. The egg hatches and the larva immediately starts feeding on the inside of the bad insect. Predators and parasites offer free control of the bad insects benefit farmers. They should be protected from pesticide sprays, as much as possible.

### Feeding/egg laying potential of different parasitoids/predators









Predators/ Parasitoids	Feeding potential/ Egg laying capacity
 Lady bird beetle	Predatory rate of adult coccinellid on aphids is 50 aphids per day
 Hover fly	1 <sup>st</sup> instar larva can consume 15-19 aphids/day 2 <sup>nd</sup> instar larva can consume 45-52 aphids/day 3 <sup>rd</sup> instar larva can consume 80-90 aphids/day In total life cycle they can consume approx. 400 aphids.
 Green Lace wing	Each larva can consume 100 aphids, 329 pupa of whitefly and 288 nymphs of jassids
 Reduviid bug	1 <sup>st</sup> & 2 <sup>nd</sup> nymphal instars can consume 1 small larva/day 3 <sup>rd</sup> & 4 <sup>th</sup> nymphal instars can consume 2 to 3 medium larvae/day 5 <sup>th</sup> nymphal instar & adult can consume 3 to 4 big larvae/day In total life cycle they can consume approx. 250 to 300 larvae
 Spider	5 big larvae/day
 Predatory mite <a href="http://www.eduwebs.org/bugs/predatory_mites.htm">http://www.eduwebs.org/bugs/predatory_mites.htm</a>	Predatory rate of adult is 20-35 phytophagous mites/female/day
 <i>Bracon hebetor</i>	Egg laying capacity is 100-200 eggs/female. 1-8 eggs/larva
 <i>Trichogramma</i> sp	Egg laying capacity is 20-200 eggs/female.

Fig. 94. Beneficial insects can play an important role in managing insect pests



## Major Diseases of Chili

### Bacterial & fungal diseases of chili

#### Anthracnose

Caused by the fungi *Colletotrichum piperatum* and *C. capsisi*, anthracnose prefers high humidity, warm temperatures and poor air circulation between plants. Although the disease does not affect pod growth it can seriously damage the pods themselves. Symptoms appear in both ripe and un-ripe pods and are characterized by sunken, circular spots that can grow up to 1 inch in diameter. In moist conditions, pink or yellow spore masses may appear. Crop rotation and the use of disease-free seed usually provides adequate control this fungus. Remove affected pods as soon as possible. A fungicide application may be needed.



Fig. 95. Anthracnose, a fungal disease, on chili

#### Bacterial leaf spot

Caused by the seed borne bacterium *Xanthomonas campestris*, bacterial leaf spot affects tomatoes as well chilis. The disease is spread through infected seed, which is another reason to purchase fresh, disease-free seed every year or two. Moist conditions also encourage development of this disease. The disease first appears as small water-soaked areas that enlarge up to a quarter of an inch in diameter. The disease spots have black centers and yellow halos. The spots are depressed on the upper leaf surface, but on the lower surface the spots are raised and scab-like. Severely spotted leaves will eventually turn yellow and drop off, leaving pods susceptible to sunscald. To avoid this condition, buy disease-free seeds from a reputable source. The use of copper-based fungicides can provide some control.





Fig. 96. Bacterial leaf spot, a bacterial disease

### Bacterial leaf spot

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Fig. 97. Bacterial soft rot of chilis

## Bacterial Wilt

Caused by the bacterium *Pseudomonas solanacearum*, the first symptoms start with wilting leaves. After a few days the entire plant will wilt with no leaf yellowing. A quick field test to confirm bacterial wilt involves cutting the roots and lower stems and looking for milky-white streams coming from the roots and stems when they are suspended in water. There is no treatment for this disease. Buy seed from a reputable dealer to help avoid bacterial wilt.



Fig. 98. Bacterial wilt of chilis

## Cercospora Leaf Spot (Frog Eye)

Caused by the fungus *Cercospora capsica*, frog eye leaf spot is worse under extended warm, wet conditions. The disease is characterized by small brown circular leaf lesions that have a watery appearance. Excessive leaf drop may occur in large infestations. Good airflow around the plants will minimize the problem. If the problem is severe you may wish to consider a fungicide.



Fig. 99. Cercospora, or frog eye, leafspot



## Damping-off

Caused by *Pythium debaryanum*, seedlings affected by damping-off fail to emerge or fall over and die soon after emergence. Stems usually have a dark, shriveled portion at the soil line. Damping-off is generally limited to areas where drainage is poor or where soil is compacted, but whole fields can be affected, especially in early plantings exposed to rain.

Symptoms vary and can appear as any of the following: seedlings fail to emerge (pre-emergence damping-off), small seedlings collapse (post-emergence damping-off) or seedlings are stunted (root rot or collar rot). Poorly drained soil is often a major contributor to this condition. Affected seedlings seldom survive to become productive plants. The disease often infects tissue damaged by extreme temperatures, wind damage, sandblasting or rough handling. Infections are common in stressed transplants, such as those held back or stored for a period of time before transplanting to the field.

Buy fungicide-treated seed or treat seed yourself.



Fig. 100. "Damping-off" disease caused by a related group of fungi



### Grey Mold or Botrytis Blight

A relatively common problem with chilis, it is caused by the fungus *Botrytis cinerea*. Symptoms include a sudden collapse of succulent tissues such as young leaves, stems, flowers and fruit. Grey powdery spore masses occur on the surface of dead plant matter. This condition is worsened by high humidity. Good air circulation can help in prevention. Remove affected areas of the plant immediately. Apply fungicides preventatively prior to dense canopy growth



Fig. 101. Gray mold, or *Botrytis blight* on tomato stem.  
<http://blogs.cornell.edu/livepath/gallery/tomato/tomato-gray-mold/>

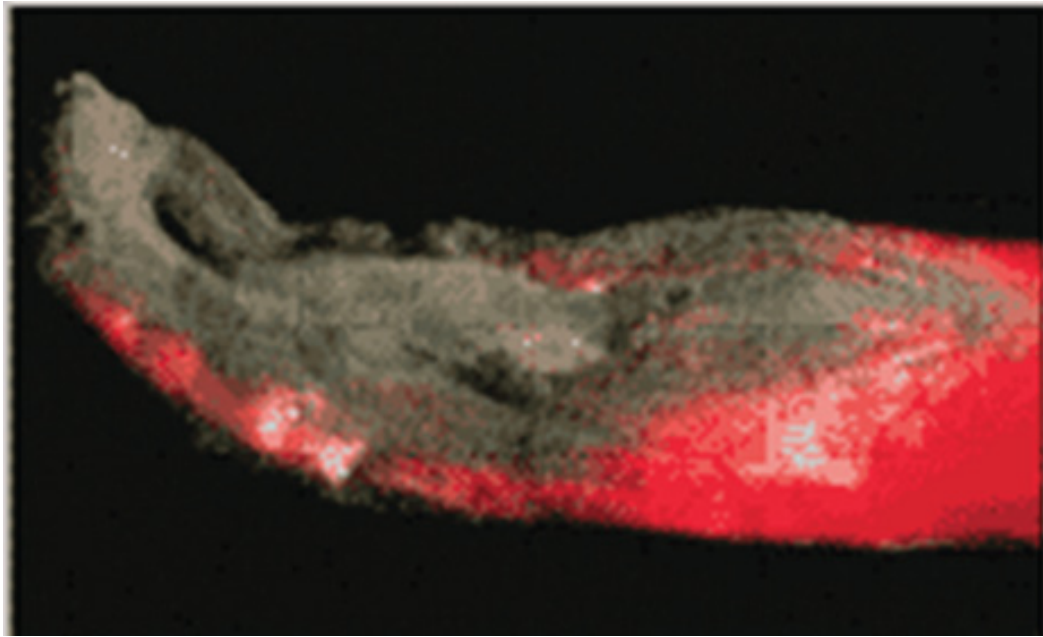


Fig. 102. Gray mold, or *Botrytis blight* on chili pod.  
<http://ipm.illinois.edu/diseases/series900/rpd942/>

### Phytophthora Blight (Chili Wilt)

Caused by a water-borne fungus called *Phytophthora capsica*, chili wilt is generally found in wet waterlogged areas. The fungus invades all plant parts causing leaf blight, fruit rot and root rot. Plants suffering from this condition often wilt and die very quickly. Once the fungus enters the roots the plant is beyond saving.

Management practices for phytophthora blight include avoiding introducing the pathogen into a field, selecting resistant varieties, avoiding favorable conditions (soil saturated with water), applying fungicides starting before disease onset (preventive schedule), and promptly destroying affected plants at the start of an outbreak to limit spread.



Fig. 103. *Phytophthora*, or chili blight on chili plant.  
<http://blogs.cornell.edu/livepath/gallery/peppers/phytophthora-blight-on-peppers/>

## Powdery Mildew

Caused by the fungus *Leveillula taurica*, powdery mildew primarily affects the leaves of chili plants in warm, wet conditions. This disease generally affects older leaves and symptoms include patchy white, powdery growth that can enlarge to cover the entire lower leaf surface. Diseased leaves eventually drop off leaving pods susceptible to sunscald. This condition generally requires a fungicide, affected areas should be removed manually if possible.



Fig. 104. Gray mold, or *Botrytis blight* on chili pod.  
<http://ipm.illinois.edu/diseases/series900/rpd942/>

## Verticillium Wilt

Caused by the fungus *Verticillium dahliae*, a soil-borne fungus which can infect the chili plant at any growth stage, verticillium wilt can cause severe damage to chili crops. Cool air and low soil temperatures can worsen the condition. Plants may show yellowing of leaves and stunted growth. As the disease progresses the plants can shed leaves and may finally die. If the stem is cut, a brown discoloration may be visible. Crop rotation is the only control currently available.

There are no effective control methods once the disease has occurred in the field; therefore, management strategies should concentrate on avoiding the problem.

Resistance to Verticillium wilt in commercial cultivars of peppers is not common.

Because of the longevity of this disease in soil, and the broad host range of *V. dahliae*, crop rotation is usually not a feasible option for control of Verticillium wilt in many crops. However, rotations with broccoli, maize, wheat, barley, sorghum or safflower for a period of at least 2 years can reduce inoculum and subsequent plant infection. These crops are not hosts for the Verticillium pathogen, and populations of the pathogen will decline in fields where host plants are not present. In severe cases, do not replant peppers in the field for a minimum of 3 years.

**Clean equipment and tractors before entering a new field to prevent the spread of soilborne pathogens such as *V. dahliae*.**





*Fig. 105. Verticillium wilt symptoms on pepper stem.*  
<https://apps.extension.umn.edu/garden/diagnose/plant/vegetable/pepper/leaveswilted.html>



*Fig. 105. Verticillium wilt symptoms on pepper stem.*  
<https://apps.extension.umn.edu/garden/diagnose/plant/vegetable/pepper/leaveswilted.html>

## White Mold

Caused by the fungus *Sclerotinia sclerotiorum*, white mold causes blighting or rotting of any above or below-ground plant parts. At first the affected area of the plant has a dark green, greasy or water-logged appearance.

Water-soaked lesions appear on stems. Stems turn to a bleached gray-white, causing them to appear like animal bones left in the sun. All or portions of plants with infected stems develop a general wilting symptom.

On the stems, the lesion may be brown to grey in colour. Controls include well drained soil, proper plant spacing, crop rotation and careful removal of infected areas/plants.

Every effort must be taken to avoid overly dense plant canopies, as poor air circulation aggravates white mold. Rotation with crops other than tomato, pepper, potato, and snap bean may help reduce levels of initial inoculum.



Fig. 107. White mold, *Sclerotinia sclerotiorum* on chili.  
(Source: <http://www.chililicious.co.uk/chili-pests-and-problems.html>)



Fig. 108. White mold, *Sclerotinia sclerotiorum* on chili. Sclerotia (fruiting bodies that allow the fungus to survive over the winter, are small, hard resistant structures that look like bits of black coal.  
[http://ipm.ifas.ufl.edu/pdfs/White\\_mold.pdf](http://ipm.ifas.ufl.edu/pdfs/White_mold.pdf)

## Viral diseases of chili

Viruses are obligate parasites, meaning that they must be within living tissue before they can reproduce themselves. They require a wound to gain entrance to a plant cell. In nature, they depend primarily on biological agents such as insects and man for their spread. Once duplication starts, the virus is translocated from cell to cell through the plant.

In general, viruses are seldom lethal to plants, but do severely affect the host both in quantity, quality and longevity. Symptoms may often be very characteristic for a specific virus on a specific host. Symptoms along with other criteria are used to identify virus diseases. An advanced array of symptoms can be recognized today as expressions of viral diseases in plants.

Viruses in chili are usually spread by insects that feed on an infected plant and transfer the virus to another plant. The same occurs with man transferring a virus on tools or through handling of infected plants. Therefore, sanitation and cleanliness are important in preventing viral diseases. Working with clean tools, clean hands and clean clothing costs nothing and is easy to do and can help to prevent destructive diseases. Always look for virus-resistant varieties if available.

In some instances, when the spread of the virus is slow, loss from disease can be reduced by removing diseased plants and replacing them with healthy replants. This method has been used to reduce losses from peach mosaic. Reducing the population of insect vectors by insecticides or by other means, such as elimination of host plants for the insects, has given at least partial control of some virus diseases. (Texas Plant Disease Handbook,

<https://plantdiseasehandbook.tamu.edu/food-crops/fruit-crops/blackberry-dewberry-and-boysenberry/viral-diseases-of-plants/>)

## Pepper Mosaic & Pepper Mottle Virus (PeMV)

Symptoms can vary, but in general, plants show an overall lighter color along with mosaic patterns (alternating light and dark green areas) on at least some leaves, especially on the younger leaves. Plants will often show stunting, leaf curling, and fruit distortion along with the mosaic pattern on leaves. Symptoms may be similar to those caused by cucumber mosaic virus.



*Fig. 109. Field-grown chili pepper showing symptoms of pepper mottle virus. Notice crinkling, mottling, dark green vein banding and misshapen leaves.*  
<https://www.ndrs.org.uk/article.php?id=030014#>



All the potyviruses affecting pepper are transmitted from plant to plant by several species of aphids. Aphids transmit these viruses for very short periods of time (minutes to a few hours). The type of aphid activity that promotes virus spread occurs when aphids are actively moving through the chili crop and are probing the plant tissues before they begin feeding. Once aphids colonize plants, settling down to feed, transmission is greatly reduced. Thus, spread is often very rapid. In general, field spread of potyviruses occurs when aphid activity in fields is high.

All of the potyviruses that affect chilis have wide host ranges that include other crops, and many weed species, particularly tomato, potato, brinjal, and nightshade family. Various strains of the potyviruses exist. It is very common to find plants simultaneously infected by more than one of the potyviruses and by cucumber mosaic virus. While spraying for the aphid vector will not prevent virus infections from occurring, growers should still attempt to manage aphid populations when possible.

### **Tobacco Etch Virus (TEV)**

TEV is transmitted primarily by aphids. Symptoms include dark green leaf veins, leaf distortion and stunted growth. Solanaceous crops and weeds (nightshade, jimsonweed) are alternate hosts. Remove infected plants, control weeds. Some resistant varieties of bell peppers are available. Check with your seed source for availability of resistant varieties in your area. The University of California reports unacceptable success in limiting the movement of this virus through insecticide sprays for aphids.



*Fig. 110. Symptoms of TEV in tobacco. Photo by Brenda Kennedy, University of Kentucky.  
<http://www.uky.edu/Ag/Agronomy/IPM/completedDocs/5b-20-TEV.pdf>*

## Tobamoviruses

Another group of viral diseases attacking chilis are the tobamoviruses. These viruses are not transmitted by insects feeding on the chilis. Rather, these diseases are spread through debris in the soil from a previous pepper crop or virus-carrying seed. The diseases are also spread within the crop through contact between plants and mechanical transfer of virus on the hands and implements of those working with the crop. The international chili trade has likely assisted with transmission of these important viruses.

### Tobacco Mosaic Virus (TMV)

TMV is a highly infectious and persistent disease that is carried by tobacco in cigarettes and spread to other crops including chili. It is commonly spread by touching plants after handling tobacco or smoking. Symptoms include curling leaves, spotted or mottled fruit, stunted growth and excessive leaf drop.

An important source of primary inoculum is contaminated seed. The virus is carried on the seed coat, and thus can be removed from contaminated seeds by washing seed with dilute solutions of tri-sodium phosphate. TMV on chili is spread mechanically within the field by handling and mechanical damage to plants, but not by insect, nematode or fungal vectors. TMV can survive in plant debris for many years.

The best control is to use seed that has been treated to eliminate the seedborne inoculum. Minimizing plant handling and damage also is important for reducing field spread of tobacco mosaic virus. Resistant varieties should be used. No chemical strategies are effective.



*Fig. 111. Symptoms of tobacco mosaic virus on chili leaves.*

*Source: <https://www.bakhaber-kissan.com/chili/2/>*







## CHAPTER 6

### HARVEST AND POST-HARVEST MANAGEMENT

#### Chili Harvest and Post-Harvest

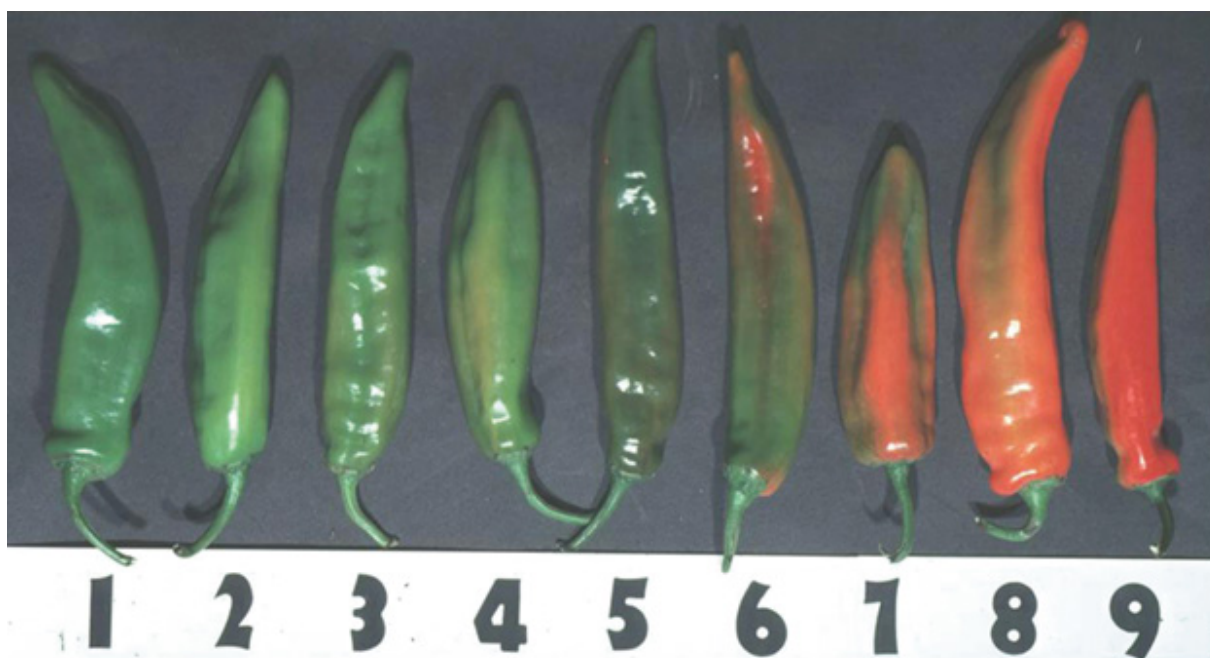
Chili is a high value crop, producing flavorful and pungent fruit that are highly desired in Pakistan and many other countries. Farmers should strive to produce clean, healthy and wholesome chilis in order to increase income and develop market potential for domestic and export.

Chilis at harvest will reflect, to a large extent, the care given to them throughout the growing season, from planting to harvest. The growing season is long and requires many decisions. Farmers who purchase high quality seed, prepare a good seedbed, provide optimum fertilizer and devote many hours to managing pests and irrigation, will most likely produce a high-quality crop that sells easy and develops his reputation as a quality grower. However, quality crop at maturity can be damaged with poor harvest and post-harvest practices.

Chilis in Pakistan are usually harvested at full maturity when the fruit are completely red in color. Partially red chilis should not be picked as they contain higher moisture content and take longer to dry. The most desirable and highest value chilis are fully ripe, fresh, and free from diseases, mechanical injuries, insects, blemishes and sunscald. These will bring the best price and sell quickly.

Harvesting of red chili is not a “one time” event. Chilis mature over an extended time period so harvest also occurs over an extended time period. Harvesting fruit encourages the plant to produce more fruit, so it's important that fruit don't remain on the plant any longer than necessary to reach maturity. On average, growers will harvest chilis over 6-10 separate harvests (8-10 for Dandicut varieties), at 15-day intervals, which will carry harvest over a period 2-4 months. It's important that farmers observe the weather forecasts and plan their activities accordingly. Picking and drying on cloudy and rainy days will lead to reduced quality.

Mature chilis will come off the plant easily, whereas immature chilis will be more difficult to remove from the plant. Chili color is a good indicator of maturity. Workers should select mature fruit for harvest and use gentle force to remove the fruit. Pulling or jerking of the fruit can damage the plant or bruise fruit.



*Fig. 112. Maturity and ripeness colors of chili peppers.*

[http://postharvest.ucdavis.edu/Commodity\\_Resources/Fact\\_Sheets/Datastores/Vegetables\\_English/?uid=12&ds=799](http://postharvest.ucdavis.edu/Commodity_Resources/Fact_Sheets/Datastores/Vegetables_English/?uid=12&ds=799) Photo Credit: Adel Kader, UC Davis

### Preparing for harvest

Harvest should take place when the field is dry. Muddy fields decrease harvest efficiency and can lead to increased contamination of the fruit. Chili plants should be free of dew each day before harvest starts. Delaying harvest until mid-morning is usually enough, but plants should be checked before starting.

Workers must be given Personal Protective Equipment to use during harvest, including gloves, surgical mask to cover mouth and nose, a reusable cloth apron and washing facilities to wash hands, face, etc. These are important in order to provide protection from capsaicin, an active component of chili peppers. Capsaicin is an irritant for mammals, including humans, and produces a sensation of burning in any tissue with which it comes into contact. Workers must be trained to avoid touching their eyes, faces or other body parts when harvesting chilis.

Chilis should be picked and immediately placed in well-ventilated plastic baskets. Burlap or jute bags do not provide adequate ventilation and can lead to fungal contamination and secondary disease infection. Baskets should be washed and disinfected daily in order to reduce disease transmission. Use a mild detergent and hot water to wash, and spray with a 10% bleach solution.



*Fig. 113. Worker transferring fruit from harvest apron to stackable, ventilated plastic basket.*

*Clean plastic buckets are also an acceptable option. Since chilis are lightweight, they can be placed in a bucket, gently, without danger of excessive weight on the bottom fruit.*

		Problem	Resulting Loss
1	Picking	<ol style="list-style-type: none"> <li>1. Harvesting of unripe chili</li> <li>2. Cracking of pods during picking</li> </ol>	<ol style="list-style-type: none"> <li>1. Quality deterioration leading to fungal attack</li> <li>2. Physical damage</li> </ol>
2	Collection	<ol style="list-style-type: none"> <li>1. Stuffing of chili in bags</li> <li>2. Packing in polypropylene bags</li> <li>3. Chilis remaining in sun more than 1 hour after picking</li> </ol>	<ol style="list-style-type: none"> <li>1. Stress on pods</li> <li>2. Overheating chilis</li> </ol>
3	Transportation from field to drying floor	<ol style="list-style-type: none"> <li>1. Over stacking of bags</li> <li>2. People sitting on bags</li> </ol>	<ol style="list-style-type: none"> <li>1. Physical damage</li> <li>2. Physical damage</li> </ol>
4	Sun drying	<ol style="list-style-type: none"> <li>1. Drying on barren soil or cow dung-pasted surfaces</li> <li>2. Dust blowing in drying yard</li> <li>3. Turning over of chilis by hard tools</li> <li>4. Chili lying open during night time</li> <li>5. People walking over chilis</li> <li>6. Animals trespassing</li> <li>7. Rodent damage</li> </ol>	<ol style="list-style-type: none"> <li>1. Mycotoxin contamination</li> <li>2. Aflatoxin contamination</li> <li>3. Physical damage</li> <li>4. Physical damage &amp; contamination</li> <li>5. Salmonella &amp; mycotoxin contamination</li> </ol>
5	Packing and transportation from field to market	<ol style="list-style-type: none"> <li>1. No or little grading and separation of substandard chili pods</li> <li>2. Packaging in polypropylene bags</li> <li>3. Stacking bags too deep</li> <li>4. Placing chilis in used or dirty bags</li> </ol>	<ol style="list-style-type: none"> <li>1. Quality deterioration leading to fungal attack</li> <li>2. Physical damage</li> <li>3. Physical damage</li> <li>4. Multiplication of stored grain pest</li> </ol>
6	Storage	<ol style="list-style-type: none"> <li>1. Insufficient ventilation</li> <li>2. Stacking bags too deep</li> <li>3. Placement of bags on ground without pallets</li> <li>4. Stored pest in used bags</li> <li>5. No or late fumigation</li> </ol>	<ol style="list-style-type: none"> <li>1. Quality deterioration leading to fungal attack</li> <li>2. Physical damage</li> <li>3. Quality deterioration</li> <li>4. Quality deterioration &amp; product loss</li> </ol>





*Fig. 114. Food grade plastic, stackable, nesting 30 lb harvesting bins.*

*Turned 180 degrees, they can be 'nested' making for efficient space utilization.*

*Nesting containers make it more cost effective to transport chilis to market and return the containers to the farm.*

*<http://www.pacinj.com/products/30lb-harvesting-lug/>*

Reusable harvest containers should be cleaned and sanitized regularly. A 4-step process is recommended:

- ▶ Pre-rinse containers with water hose to remove visible soil particles
- ▶ Wash with dishwashing soap applied to the surface, either in dispersion or directly, to break down contaminants and soil. A brush is used to scrub the containers while they are soapy to further remove soil and other particles from the inside and outside surfaces
- ▶ Containers are then rinsed with water to remove soil particles, contaminant particles and any soap residues
- ▶ Containers are sanitized with 10% household bleach solution (mix 13 oz bleach in 1 gallon of water) and spray the harvest containers. Let containers dry

### **Immediate post-harvest**

When chilis are harvested, they should spend no more than 1 hour in the field. It's important to move them to a shaded area within an hour or they become overheated and start to lose quality. This shade can be under trees at the field edge, under temporary shelters built in the field or on the field edge, or shelters at the farm if located close to the field.

After removing the chilis from the field, it's critical to remove field heat which helps maintain fruit quality and prevent deterioration. The best way to reduce field heat is to dip the chilis in water. Farmers can construct a small concrete, open-top tank to fill with water, or, purchase a plastic tank. A shade over this tank would be

a very good addition. The water should be mixed with two percent salt for cleaning of pesticide residues, and this might be enough to meet international standards for pesticide residues but would be subject to testing and approval. Chilis should be placed into this cooling tank, loose, for 10 minutes, then removed and placed in clean ventilated plastic containers. Sorting of damaged, immature or diseased chilis should take place at this location, before chilis are placed in the water. Sorting could also take place in the field.

Once the chilis are cooled in the water bath, they should be transported to the drying area quickly. If the chilis must be transported to the drying area, the transportation method should be fast and with a smooth ride in order to reduce additional heating and bruising.

## Drying & storage

### Establish an area for drying and maintaining cleanliness

In Pakistan, most chilis are dried on the farm. Drying areas should be on level, firm, sunny and compacted areas. Sloped or loose areas increase handling efficiency and increase the opportunity for dust contamination. Livestock should not be nearby, and they should not be able to trespass to the drying area. The drying area should be in an area with abundant sunshine and wind protection. Blowing wind carries dust, which carries disease organisms. Manure paddies or alkali surfaces should not be used for drying surfaces. These increase the potential for contamination and reduced quality.

Chilis should be dried off the ground, raised several inches above the packed soil surface. Raised drying platforms (Fig. 4.) are the best practice. These provide good air movement above and below the chilis and reduce drying times. With steel frames and long-lasting ventilated geotextile fabric, these drying platforms will last for years. Metal frames provide strength and protection from rodents. The raised platforms, made no more than 5-6 feet wide, allow farmers to walk along each side of the drying table to identify and remove damaged and undesirable pods. Chilis should only be one-layer thick on the drying platforms, they should not be piled on top of each other. Chilis should be turned daily with clean brooms or brushes, not hard wooden or metal tools. This reduces bruising and maintains quality.



*Fig. 115. Chili drying on raised drying platforms. This keeps chilis off the ground. Notice barrier in background to reduce wind and blowing dust*



Pods should be covered at night to protect them from dew. Doing so will reduce drying time by 2-3 days. Covering the pods with a Tyvek sheet is the best. The material allows air to circulate but moisture can't penetrate. Cover the pods late in the evening and uncover them early in the morning.



*Fig. 116. Chilis should be protected from dew at night. Covering the pods with a Tyvek sheet is the best. The material allows air to circulate but moisture won't penetrate. Workers should cover the pods late in the evening and uncover them early in the morning*



*Fig. 117. Can you name at least three things in this picture that are wrong? 1. Chilis are being dried on the ground. 2. The worker is walking on the chilis, 3. The worker is using a hard wooden tool to turn the chilis. Can you see any other bad practices?*



It's important to prevent trespassing by livestock, dogs and people. Well-designed fencing can serve the purpose of preventing trespass and reducing wind. Trees or other vegetation can also serve as an effective barrier to wind and livestock. Rodents should be killed with poison or trapped, or both.

Chilis should be dried to 10% moisture. If not dried to this level, chilis can develop aflatoxin, a poisonous fungal disease that can sicken, or even kill humans and livestock. Moisture testing equipment is the best way to measure moisture precisely.



*Fig. 118. Chilis, highly toxic and unfit for human or animal consumption*

## Packing & preparation for storage

Once the chilis are dried to no more than 10% moisture they should go through the final sorting. Any damaged, discolored, diseased or cracked pods should be removed. The remaining chilis will be the farmer's top quality and are ready to be removed from the drying platforms, packed and prepared for transportation to market.

Pods, even at 10% moisture, can still become infested with disease. It's important to protect chilis from disease and ventilation can be the best preventative method after harvest.

If the pods are going to the wholesale market or buyer's location, they should be placed again in clean, well-ventilated, stackable plastic baskets. These would be the same baskets used at harvest and should be cleaned and sanitized again. Do not overfill the baskets. They should be packed, stacked and transported as quickly and smoothly as possible.

If the chilis are going into storage, they should be placed into new, or freshly-washed and very clean, jute bags. Do not overfill the bags as it's important to maintain ventilation. Sew the opening of the bag closed. Placing an identification tag onto the bag is helpful to maintain the identity of the grower. If tags aren't

available, other distinctive markers can be used, such as permanent markers to write the grower's name on the bag, or pieces of distinctive fabric, even with written name of farmer, can be attached to the bag.

## Storage

There are generally two storage alternatives for chili pods: commercial, or on-farm.

### • Commercial storage

- ▶ Commercial: Most chilis go from the farm to the market and are stored by the spice company which purchases the chilis. It is not the Commercial storage should meet minimum sanitation standards, including:

### • Sound structure

- ▶ Floor: Brick, tile or concrete without holes that allow rodents and insects to enter
- ▶ Roof: Rainproof and sealed against insects and rodents
- ▶ Walls: Solid construction with concrete, brick, metal. No holes open to rodents, birds or insects
- ▶ High walls, with space between top of wall and ceiling through which heat can escape
- ▶ Tight, fine mesh screen area between top of walls and ceiling for heat escape

### • Ventilation

- ▶ Temperature will increase, on average, between 0.5 – 1.5 °C for each elevated foot that heat rises. So, if a ceiling is 20 feet high, there can be a 10-20 °C variance in temperature between the floor and ceiling. Thus, screened openings at the top of walls is of significant benefit in reducing storage temperature. Fans that circulate air inside the warehouse help to mix the air and remove heat
- ▶ Storage of bins or bags must be off the floor, either using pallets or industrial shelving

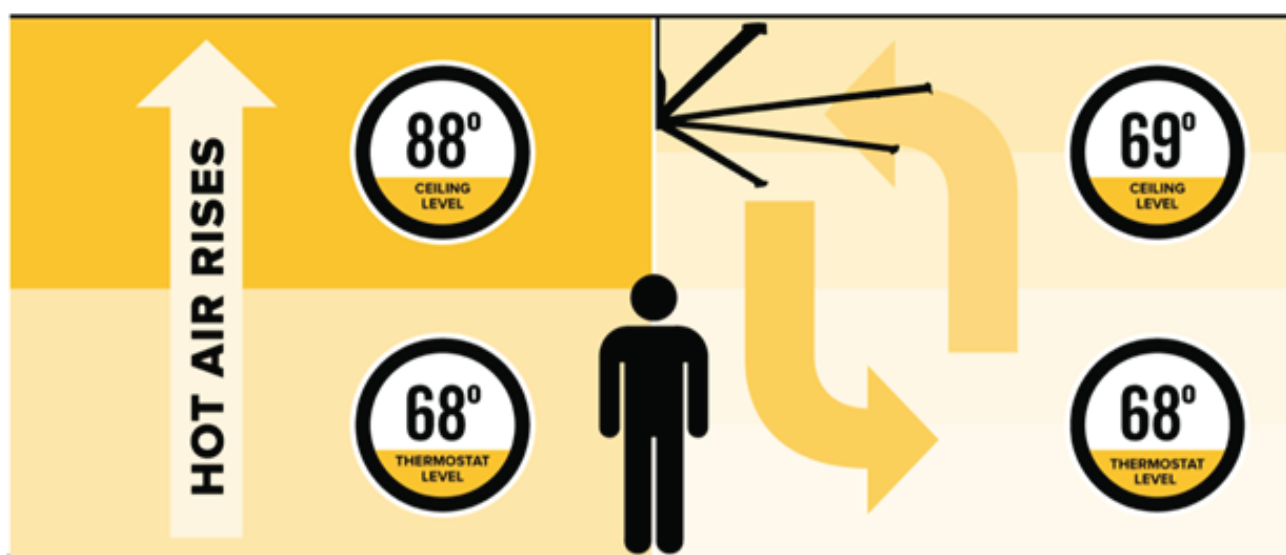


Fig. 119. Chilis, highly toxic and unfit for human or animal consumption



*Fig. 120. Example of a de-stratification fan to circulate air within a warehouse*



*Fig. 121. Metal racks for large warehouse storage of plastic bins, or pallets of bags.*  
<http://www.minifastindia.com/Heavy%20Duty%20Pallet%20Racks.html>



- **Humidity control**

- ▶ Dried chilis attract moisture and can become infected with disease. Ventilation in storage will help to reduce humidity
- ▶ Refrigeration-based dehumidifiers are available and a viable option for large-scale storage facilities. Ground chilis will maintain color longer at lower temperatures

- **Pest management**

- ▶ Exclusion is the primary method of pest management, through good construction (no gaps or openings, fine screens, etc.) and maintenance.
  - ▶ Sanitation must be practiced. Remove all debris, dirt, dust and trash from the storage facility before chilis are moved in
  - ▶ Rodents should be trapped, and traps monitored daily
- Monitor for insects and treat premises as recommended on product labels
- ▶ Unless a structure is sealed and cooled with refrigeration, insect management through fumigation will have to rely on batch-fumigation instead of whole-structure fumigation.
  - For batch-fumigation, chilis should be placed on pallets and covered with plastic sheet, fumigant product tablets are evenly distributed under the plastic and the plastic sheet is taped to the floor to prevent leaks. Follow label directions
  - With batch-fumigation, it is very important to also spray the premises (inside and outside) with insecticide. Follow label directions



*Fig. 122. Batch fumigation. Product on pallets and covered with plastic, taped to the floor to seal*

## On-farm storage

Farmers should have on-farm storage facilities in which to store their chili crop. Holding the chilis for a few months will often result in higher prices. The economic advantage of on-farm storage is often worth the expense.

On-farm storage needn't be as sophisticated as commercial storage, but it must serve the purpose effectively. Some considerations for on-farm storage include:

- **Chilis must remain dry**

A waterproof structure is required

- **The floor should be solid and waterproof**

**Walls or gates to the storage area should not have holes or cracks in order to keep rodents and birds out**

- **Insects should not be able to attack the chilis**

**The chilis need good ventilation. Store bags of pods on pallets, off the ground**

- **Good sanitation is required, keep the area clean**

- **Treat with a premise spray of insecticide before storing bagged pods**

- **Use traps and poisons to reduce rodent populations**

- **Fumigate if possible, at soon as the bags go into storage**

Various styles of structures are available, including mud, brick, wood or metal bins. Raised bins on rodent-proof legs could be acceptable.

## Common insect pests of stored products

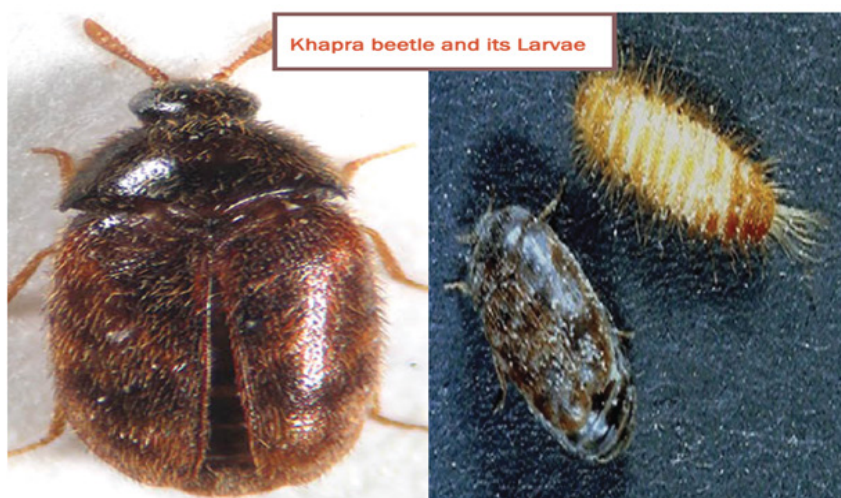


Fig. 123. Khapra beetle and larva

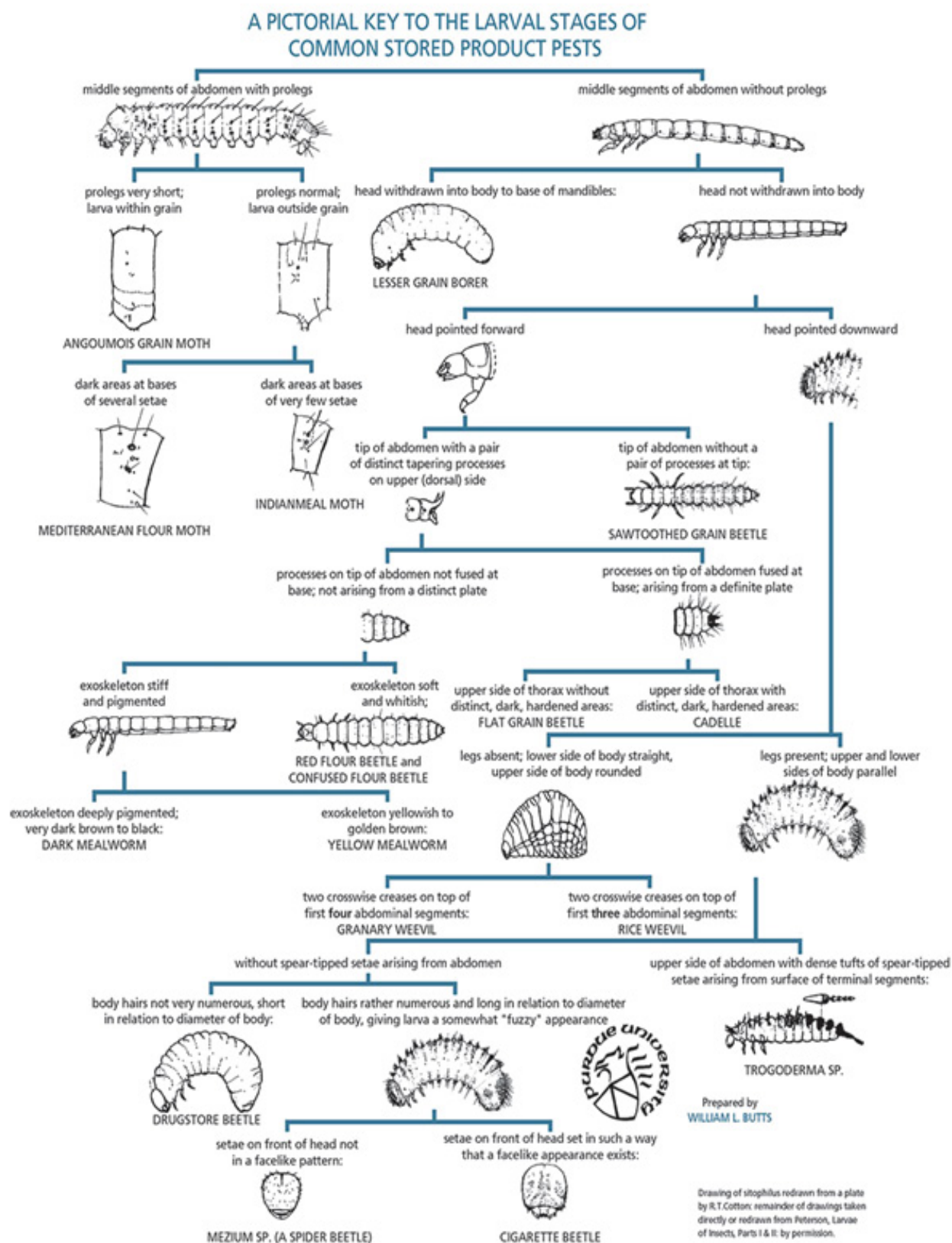


Fig. 124. Pictorial guide to immature stages of common stored product pests



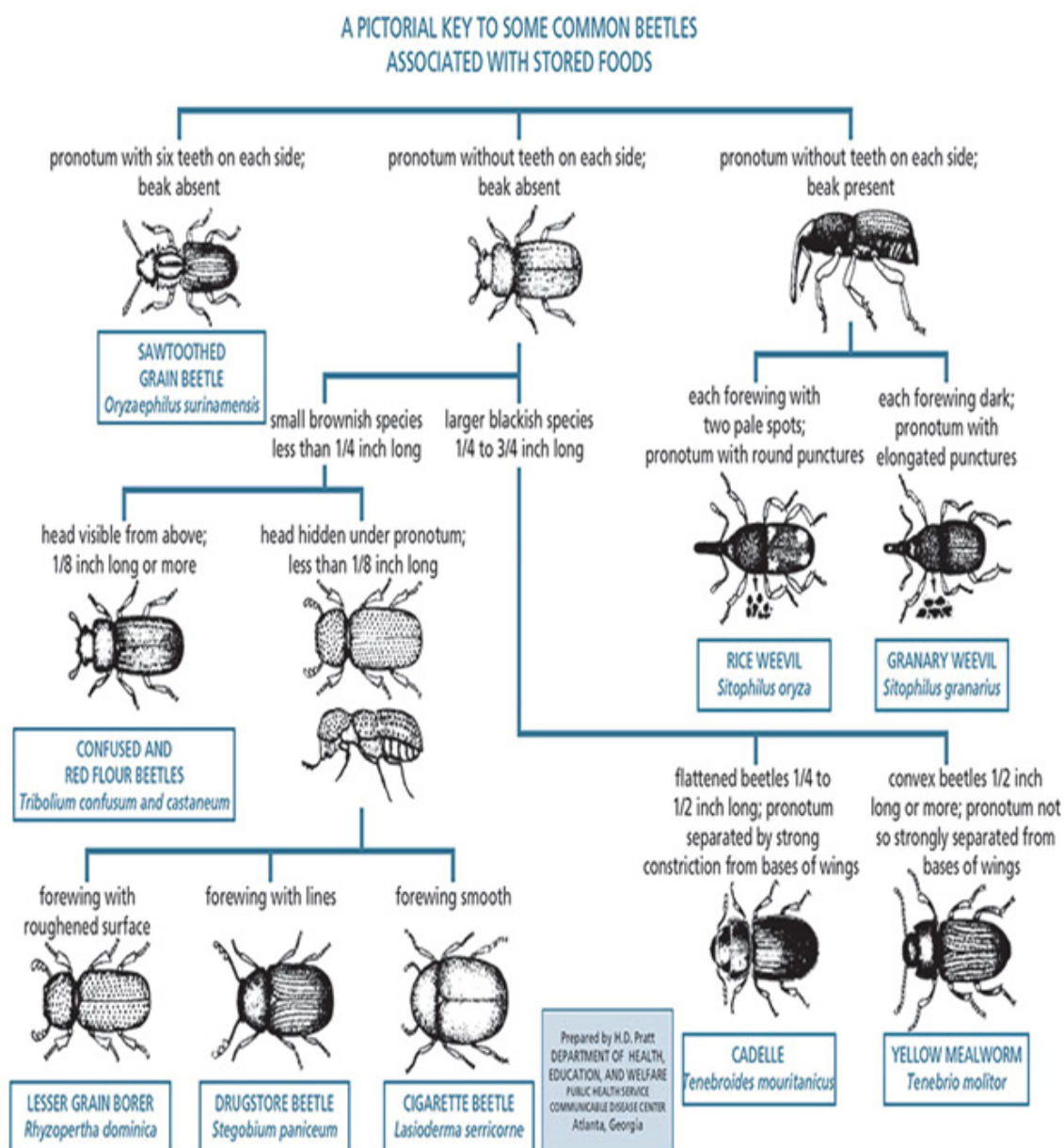


Fig. 125. Khapra beetle and larva



*Fig. 126. Adult granary weevil.*  
<https://bugguide.net/node/view/355245>

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*Fig. 127. Khapra beetle and larva*

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