# EGGPLANT, PEPPER, AND TOMATO PRODUCTION GUIDE FOR GUAM

## Production and IPM Practices for Solanaceous Crops in Guam

2002

Guam Cooperative Extension

College of Agriculture & Life Sciences

University of Guam

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## Preface *(Second Edition)*

Eggplant, Pepper, and Tomato Production Guide for Guam - Production and IPM Practices for Solanaceous crops in Guam (Second Edition) is a revised edition of the textbook Eggplant, Pepper, and Tomato Production for Guam published in 1998 by Guam Cooperative Extension. The second edition was funded by the United States Department of Agriculture National Institute of Food and Agriculture Crop Protection and Pest Management (USDA-NIFA-CPPM) Grant, Awards No. 2014-70006-22504. The content of the second edition is that of the original with the exception of a few small revisions and updates. During the course of writing the second edition, the original authors were solicited for comments. Additional contributors to the second edition include Samantha J. Danguilan, Dr. Kai-Shu Ling, Sheeka Jo A. Tareyama, and Roger Brown.

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### Conversion Table

#### Liquid

1 tablespoon (T, tbsp) = 3 teaspoons (t, ts, tspn)

1 U.S. fluid ounce (fl oz) = 2 Tablespoons

1 cup (C) = 8 fl oz

1 pint (pt) = 16 fl oz

1 gallon (gal) = 3.785 liters (L) = 128 fl oz

1 quart = 946 milliliters (ml)

1 fluid ounce = 29.54 ml

1 liter = 1.06 qt = 0.264 gal

#### Dry

1 ox = 28.35 grams (g)

1 pound (lb, lbs) = 454 g = 16 oz

1 ton = 2,000 lbs

1 hundredweight = 100 lbs

1 gram = 0.0353 oz

1 kilogram (kg) = 2.205 lbs

1 kg = 1,000 g

1 metric ton (MT) = 1.1 tons

1 cup of granular fertilizer = 217.6 g = 0.478 lbs

#### Area

1 acre (A) = 43,560 square feet (sq ft)

1 hectare (ha) = 2.47 acres

1 A = 0.405 ha

#### Yield or Rate

1 lb/A = 1.12 kg/ha

1 gallon/acre = 9.35 L/ha

1 mile per hour (mph) = 1.6 km per hour (kh)

1 kg/ha = 0.892 lbs/A

1 gallon/minute = 3.785 liters/minute

#### Temperature

$°F = (^9/_5 \bullet °C) + 32$

$°C = ^5/_9 (°F - 32)$

For easy conversion, go to http://www.sciencemadesimple.com/conversions.html

# Brief Contents

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# Foreword

**Robert L. Schlub, Editor**
**Lee S. Yudin, Editor**

The Eggplant, Pepper, and Tomato Production Guide for Guam is comprehensive in nature and carefully designed to provide growers of solanaceous crops on Guam, agricultural extension agents, agricultural students, and home-owners with a comprehensive manual covering all aspects of solanaceous production. This publication incorporates information from a number of sources as it relates to extension activities on Guam. The sources include compendiums, guides, and fact sheets from U.S. Land Grant Universities, USDA Animal Plant Health Inspection Service and Plant Protection Quarantine; historical data from the Guam Agricultural Experiment Station; and current research and surveys conducted by faculty of the College of Agriculture and Life Sciences. Since eggplants, peppers, and tomatoes are worldwide in distribution, fundamental information on growth requirements, cultivated varieties, diseases, insects, and weeds will be of interest to all growers. Even though the production/protection practices in this guide were designed for Guam, the fundamental principles can be applied elsewhere. The chapters on Economic Assessment, Developing Budgets, and Financial Assistance to Guam Farmers were included to assist those wanting to assess business opportunities. The chapter on Nutrition and Recipes provides a variety of information about eggplants, peppers, and tomatoes and includes a few recipes to try. The goal of this publication is to empower any eggplant, pepper and tomato producer with enough general and specific information to enhance learning and encourage sound production practices on Guam and elsewhere.


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# Contributors and Acknowledgements

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# Part 1. Getting Started

# Chapter 1 Nomenclature

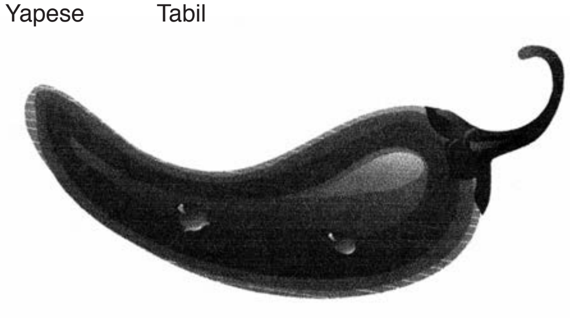
**Mari Marutani, Horticulturist**
**Robert L. Schlub, Extension Plant Pathologist**

**Botanical name:**
*Capsicum annuum* cv. Hot Beauty

**Genus** — **Species** — **Cultivar** or **Variety**

**Common Names:**

| | |
|---|---|
| Chamorro | Doni Ti'ao (long hot pepper) |
| Chinese | La-chiao |
| Chuukese | Mwi |
| English | Chili Pepper |
| Hindi | Mirchai |
| Japanese | Togarashi |
| Korean | Maewoon-Gochoo |
| Kosraean | Pwepu |
| Marshallese | Peba |
| Nepali | Khursani |
| Palauan | Meringel |
| Pohnpeian | Sele |
| Spanish | Pimiento |
| Tagalog | Sili |
| Yapese | Tabil |



**Plant Classification**

| Taxon | Scientific Name | Common Name |
|---|---|---|
| **Kingdom** | Plantae | Plant |
| **Division** | Magnoliophyta | Flowering plant |
| **Class** | Magnoliopsida | Dicot |
| **Subclass** | Asteridae | |
| **Order** | Solanales | |
| **Family** | Solanaceae | Nightshade or Tomato family |
| **Genus** | Capsicum | |
| **Species** | annuum | Hot pepper, Bell pepper, cherry pepper, paprika, jalapeno |
| | frutescenes | Tabasco pepper, bird pepper |
| | chinense | Habanero pepper, scotch bonnet |

Each plant typically has two names, the **common** name and the **botanical** or scientific name. The Common name of a plant is used locally among people with the same culture or language; eggplants, peppers, and tomatoes are common plant names. It is not unusual for one plant to have many common names. On the other hand, a plant has only one botanical or scientific name. By using a botanical name, individuals from different places or countries can exchange information about a plant without confusion as to which plant is being discussed. The botanical name is **binomial** which means there are two parts to describe one plant. The first part is **genus** and the second **species**. The genus (plural: genera) contains a group of species (sometimes a single species). A generic name may be written alone when one is referring to the entire group of species comprising that genus. The species name is used to describe a particular genus and by itself is meaningless because more than one genus may have the same species name; for examples: *Cerapsicum pubescens; Physalis pubescens; Bemisia tabaci*; and *Thrips tabaci*. Plant species (singular and plural: species) in the same genus have many structural characteristics in common, but differ from those plants belonging to other genera. A species may have a variant. A group of plants that are significantly different from the original form of a species may have a **variety** name after the species name. The abbreviation '**var.**' refers to a botanical variety. An example is cherry tomato, *Lycopersicon esculentum* var. *cerasiforme*. The variety name, *cerasiforme,* follows generic and species name, *Lycopersicon esculentum*, implies that cherry tomato has little structural difference from regular tomato which has the botanical name of *Lycopersicon esculentum*.

All names referring to genus, species and variety (sometimes subspecies) are either italicized or underlined, and the first letter of the generic name is a capital letter. Each botanical name also has one or more author names, i.e., who named and described the species. In some cases, a plant may have more than one botanical name. This happens when a plant taxonomist revises a classification system based on additional evidence. By using an author's name at the end of botanical names, we all know to which plant we are referring. The United States Department of Agriculture (USDA) classification follows the International Rules on

### Other Solanaceous Crops

| Botanical name | Common name |
|---|---|
| *Cyphomandra betacea* | tree tomato<br>tamarillo |
| *Lycium chinense* | Chinese box thorn |
| *Physalis alkekengi* | Chinese lantern<br>strawberry tomato |
| *P. ixocarpa* | husk tomato<br>tomatillo |
| *P. peruviana* | cape gooseberry<br>uchuba |
| *P. pruinosa* | dwarf cape gooseberry |
| *P. pubescens* | ground cherry |
| *Solanum aethiopicum* | cut eggplant<br>moch tomato |
| *S. americanum* | glossy nightshade |
| *S. gilo* | gilo<br>garden egg |
| *S. hirsutissimum* | lulita |
| *S. hygrothermicum* | peruvian potato |
| *S. incanum* | sodom apple |
| *S. indicum* | Indian nightshade |
| *S. integrifolium* | tomato eggplant<br>scarlet eggplant |
| *S. macrocarpon* | african eggplant |
| *S. muricatum* | pepino<br>sweet pepino |
| *S. melanocerasum* | garden huckleberry<br>wonderberry<br>pea eggplant |
| *S. quitoense* | naranjilla<br>lulo |
| *S. sessiliflorum* | cubiu<br>cocona |
| *S. torvum* | turkeyberry<br>devil's fig<br>takokak |

nomenclature in classifying plant family, genus, species, and variety (or subspecies).

Plant breeders are continually developing new types of eggplants, peppers, and tomatoes. When a new subspecies is the result of nature it is referred to as **variety**; when it is the result of scientific plant breeding it is referred to as a **cultivar**. A cultivar, abbreviated '**cv.**', is a contraction of the terms cultivated and variety. Occasionally 'variety' is used to refer to 'cultivar;' however this 'variety' is different from botanical variety. A cultivar name is not italicized or underlined. After a cultivar is released to the public, the terms variety and cultivar are often used synonymously.

There are more than 80 genera and over 2,000 species in the family Solanaceae. Genera of important vegetables in the Solanaceae include *Solanum*, *Lycopersicon*, and *Capsicum*. Eggplant, *Solanum melongena* L. is one of the most important crops on Guam. There are two types of tomatoes grown on Guam: the common tomato, *Lycopersicon esculentum* Mill., and the cherry tomato, *Lycopersicon esculentum* var. *cerasiforme* (Dunal) A. Gray. All sweet or bell peppers and some hot peppers are *Capsicum annuum* L. while most *Capsicum frutescens* and several *Capsicum* species and their hybrids are hot peppers.

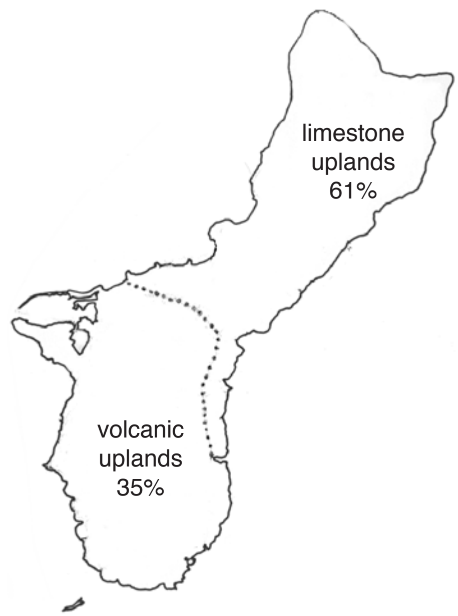
Some other familiar plants in the Solanaceae include the potato, *Solanum tuberosum* L.; tobacco, *Nicotiana tabacum* L.; cape gooseberry, *Physalis peruviana* L., and tomatillo or husk tomato, *Physalis ixocarpa* Brot. ex Hornem. Other ornamental or medicinal plants are *Petunia* and *Datura*.

# Chapter 2 Growth and Development

Robert L. Schlub, Extension Plant Pathologist

For an eggplant, pepper or tomato seed to germinate and grow into a fruit bearing plant, its environment must contain sufficient light, temperature, moisture, air, and nutrients. As the plant passes from the seedling stage to the flowering and eventually to the fruiting stage, its environmental requirements change as well. In this chapter, the various environmental requirements of eggplant, pepper, and tomato production will be discussed.

The eggplant, pepper and tomato are grown from seed, cultivated as short-lived perennials and grown for their fruits. Given their tropical origin, they thrive in Guam's climatic and soil conditions.




**Eggplant, pepper, and tomato production is well suited to Guam's climatic and soil conditions.**

As members of the subclass Dicotyledonae, eggplant, pepper, and tomato plants have seeds that have two cotyledons. Cotyledons are a part of the embryo (immature plant), that serves to fuel seed germination and later function as temporary leaves for the developing seedling. They also have a tap root containing secondary roots, broadleaves with feather like veins, a branching growth habit, and stems which thicken as the plant matures.

## Germination and Emergence

Germination and emergence depends on the proper soil temperature and moisture. Germination begins when the seed starts to take up water and is completed when the embryonic root (radicle) emerges from the seed. Emergence from the soil is complete when the middle of the embryo (hypocotyl) elongates and breaks through the soil, pulling the cotyledons and enclosed plumule (embryonic leaves and stem) through the ground and projecting them into the air **[Figure 2.1]**. After emergence, the cotyledons functions as leaves converting energy from the sun into food for the plant. The expanded cotyledons are often referred to as seed leaves. Because cotyledons play such an important role in early seedling development, any seedling with missing or severely damaged cotyledons should be discarded. The time from germination to completion of emergence for tomato decreases with temperature: 43 days at 10° C (50° F); 6 days at 30° C (86° F).

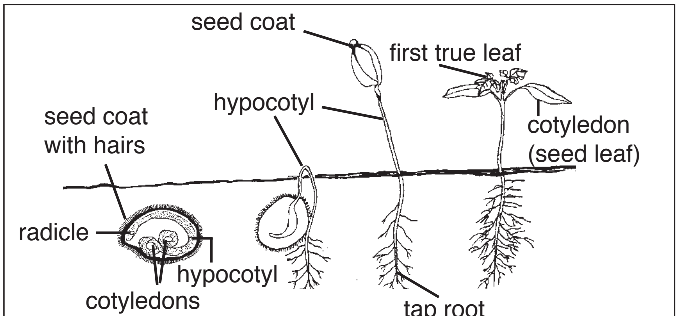
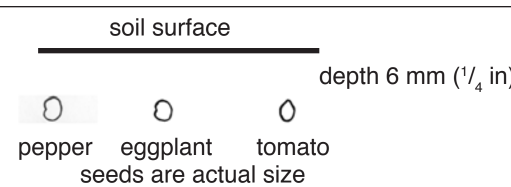



**Figure 2.1.** Seed anatomy and germination of tomato. (Derived from Mayer, A.M. and A. Poljakoff-Mayber. 1963 and Papadopulos, A.P. 1991 in Jones, J.B. 1999).

Due to eggplant, pepper, and tomato's small seed size and subsequent small cotyledons, seeds should only be planted 6 mm ($^1/_4$ inches) deep. The optimum soil temperature for germination is 30° C (86° F) and the optimal soil moisture is field capacity.

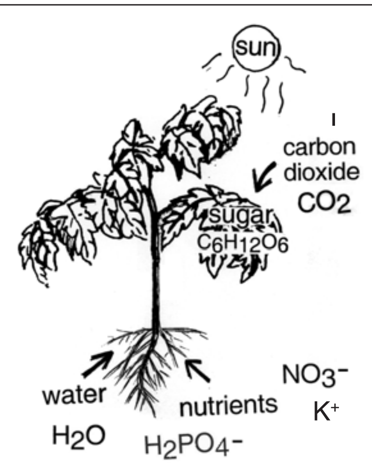



Seeds should be planted 6 mm ($^1/_4$ in) deep.

Field capacity is the amount of moisture held in a soil after a heavy rain followed by thorough drainage. At field capacity, there is enough moisture for the seed to absorb water and enough air spaces to supply its oxygen needs. Oxygen is needed by all living cells found in seeds, leaves, stems and roots. Various materials such as peat moss, compost, vermiculite, perlite, and coarse sand can be added to soil to increase its air spaces (aeration) and decrease the likelihood of overwatering (waterlogging). There are a number of artificial soils or potting mixes formulated to maximize germination. The commercially available artificial soils also have the advantage of being free of insects, disease organisms, and weed seeds.

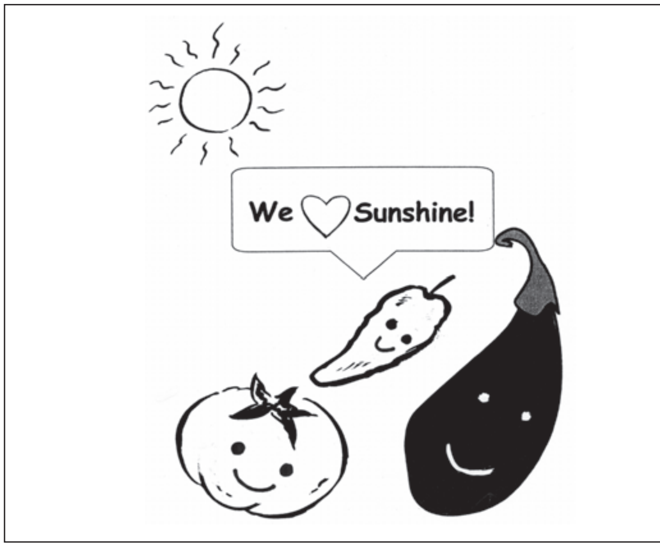
### Growth

After emergence and the exhaustion of the food reserves in the cotyledons, the plant depends on photosynthesis and sunlight energy to make the necessary food for growth. The process known as photosynthesis, which occurs in the green parts of the plant and primarily in the leaves, uses the energy from sunlight in combination with water and nutrients from the soil and carbon dioxide from the air to make carbohydrates (sugars) and oxygen. The process of respiration, which occurs in all living plant cells, green or not, uses carbohydrates in the presence of oxygen to produce chemical energy. Carbohydrates not used in respiration are used as constituents for plant growth and development or are stored in the stems, roots, and fruits as sugars and starches for later use.




**Plants make their own food by using the energy from the sun, carbon dioxide from the air and water and nutrients from the soil.**

Pepper, eggplant, and tomato are sun loving, preferring long sunny days. To maximize light intensity, avoid planting in shady areas and during the rainy season when excess cloud coverage is common. The rainy season on Guam extends from mid-July to mid-November. Low light intensity and high night temperatures are conducive to tomatoes with lanky vegetative growth and less fruits. The total hours of sunlight is highest during the summer. Guam has day lengths ranging from 11 hours and 19 minutes in December to 12 hours and 56 minutes in June.




Guam's climate is well suited for eggplant, pepper, and tomato production. Guam's relatively uniform and high temperatures (average monthly highs-lows of 30–22° C (86–72° F), stimulate rapid growth **[Figure 2.2]**.

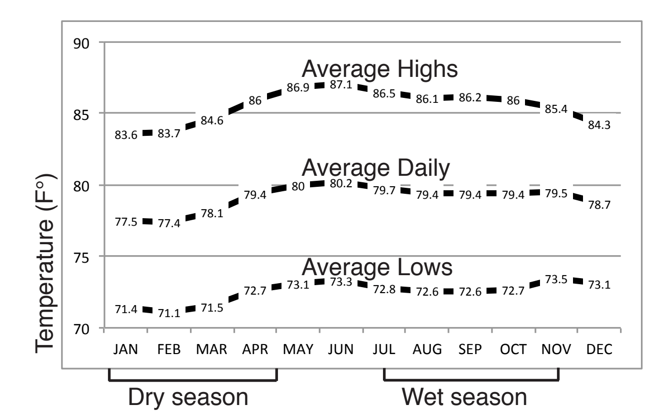
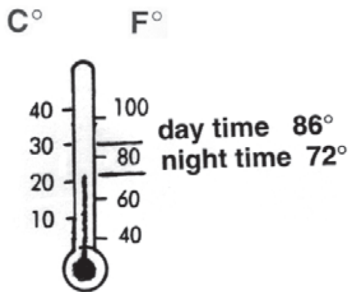



**Figure 2.2.** Monthly average high, low and daily temperatures on Guam.




**Guam's temperatures are suitable for rapid growth of eggplant, pepper, and tomato. High temperatures can influence fruit color and reduce production in tomato.**

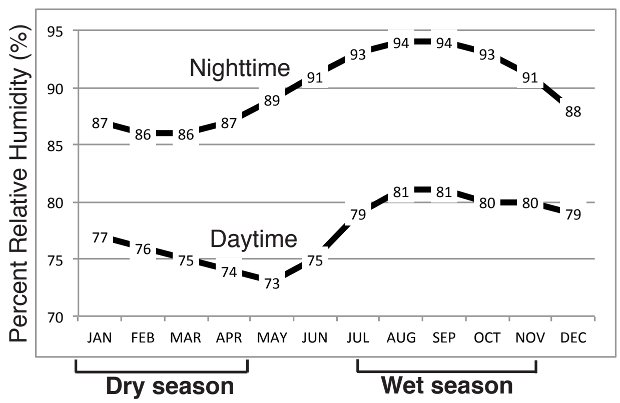



**Figure 2.3.** Monthly average daytime and nighttime relative humidity values on Guam.

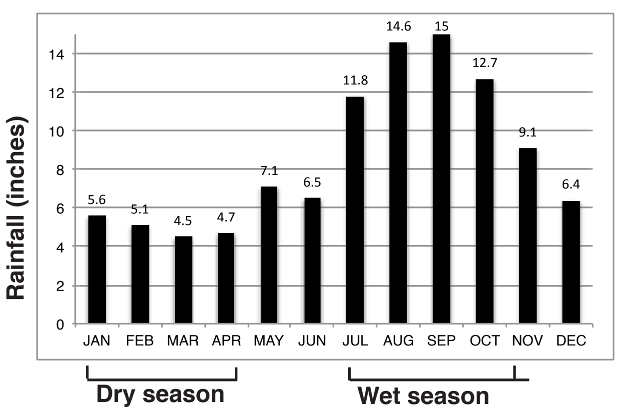
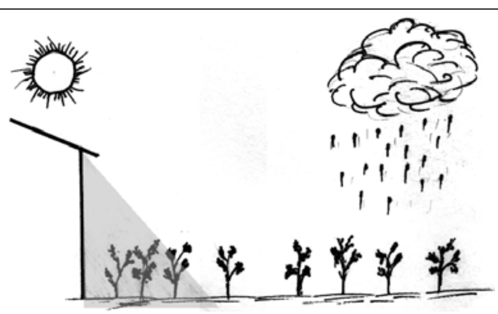



**Figure 2.4.** Average monthly rainfall on Guam.



**For maximum production do not plant during the rainy season or in a shady area. Eggplant, pepper, and tomato production is best during the dry season.**

During Guam's rainy season, little additional water is needed because of its high humidity **[Figure 2.3]** and rainfall **[Figure 2.4]**.

High soil temperatures may be injurious to the root system of eggplant. In general, high night temperatures increase respiration rates, resulting in an increased utilization of carbohydrates for growth and a reduction of carbohydrates available for fruit production. Mulches made of plant material can be applied to reduce variation in soil temperature.

The mean annual rainfall on Guam ranges from around 95 inches (241 mm) on the windward (east side of the higher mountains in the south to about 80 inches (203 mm) along the coast of the western side of the southern half of the island. On average, about 15 percent of the rainfall occurs during the dry season and 55 percent during the rainy season. Irrigation is necessary during the dry season of January to April due to the small amount of rainfall and the drying winds. The average monthly rainfall varies widely from year to year during the transitional seasons of May to mid-July and mid-November through December. Since the majority of Guam's rainfall occurs from tropical storms or typhoons **[Figure 2.5]**, rainfall is generally intermittent. Although typhoons have passed through the area during all months of the year, the majority (66%) have occurred during the rainy season, with peak activity (23% of the annual) occurring in October. Between 1945–1990, 8 typhoons and 29 tropical storms occurred in October **[Figure 2.5]**.

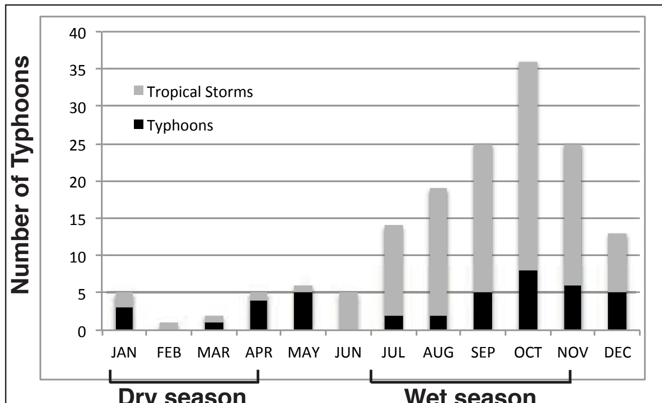
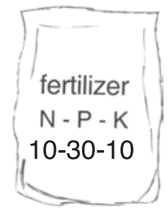



**Figure 2.5.** Total number of tropical storms and typhoons within 180 nautical miles of Guam for the period 1945–1990.

Soil productivity is a combination of fertility, water, aeration, and crop preference. A fertile soil is one that has a good soil structure and an abundance of plant nutrients and organic matter. There are 17 elements (nutrients) that are essential for plant growth. Three of the 17 elements, carbon (C), hydrogen (H), and oxygen (O) are supplied by water and air. The remaining 14 elements (nutrients) are dissolved in the soil water and absorbed by the roots. Soil fertility is partially dependent on soil acidity (pH), calcium (Ca), magnesium (Mg), molybdenum (Mo), and phosphorus (P) are nutrients most likely to be sparse in acid soils where the pH is less than 5.5. Eggplants, peppers, and tomatoes prefer a pH range of 5.5 to 7.0. For roots to be healthy, the soil must have good aeration; that is, the soil must contain a large number of pore spaces. Pore spaces are important because they contain air which contain oxygen. Pore spaces are also important because they hold moisture and allow for root growth. The final component determining crop performance is crop preference. Each crop has its own set of soil and climatic conditions of which it is best suited. For example, even under the best of soil conditions, peas do not do well on Guam because of Guam's high year-round temperatures. For another example, Guam lacks the sandy loam or peat soils necessary for ideal carrot production.

To maintain soil fertility during a crop cycle, applications of the primary elements nitrogen (N), phosphorus (P), and potassium (K) often required. Nitrogen (N) gives dark green color to leaves; improves the quality and quantity of leaves; promotes rapid plant growth; and increases protein content of food crops. (Caution–the application of excessive nitrogen may suppress flowering and fruiting). Phosphorus (P) hastens plant maturity, stimulates flowering and fruiting; and gives added hardiness to plants. It also stimulates early root formation which is one reason it is applied to the field soil at the time of transplanting. Potassium (K), or potash, increases the plant's resistance to diseases; promotes plant growth, fruit quality and color; aids in protein production; and provides for the formation and movement of starches, sugar, and fats (oil).




**To maintain soil fertility during a crop cycle it may be necessary to apply additional soil nutrients in either a chemical or organic form. It is recommended that additional nitrogen be applied because it dissolves readily in water and is not strongly held by soil particles.**

Nearly all plant functions require water. It is the force of water pushing against the cell walls that gives roots, leaves, flowers, and fruits their shape. When the cells in leaves contain insufficient quantities of water, the leaves being to wilt. Water is essential for photosynthesis, transporting of carbohydrates and nutrients, and cooling the plant. Only about 1% of the water taken up by a plant becomes an integral part of the plant. Water loss from plant parts (transpiration) is mainly through the stomata in the leaves (small openings or breathing pores). The rate of transpiration is greatest during the dry season when humidity and rainfall are low **[Figure 2.3**, **2.4]** and when winds are brisk **[Figure 2.6]**.

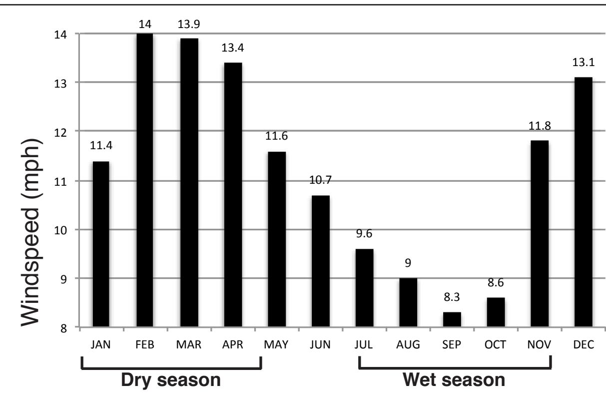



**Figure 2.6.** Average monthly windspeeds on Guam. Less disease pressure during the dry season.

Windbreaks can be used to reduce the rate of transpiration, thereby reducing moisture stress. Controlling foliar pathogens can also reduce transpiration since many cause destruction of leaf tissue and dysfunction of stomata. Moisture stress can also be reduced by increasing the depth and size of roots. Roots of eggplant, pepper, and tomato will penetrate 92–122 cm (36–48 inches) if provided with loose soil. To encourage deep healthy roots, watering should be long and slow and the soil should be deep and of a loam texture.

**The strong trade winds from November through May increases the need for water.**

Too much water (waterlogging) can also cause wilting because the roots cannot obtain enough oxygen to operate efficiently. Although sugars moves from the leaves to the roots, oxygen is not transported in solanaceous plants; therefore, root cells must obtain oxygen by absorption through root hairs, and outer cellular layers, which is not possible under waterlogged conditions. Waterlogging of pepper causes leaf wilting and leaf drop. Long-term waterlogging of tomato plants will result in epinasty, adventitious rooting, and leaf senescence. Since the root systems of eggplant and sweet pepper are sensitive to excess water, deep cultivation prior to planting is advisable. Planting on a raised soil bed will improve drainage in heavy soil and increase soil depth in shallow soils. Eggplant is adapted to both wet and dry season cultivation, but excessive rainfall will reduce vegetative growth and flower formation. Excess water from rains increases the chance of disease from soilborne and leaf microorganisms. Staking or trellising partially reduces leaf pathogens associated with excess leaf wetness.

### Flowering & Fruit Development

One of the main causes of blossom drop is lack of pollination. Botanically, the fruit of the eggplant, pepper, and tomato is a many seeded berry. Seeds are the result of sexual reproductive processes involving the union of male and female gametes. The male gamete is produced by the male part of the flower (stamen) and is contained in the pollen of the anther **[Figure 2.7]**. The female gamete is produced by the female part of the flower (pistil) and is contained in the ovule. The pistil is composed of the stigma, style, and ovary. Solanaceous plants have what is referred to as perfect flowers–stamen and pistil contained in the same flower. Another characteristic of Solanaceous plants is the location of the ovary. It is said to be hypogynous because the sepals, petals, and stamens are attached to the receptacle below the ovary. It is the ovary which develops into the edible fruit.

The first step in reproduction is pollination which is the transfer of pollen from the stamen to the pistil. Flowers of commercial varieties of eggplants, peppers, and tomatoes can pollinate themselves. Such plants are referred to as self-fertile. The pollination requirements of eggplant are poorly understood but wind is not a factor in eggplant pollination. Approximately half the fruit set is attributed to contact and gravity and the other half to insects. Oregon State University recommends bees be provided if wild bee populations are inadequate. Even self-fertile varieties may be subject to significant amounts of pollination by insects. Cross-pollination in peppers is mainly due to bees and may be as high as 36%. Tomato flowers are self-pollinated but must be shaken by the wind. When grown in the green house where wind movement is minimal, tomatoes must be pollinated by hand or with bees to assure a good fruit set. Hand pollination involves tapping or vibrating each flower cluster to transfer the pollen grains from the anther to the stigma. Peppers are even more self-fertile than tomatoes and will set fruit under row covers.

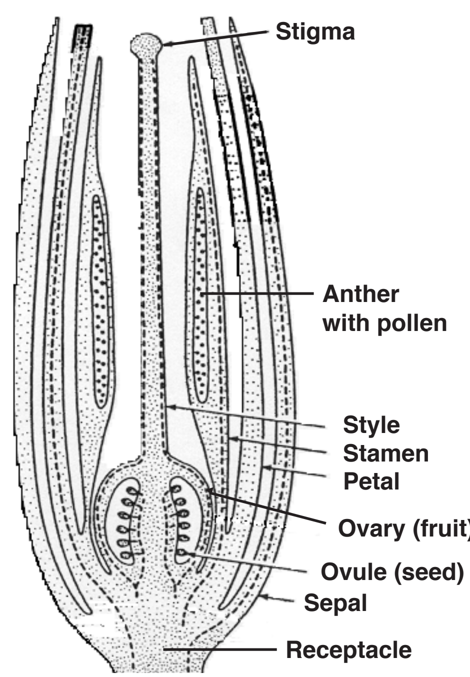
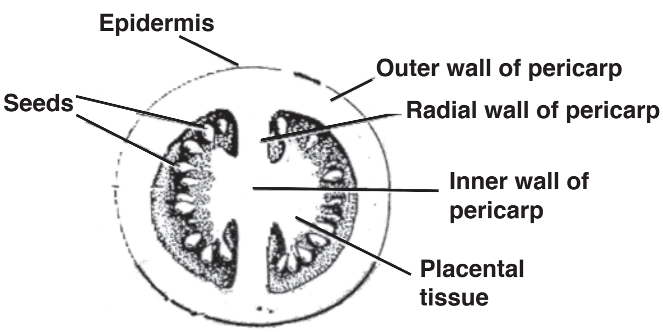



**Figure 2.7**. Cultivated tomato flower (Derived from Esau, K. Plant Anatomy, 2nd ed. John Wiley & Son, New York 1965).

The quality of fruit depends on the formation of seeds in the fruit. After pollination, the pollen germinates on the tip of the pistil (stigma) and forms a pollen tube down through the style to the ovule. After fertilization [union of male (sperm) and female gamete (egg)], the seed begins to form and stimulates the enlargement of tissue that surround the seed (ovary). The ovary wall (pericarp) is the fleshy edible part of the fruit. Since seed formation stimulates the production of the ovary, the quality of fruit depends on the amount of pollination and fertilization. In the case of eggplant, pepper, and tomato a single ovary surrounds all the seeds. Recently, parthenocarpic eggplant cultivars have been introduced. Parthenocarpic cultivars do not require fertilization for fruit formation.




**Fruit quality depends on good seed production**. (Derived from Ho, L.C. and J.D. Hewitt 1986 in Jones, J.B. 1999)

Growth, and the development of flower and fruits all depend on the availability of soil nutrients. Of the 15 essential elements which are found in the soil, nitrogen (N) is generally required in the largest amounts and more frequently than any other nutrient. Nitrogen needs to be applied more than once during a crop cycle because it dissolves readily in water and is not strongly held by soil particles. If the entire nitrogen requirement of a crop were supplied at one time, some of the nitrogen would leach out of the root zone and possibly enter underground drinking water. Additional potassium (K) is often added at first fruit set to ensure fruit quality and color.

The light requirement for plants has two main components: day length (for those located north of the equator, the summer months have the longest days) and light intensity (highest being at noon in a sunny spot). Eggplant, pepper, and tomato plants are day neutral so day length is not a factor in fruit set; however, longer days do provide for optimum plant development.

High light intensity is essential for good production. Light intensity is greatest during the dry season **[Figure 2.8]**. Eggplant, pepper, and tomato yields decrease with increasing shade. Low light intensity limits growth and may also delay flowering in tomatoes. Hot pepper and particularly the local pepper are the most tolerant of poor light conditions. Tomatoes require at least 6 hours of full sunlight per day. High light intensity tends to accelerate flowering in many tomato cultivars. It also is associated with increases in fruit development, size, color intensity, and number per flower cluster.

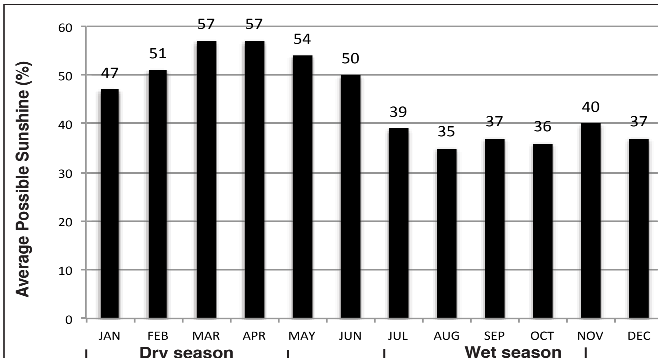



**Figure 2.8.** Average monthly percentage of possible sunshine on Guam.

High light intensity can also negatively impact production. Fruits of sweet pepper and to a lesser extent eggplant may suffer sun-scorch if fully exposed to the sun. In some tomato varieties, high intensity impacts fruit by causing cracking, sunscald, and green shoulders.

Crop production is best during the dry season because of reduced disease pressures, uniform watering as a result of irrigation, and maximum sunshine. During the rainy season, fruit and leaf diseases can be particularly bad, occasionally resulting in large losses. Local hot pepper is more tolerant of excessive rainfall than any of the others. Peppers are more tolerant of extremes of dryness than either eggplants or tomatoes.

Adequate moisture must be provided during the dry season. An extended period of water stress will retard plant growth and will invite insect and disease problems. The local hot pepper is the most drought tolerant followed by eggplant, sweet pepper and tomato. Lack of water in eggplants will cause a lower yield and fruit that is harder in texture and less sweet.

Although peppers are generally drought resistant, even intermittent periods of moisture and/or nutritional stress can dramatically reduce plant growth and limit fruit size and yield. Lack of moisture during flowering may cause flowers and young fruit to drop. During fruit development, moisture stress, in association with high temperature, can increase the incidence of blossom end rot in pepper.

Tomato production on Guam is favored in the dry season over the wet season for several reasons: fruit marketability increases, plant size increases, insect and disease levels decrease, fruit number increases, fruit size increases, and fruit cracking decreases. Erratic watering and excess water associated with the rainy season may produce cracking and splitting of the tomato fruit skin. Fruits do not ripen as rapidly or as fully during wet periods.

The eggplant is adapted to both wet and dry season cultivation but excessive rainfall will result in increased vegetative growth and reduced fruit set. The dry season on Guam is favored over the wet season for eggplant production because of reduced damage from insects and diseases, an increase in the total number of fruits, and an increase in the number of marketable fruits.

**If possible, never allow your plants to become wilted. Even intermediate periods of low moisture can reduce production.**

Hot peppers and eggplants are more tolerant to daytime temperatures above 30° C (86° F) than tomatoes and sweet peppers. Cherry tomatoes are more tolerant to high temperature than large tomatoes. Elongated fruit producing eggplants tend to be more resistant to high temperature extremes than small egg  or oval-shaped cultivars. A diurnal (daytime-nighttime) variation of 5–6° C (41–43° F) is considered necessary for optimum growth and development for tomatoes. A variation of 3° C (37° F) has been shown to improve fruit size in bell peppers. In the case of eggplant, diurnal variation is not necessary and may limit development. Sweet peppers are adapted to high temperatures, but excessively hot, dry weather may produce infertile pollen and therefore reduce fruit set. Excess transpiration at temperatures above 32° C (90° F), can result in the dropping of buds, flowers and fruits of sweet peppers. Fruit set of peppers is poor at temperatures above 32° C (90° F).

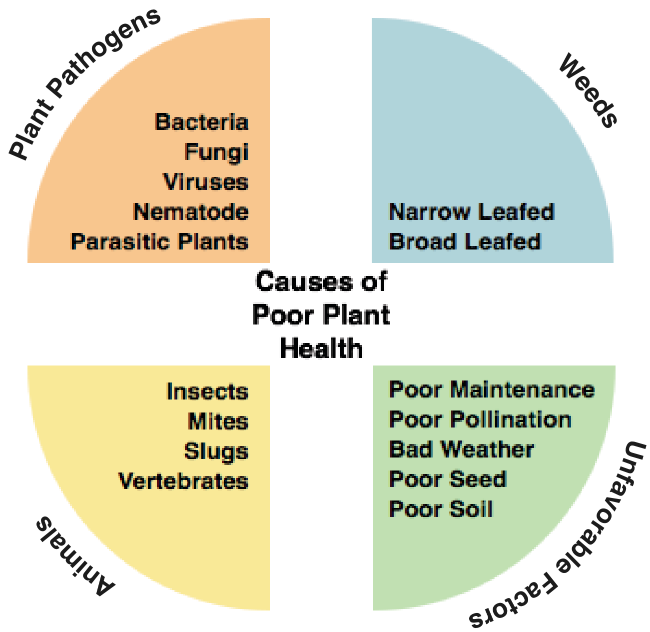

**It is important to select cultivars of eggplant, pepper, and tomato that are adapted to warm or tropical climates.**

High temperatures can influence fruit color and reduce production in tomatoes. Tomato fruit color is more yellow to orange when temperatures are greater than 32° C (90° F). At temperatures greater than 40° C (104° F), tomato fruit tends to remain green. Destruction of pollen and egg cells occurs if the maximum day temperatures exceed 38° C (100° F) for 5–10 days before anthesis (full blossom). The embryo is destroyed after pollination if temperature exceeds 38° C (100° F) for 1–3 days following anthesis. Style elongation has also been associated with high temperature exposure, and this is believed to reduce the efficiency of tomatoes to self-pollinate. Also, fruit set is poor if the minimum night temperatures are greater than 27° C (80° F) a few days before and a few days after full blossom. Hot weather or tropical tomato varieties have a higher night time heat tolerance than other types of tomatoes.

# Chapter 3 Production and IPM Pest Prevention

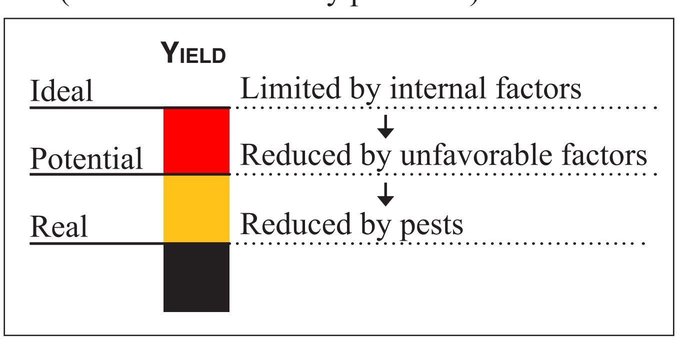
**Robert L. Schlub, Extension Plant Pathologist**
**Mari Marutani, Horticulturist**

There are perhaps as many formulas for raising a successful crop as there are growers; however, all these formulas have some underlying principles and practices. In this chapter, you will learn the basics of eggplant, pepper, and tomato production. After learning the basics, it will be up to you to formulate your own recipe for success.




### Yield and IPM Pest Prevention

To fully understand the purpose of various production practices, it is necessary to understand yield. There are three types of yield associated with each crop grown on Guam: ideal (that which seed companies claims as achievable), potential (that which is possible on Guam under ideal conditions), and real (that which is actually produced).




Ideal yield is limited by internal factors such as the genetics of the crop. Potential yield is limited by the impact of internal factors plus the 'non-living' or 'abiotic' environment, which consists of climate, soil structure, topography and other conditions hereafter referred to as unfavorable factors. Real yield is limited by the cumulative impact of the internal factors, unfavorable factors, and the 'biotic' environment, which consists of the components of the environment that are 'biotic' or 'living' such as pests (plant pathogens, weeds, and animals). Of the three components that impact yield, a crop's biotic environment is the only one a grower has much control over.

To minimize the impact of a negative biotic environment, successful farmers utilize a wide range of practices. When these practices are combined to solve problems caused by pests (animals, plant diseases and weeds), while minimizing risks to people and the environment, it is referred to as Integrated pest management (IPM). The most effective IPM programs incorporate practices before a crop is planted and continued through harvest. This chapter will concentrate on pre-plant considerations.

### Crop Selection

A good way to insure the success of your crop is by selecting the right variety to plant. Your choice should be based on suitability for Guam's climate and soil, disease and insect resistance, personal preference, marketability, yield, and ease of production.

To determine which varieties are suitable for Guam's climate and soil, you should contact your local cooperative extension office, find out what is being sold in roadside markets and grocery stores, and inquire at your local seed supply store or plant nursery. Through sampling local produce, you can evaluate the varieties based on your own personal preferences of size, color, and taste.

When selecting varieties based on seed packet or catalog descriptions, select plants which are referred to as tropical, heat tolerant, southern, or mid-summer varieties. Also, increase your chances for good production by planting two or more varieties. If possible, varieties should have resistance to the major diseases found on Guam; refer to **Chapter 12: Plant Diseases** for more information. Hybrid cultivars are more expensive but the extra cost is offset by improvements in various desirable characteristics. Plant habit, stem type, fruit size, shape, color, smoothness, and resistance to defects should be selection considerations. Yield and ease of production will be difficult to determine unless someone else has grown that particular variety on Guam. The cost of harvesting can be reduced by growing large fruits versus small fruits.

Once you have made your selection, you will need to obtain high quality seed. Seeds obtained from a seed company are generally better because they have a guaranteed rate of germination, lower incidence of seed borne diseases and a higher assurance of cultivar purity. If financial resources are limited or a variety is no longer commercially available, you may want to collect your own seeds instead of purchasing them from an independent company. Save seeds only from open pollinated cultivars. Seeds from hybrid plants are not good to save because the resulting crop will not be of uniform quality. Saving seeds from store purchased produce is also not recommended because the seeds may not be mature enough and the variety may not be adaptable for Guam's climate.

### Eggplant

Eggplant is considered a native to India, where the major domestication of large fruited cultivars occurred and where wild forms can still be found. Some white eggplants found in India look like chicken eggs. Thus, they are called eggplants. In the tropics, eggplants are short-lived perennials and are well adapted to Guam and other Micronesian islands **[Table 3.1]**. Eggplants can be grown year-round on Guam. They can be planted any time of the year under a wide range of soil pH (acidity, alkalinity) conditions ranging from 5.5 to 7.5. Well-drained fertile soils free from soil-borne diseases are required for good plant development and high crop yields. Adding organic matter such as chicken manure will improve soil productivity.

Eggplants grow as a bush often to a height of 1.5 m (5 ft). Leaves are large and lobed and their under-surface has a dense grayish woolly covering. Purple flowers, 2.5–3.8 cm (1–1.5 inches) diameter, form as individual flowers or in clusters of two or more. Flowers may open for 2 to 3 days. The fruits are round, oval, pear shaped, oblong or elongated with lengths ranging from 5–31 cm (2–12 inches). The most common fruit colors are green and purple. Other fruit colors include white, yellow, red, black, or a mixture of colors with streaks. The elongated or cylindrical varieties have the largest market share on Guam.

There are four basic varieties of eggplant grown on Guam:

1. Long purple-black
2. Long green
3. Medium-small pear-shaped purple-black or green streaked
4. Round purple-black

The long purple-black variety is the most commonly grown eggplant on Guam. Examples of cultivars include two Nitta hybrids (Nitta x Waimanalo and Nitta x Molokai), Waimanalo (B-1), Millionaire, Takii Long Black, Farmer's Long and Pingtung Long. The fruit size of these cultivars is about 1–1.5 inches (2.54–3.8 cm) in diameter and 8–12 inches (20.32–30.48 cm) long. Long green eggplants have been grown locally for a long time and seem to be more tolerant to many insect and disease problems. The teardrop or pear-shaped purple eggplant such as Money Maker No. 2 is popular among hotels and Japanese restaurants. Lastly, large round eggplants are used in many European dishes.

Generally, it takes 60–65 days from transplanting to first harvest of fruits. The fruits are harvested immature while the skin is still glossy. The fruits are clipped from the plant, leaving the calyx and a short piece of stem with the fruit. Overripe fruits have a dull color and large bitter tasting seeds. It is important to harvest, grade and pack with care because the skin is very tender. Long exposure of fruits to high temperature will hasten water loss resulting in wilting and discoloration of fruits.

**Table 3.1** Eggplant varieties recommended for Guam.

| Cultivar* | Description** |
|---|---|
| **Long Varieties** | |
| Batangas Long Purple | A moderately early variety with long slim and dark purple fruits about 27 cm. (**EWSC**) |
| Bingo | A vigorous bacterial wilt resistant variety with long glossy purple cylindrical straight fruits about 25 cm long. (**EWSC**) |
| Black Shine | Long shaped productive hybrid. High quality fruit. (**TKS**) |
| Black Torpedo | Long fruit type, top yielder in 1977 Guam trial. (**TKS**) |
| Farmer's Long | Dark purple, long, thin variety, good producer. (**KYS**) |
| Kurume Long Purple | Open pollinated, long black fruit with purple calyx. (**TKS**) |
| Market More | Long dark black variety, good producer. (**TKS**) |
| Nitta X Molokai | Long purple variety, good production locally. (**UH**) |
| Nitta X Waimanalo | Long purple variety, good producer. (**UH**) |
| Pingtung | Dark purple fruit, tolerant to heat, moisture, and many diseases. (**KYS**) |
| Pingtung Long | Same as Pingtung except longer fruits. (**KYS**) |
| Takii's Long Black | Long, slender, very dark fruit. (**TKS**) |
| Waimanalo Long | Long purple variety, good producer. (**UH**) |
| **Long Varieties** | |
| Short Tom No. 1 | Short thin fruit, dark purple, good producer. (**SKS**) |
| Money Maker | Glossy, black, egg shaped fruits, good producer. (**SKS**) |
| Okitsu No. 1 | Short oval fruit, dark purple to black. (**TKS**) |
| Pingpong | Tall plant produces small, round, white fruits with light green striped shoulder, weighing 60–80 g.; vigorous plants can be harvested for at least 4 months. (**EWSC**) |

**EWSC** East West Seed Company
**TKS** Takii Seed Company
**KYS** Known-You Seed
**UH** University of Hawaii
**SKS** Sakata Seed Company

* Recommendations are based on field trial results and recommendations from growers, extension and research personnel.
** Most of the descriptions are provided by the seed source.

**Ping-pong eggplant**
(East West Seed Company)

**Teardrop eggplant**
(*Money Maker No. 2, Takii seed*)

**Elongated eggplant**
(*Farmer's Long, Known-You Seed*)

## Pepper

The Pepper originated in tropical and subtropical South America. Spanish and Portuguese traders were largely responsible for worldwide dispersal of pepper. **Table 3.2** lists some of the different varieties of peppers that are being grown on Guam.

**Table 3.2.** Pepper varieties recommended for Guam.

| Cultivar* | Description** |
|---|---|
| **Hot Varieties** | |
| Asian Hot | Very pungent, long thin type pod. (**PG**) |
| Golden Heat | Long slender fruit, heavy fruit set; thin and hot flesh and red when ripe. (**GDoA**, **KYS**) |
| Habanero | One of the most pungent types of peppers, wrinkled fruit 1 inch long, 1-$^1/_2$ inches wide, orange when ripe. (**CS**, **HS**, **JS**, **PG**, **RP**, **SS**, **TGSC**, **TS**, **TT**) |
| Hot Beauty | Very pungent, long thin type. On Guam, found to resist storm damage and is among top performers. (**KYS**) |
| Jalapeno | Very hot, ideal for Mexican dishes. Deep green fruits mature to red. Sausage shaped fruits, 3-1/2 inches long. (**CS**, **HS**, **JS**, **PS**, **RP**, **TGSC**, **TS**, **TT**) |
| Long Chili | Very pungent, long thin type. (**KYS**, **PG**) |
| Local Hot Pepper (Donne Ti'ao) | Local favorite in gardens all over the island. Very pungent. (**GDoA**) |
| Thai Dragon | Very pungent, long thin fruits. (**JS**, **NESC**, **PG**, **TGSC**, **TT**) |
| **Sweet/Bell Varieties** | |
| Bell Boy Hybrid | Abundant yielder, thick-walled, resists *Tobacco mosaic virus*. (**CS**, **NESC**, **RP**, **SS**, **TGSC**, **TT**) |
| California Wonder | Deep green to red, thick-walled with an attractive glossy flesh. Fruits are medium sized, 4 inches by 4 inches, three to four lobed, smooth and block. (**CS**, **EWSC**, **HS**, **JS**, **NESC**, **PG**, **PS**, **RP**, **SS**, **TGSC**, **TS**, **TT**, **GDoA**) |
| Colossal | Extra large, thick-walled sweet pepper. (**PS**) |
| Keystone Giant | Large fruit, resists *Tobacco mosaic virus*. (**RP**) |
| Keystone Resistant Giant #3 | Popular large thick-walled fruits, resists *Tobacco mosaic virus*. (**CS**, **KSC**, **RP**, **TT**) |
| Midway | Large dark green variety. Resists *Tobacco mosaic virus*. (**CS**, **RP**, **SS**) |
| Peto Wonder | Very large, thick-walled fruits, 6-$^1/_2$ inches long by 4-$^1/_2$ inches wide. (**CS**, **RP**, **TT**) |
| Yolo Wonder (Varieties A, B, C) | All Yolo Wonder types are large block 4 lobed fruits, dark green maturing to bright red. Resists *Tobacco mosaic virus*. (**CS**, **EWSC**, **KSC**, **PG**, **RP**, **TT**) |

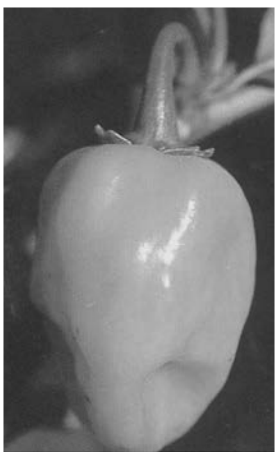
**CS** Carolina Seeds
**EWSC** East West Seed Company
**GDoA** Guam Department of Agriculture
**HS** Harris Seed
**JS** Johnny's Seeds
**KSC** Kilgore Seed Company
**KYS** Known-You Seed
**NESC** New England Seed Company
**PG** Pepper Gal
**PS** Park Seed
**RP** Rachel's Pepper Seed Company
**SS** Stoke Seed
**TGSC** Tomato Growers Seed Company
**TS** Twilley Seed
**TT** Totally Tomatoes

* Recommendations are based on field trial results and recommendations from growers, extension and research personnel.
** Most of the descriptions are provided by the seed source.

Peppers have tender stems when young and over time most become woody, particularly at the base. Many become shrub-like and are usually grown as an annual but may be grown as a perennial on Guam. Plants are generally erect, highly branched, and from 0.5 to 1.5 m (1.6 – 4.9 ft) tall.

Flowers differ with species and varieties from white to greenish white, and lavender to purple. Fruit are frequently borne singularly at each node for *C. annuum* cultivars, and with multiple fruits (typically two or three) per node for some other species. In contrast to tomatoes, seeds are dry at maturity and easily detach from the fruit. Pepper fruit colors are highly variable: green, yellow, or even purple when young and later turning to red, orange, yellow, or a mixture of these colors. As with color, fruit shapes vary greatly, ranging from linear, conical, or globose, and all combinations of these shapes. Fruit may be thick- or thin-walled and range from 1 inch (2.5 cm) to more than 12 inches (31 cm) in length, and from 1 to about 6 inches (15 cm) in width. Peppers can generally be classified into two groups: mild- or sweet-tasting fruit (bell, pimento, sweet wax) and fruit with hot or pungent flesh (long green and jalapeno). Pungency (hotness) is not related to fruit shape nor is it found in the seed. Chemicals know as capsaicinoids gives fruits their pungency. They are produced in tissues located where the seed attaches to the inside of the fruit wall. A pepper under water stress conditions will increase in pungency.

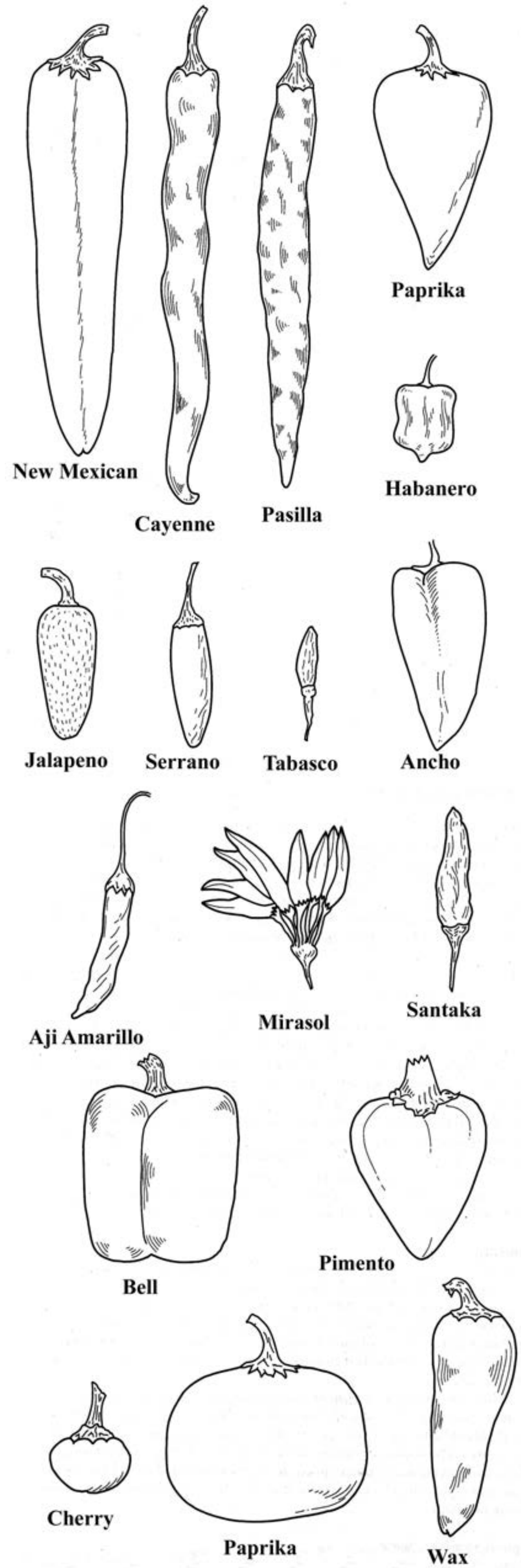
Bell pepper types are generally harvested as green mature fruits. Maturity is determined when fruits are smooth and firm to the touch. Cherry types are harvested as both green and red fruits, and the banana types are generally harvested as yellow mature peppers; however, some banana are light green or red at maturity. Refer to **Chapter 5: Harvest and Postharvest Handling** for more information about harvesting.



**Habanero pepper**
(Tomato Growers Supply Company)

**Long hot pepper**
(Hot Beauty, Know-You Seed)

**Jalapeno**
(Johnny Seed)




**Fruit shapes of some of the common pod types of peppers.** Bosland, P.W. and E.J. Votava. Peppers: Vegetable and Spice Capsicums.

## Tomato

Tomato is second only to potato in being the most widely grown solanaceous vegetable, achieving its prominence largely in the past century. Indigenous to western South American (Peru, Ecuador, and Chile), its center of domestication is Mexico. Cultivated forms of the tomato are diploid (2n=24), self-pollinating, tender, annual/perennial. Tomatoes can be grown year round on Guam, but yields and quality are best during the dry season. For varietal recommendations for Guam, refer to **Table 3.3**. Tomato flowers have both functional male and female parts. Cultivated varieties are self-pollinated due to the tight, protective anther cone which surrounds the stigma. The time from pollination to fruit ripening varies from less than 6 weeks to more than 10 weeks, depending on variety and temperature.

Tomato seed is mature when fruit ripening is complete. Three maturity stages are generally recognized: mature green, pink or breaker, and red-ripe. For nearby markets, harvest fruits at the pink or breaker stage. Large stores may require fruits at mature green. Cultivated tomato fruit range in size from 1 ounce to over a pound of which 94–95% is water. Most varieties are red in color but various shade of yellow, orange, or green fruits also exist.

**Table 3.3.** Tomato varieties recommended for Guam.

| Cultivar* | Description** |
|---|---|
| **Small/Cherry Varieties** | |
| Dynamo | Good producer, heat tolerant. Medium to large fruits bears well. Indeterminate. Recommended for dry season. (**SKS**) |
| Cherry Grande | Large cherry type tomato; good producing determinate hybrid. (**SS**, **TGSC**, **TS**, **TT**) |
| Lee's Plum | Pear-shaped fruit, indeterminate plant. (**GDoA**) |
| Precious | Egg-shaped, vigorous and prolific; heat and *Tomato mosaic virus*-tolerant; resists Fusarium wilt; good producer for Guam; highly recommended. Indeterminate. (**KYS**) |
| Roma | Compact determinate plant bears 3 inch pear/plum shaped fruit. Great for pasta. (**CS**, **HS**, **KSC**, **NESC**, **PG**, **PS**, **RT**, **SS**, **TT**) |
| Season Red | Egg shaped, vigorous and prolific; heat and humidity-tolerant tomato; resists Fusarium wilt; plants are determinate, dwarf, vigorous. Recommended for dry season.. (**GDoA**, **KYS**) |
| **Medium/Large Fruit Varieties** | |
| Bonney Best | Large meaty fruits. Indeterminate. (**RT**, **TGSC**, **TT**) |
| Heatwave | Heat tolerant determinate variety with large fruits and heavy harvests; resistant to Verticillium wilt, Fusarium wilt race 1 and 2, Alternaria. Recommended for dry season. (**TGSC**) |
| Hope No. 1 | Early, determinate type, red fruited, small leaves. Uniform green. Good for fresh market and processing. 5–6 fruits per cluster. Resistant to Fusarium wilt race 1, Nematode, Tm-1, Stemphylium. High heat tolerance. Recommended for dry season. (**TKS**) |
| Master No. 2 | Very productive, indeterminate type, bright red fruit, deep semi-globe, 5–6 fruits per cluster. Resistant to Fusarium Wilt race 1, Nematode, Tm-1, Stemphylium and strong against heat. (**TKS**) |
| N-52, N-63. N-65 | All are nematode resistant varieties developed at the University of Hawaii. Indeterminate type, recommended for dry season. (**UH**) |
| Solar Set | Heat tolerant, large fruited, high yielding determinant; resistant to Verticillium wilt, Fusarium wilt race 1 and 2. Recommended for dry season. (**RT**, **TGSC**, **TT**) |
| Spring Giant | Large fruited, deep red, high yielding determinate variety. Recommended for dry season. (**TGSC**) |
| Sun Chaser | Heat tolerant determinate, produces large top quality fruit; resistant to Verticillium wilt, Fusarium wilt, Alternaria. (**TGSC**) |
| Sunmaster | Large full flavored heat tolerant determinate tomato; resistant to Verticillium wilt, Fusarium wilt race 1 and 2, Alternaria. (**CS**, **KSC**, **RT**, **TGSC**, **TT**) |
| Sun Leaper | Smooth fruited determinate variety, heat tolerant and resists cracking; resistant to Verticillium wilt, Fusarium wilt. (**CS**, **RT**, **TGSC**, **TT**) |
| Tropic Boy | Heat tolerant, medium sized fruit. Indeterminate, Recommended for dry season. (**SKS**) |

| | | | |
|---|---|---|---|
| **CS** | Carolina Seeds | **SS** | Stoke Seed |
| **GDoA** | Guam Department Of Agriculture | **SKS** | Sakata Seed Company |
| **HS** | Harris Seed | **TGSC** | Tomato Growers Seed Company |
| **KSC** | Kilgore Seed Company | **TKS** | Takii Seed Company |
| **KYS** | Known-You Seed | **TS** | Twilley Seed |
| **NESC** | New England Seed Company | **TT** | Totally Tomatoes |
| **PG** | Pepper Gal | **UH** | University of Hawaii |
| **PS** | Park Seed | | |
| **RT** | Rachel's Tomato Seed Company | | |

* Recommendations are based on field trial results and recommendations from growers, extension and research personnel.

** Most of the descriptions are provided by the seed source.

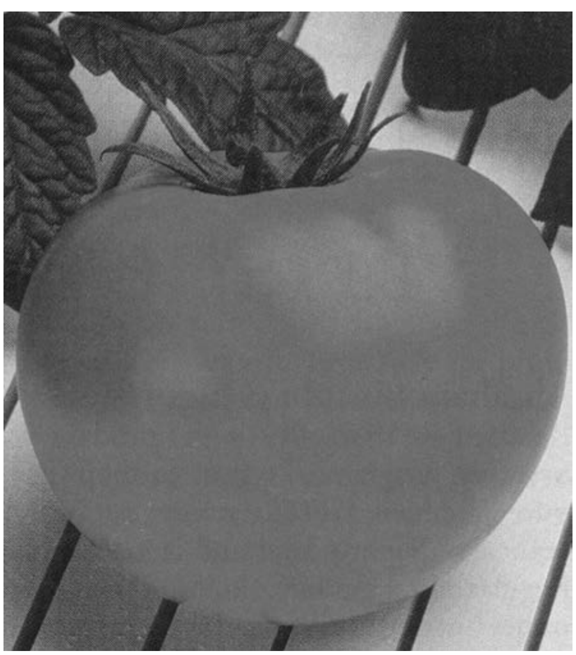
**Indeterminate type tomato**

**Large tomato**
(Solar Set, Tomato Growers Supply Company)

Mari Marutani

**Determinate type tomato**

**Cherry tomato**
(Season Red, Know You Seed)



**Large tomato**
(Sun Master, Tomato Growers Supply Company)

**Large tomato**
(Tropic Boy, Sakata Seed Company)

### Site Selection

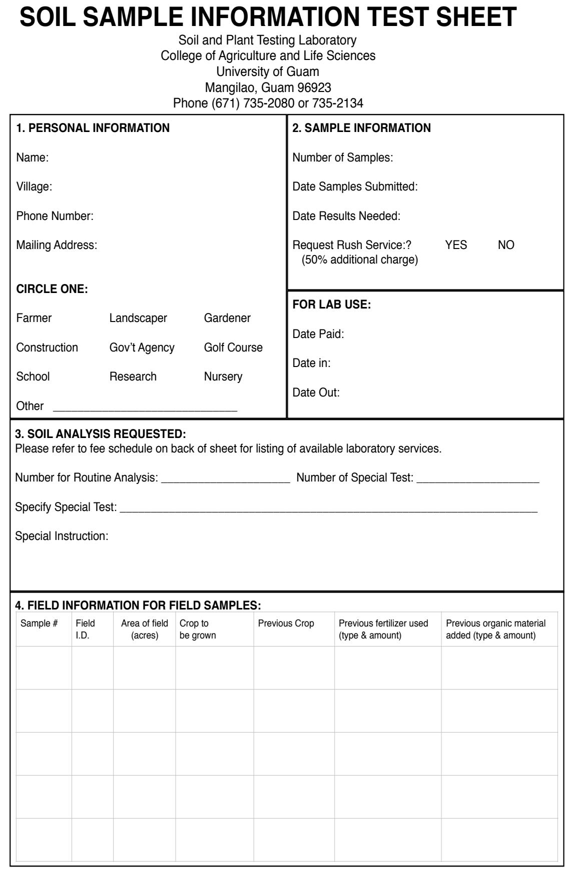
After carefully choosing a crop suitable for Guam's climate and soil conditions, you must determine where on Guam to grow your crop. The site you select will greatly impact your final yield/quality.

Site selection should be based on several factors. The most critical being accessibility to the site and water. You must have a road to your field that will remain open and accessible during the entire growing season; this can present a problem during the rainy season when farming in some of the remote areas of southern Guam. Water must be nearby for it will be needed for irrigation during the dry season. If you plan to farm in the shallow well drained soils of northern Guam, daily watering may be required even during the wet season.

### Soil Sampling

Soil sampling is recommended to help you determine your soil's fertility and suitability for eggplants, peppers, and tomatoes. Once you have found a possible planting site, sample the soil and submit it to a soil laboratory for analysis. The area you sample should be uniform; thereby, having the same texture, crop history, slope, and depth. If your site is not uniform, then split up the field and submit multiple samples. The following steps should be taken:

1. With a spade or trowel, make a hole in the soil to the depth at which you cultivate, 10 cm (4-8 inches) for shallow soil and 25 cm (10 inches) for deep soils.
2. Place the sample in a clean plastic bucket.
3. Repeat the above procedure 9 to 10 times at different areas in your field.
4. Mix thoroughly in the bucket.
5. Take out approximately one pint of soil from the bucket and place it in a clean plastic bag. Write your name and field identification on the outside of the bag with a permanent marker.
6. Record your field identification so you will be able to remember which area the sample came from.
7. Bring the sample to the College of Agriculture and Life Sciences building at the University of Guam and fill out a soil submission sheet.



**SOIL SAMPLE INFORMATION TEST SHEET**

Soil and Plant Testing Laboratory
College of Agriculture and Life Sciences
University of Guam
Mangilao, Guam 96923
Phone (671) 735-2080 or 735-2134

**1. PERSONAL INFORMATION**

Name:

Village:

Phone Number:

Mailing Address:

**CIRCLE ONE:**

Farmer Landscaper Gardener

Construction Gov't Agency Golf Course

School Research Nursery

Other ____________________

**2. SAMPLE INFORMATION**

Number of Samples:

Date Samples Submitted:

Date Results Needed:

Request Rush Service:? YES NO
(50% additional charge)

**FOR LAB USE:**

Date Paid:

Date in:

Date Out:

**3. SOIL ANALYSIS REQUESTED:**
Please refer to fee schedule on back of sheet for listing of available laboratory services.

Number for Routine Analysis: ________________ Number of Special Test: ________________

Specify Special Test: ____________________________________________

Special Instruction:

**4. FIELD INFORMATION FOR FIELD SAMPLES:**

| Sample # | Field I.D. | Area of field (acres) | Crop to be grown | Previous Crop | Previous fertilizer used (type & amount) | Previous organic material added (type & amount) |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

**Have your soil tested.**

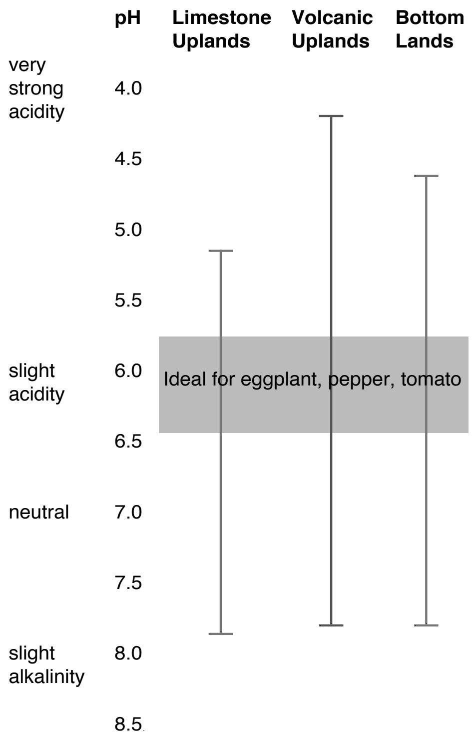
The routine soil test at the University of Guam includes analysis of the soil water pH, available phosphorus, organic matter, exchange potassium, calcium, and magnesium. Special tests include total nitrogen and phosphorus, nitrate, ammonium nitrogen, aluminum, zinc, iron manganese, copper, sodium and boron. Electrical conductivity for soluble salts and particle-size analysis is also available. A particle-size analysis will determine the texture class of the soil at the site. The soil texture (such as clay, silty clay, or sandy clay loam) will influence fertilizer, irrigation, and variety recommendations.

### Soil ph

Soil pH should between 6.0–6.5 for maximum nutrient availability. Eggplants, peppers, and tomatoes are slightly tolerant to alkaline soils. They will do well up to pH 7.6 if there is no deficiency of essential nutrients **[Table 3.4]**. Correcting soil pH requires application of soil amendments which may not be practical. If your soil lies outside the suggested pH range, contact your local Cooperative Extension Service for further assistance.

**Table 3.4.** Recommended soil pH range.

| Fruit | pH range |
|---|---|
| Eggplant | 5.5–7.5 |
| Pepper | 6.0–7.0 |
| Tomato | 5.4–7.0 |




**Range of pH values for Guam's main soil categories. Refer to the General Soil Map in this guide for more information [Plate 1].**

## Soil Salinity

Soil salinity is mainly the result of the accumulation of fertilizer in the soil and salt spray from the ocean. With an increase in soil salinity, plant roots are less able to extract water from the soil. Tomatoes are more tolerant of soil salinity than peppers **[Table 3.5]**. High winds contribute to salt spray damage and the dry season contributes to fertilizer accumulation.

**Table 3.5.** Growth response to salinity.

| Crop | No Growth Reduction | Some Growth Reduction |
|---|---|---|
| Pepper | 960 ppm | 1,094 ppm |
| Tomato | 1,600 ppm | 1,760 ppm |
| Electrical conductivity equivalents are 1 decisiemens per meter (dS=m) is equal to 1 mmho / cm which is approximately equal to 640 parts per million (ppm) salt. • Knott's Handbook for Vegetable Growers | | |

## Soil Nutrients Analysis

Soil nutrient analysis is important because your soil may be deficient in an essential nutrient **[Table 3.6, 3.7]**. Deficiencies are generally easily corrected by fertilization.

**Table 3.6.** Interpretation of soil test results for eggplant, pepper, and tomato production.

| Element | Adequate level (ppm) | Damage may occur (ppm) |
|---|---|---|
| Boron (B) | > 0.5 | N/A |
| Calcium (Ca) | > 1,000 | N/A |
| Copper (Cu) | > 16 | N/A |
| Iron (Fe) | > 5 | N/A |
| Phosphorus (P) | > 100 | > 150 |
| Potassium (K) | > 200 | > 2,000 |
| Manganese (Mn) | > 20 | N/A |
| Magnesium (Mg) | > 150 | > 1,000 |
| Molybdenum (Mo) | > 0.09 | N/A |
| Zinc (Zn) | > 1.5 | > 12.0 |
| • This is a summary of information from a number of sources. | | |

**Table 3.7.** Adequate soil nutrient levels for Boron.

| Crop | No Growth Reduction |
|---|---|
| Eggplant | greater than 0.70 ppm |
| Pepper | greater than 0.35 ppm |
| Tomato | greater than 0.70 ppm |
| • Knott's Handbook for Vegetable Growers | |

## Soil Texture

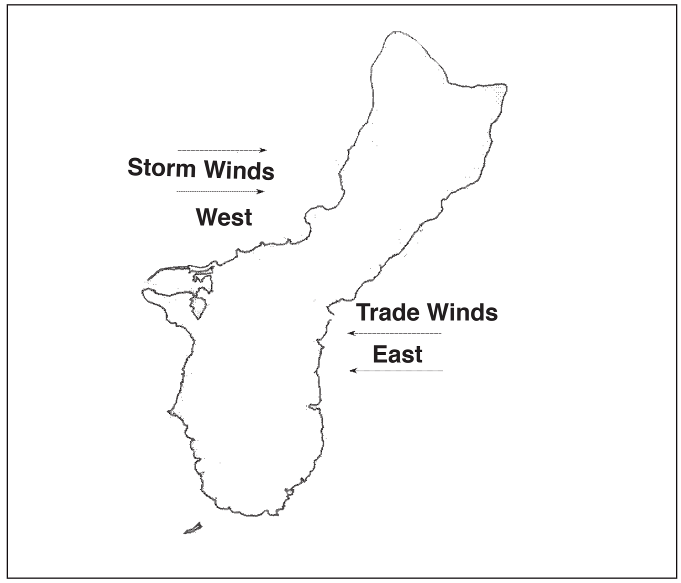
Soil texture is the relative proportions of the different size particles which make up soil. The particles are grouped according to size from the smallest to the largest: clay, silt, and sand. For pepper production, sandy loam is recommended. Clay soils tend to restrict root growth and sandy soil do not hold moisture or nutrients well.

Seventeen different soil types have been characterized by the USDA Soil Conservation Service on Guam. These can be grouped into three large categories based on the soils' parent material: bottom lands (4%), volcanic uplands (35%) and limestone uplands (61%). These three categories are subdivided into 8 major soil groups **[Plate 1]**. Of these groups, agricultural production is mainly suited to four soil types. The Inarajan-Inarajan variant soils are well suited for agriculture requiring minimal watering during the dry season. These soils are deep, clay throughout, and subject to flooding **[Plate 1-1]**. The Akina-Togcha-Ylig soils are high in clay which may limit root growth due to compaction and poor aeration in the root zone. This soil type is composed of 40% Akina soils which are red, acidic, and clayey to a depth of 51–102 cm. Steep slopes are difficult to cultivate and without adequate management are susceptible to soil erosion. Liming to increase the pH may be necessary for maximum production **[Plate 1-3]**. The high pH limestone uplands soils are subject to micronutrient deficiency [**Plate 1-4**, **5**, **6**, **7**, **8**]. Shallow soil depth and rockiness reduce the capacity of the Guam soil to hold plant nutrients and water, thereby requiring more frequent fertilization and irrigation **[Plate 1-4]**. Pulantat-Kagman-Chacha are clay to silty clay over a mixture of limestone and clay. They are moderately suitable for production **[Plate 1-8]**. For further information on the characteristics and locations of the soils of Guam, contact the Pacific Basin office of the U.S. Natural Resources Conservation Service and obtain a copy of the Soil Survey of the Territory of Guam. This publication contains detailed descriptions of the different soils and maps of their locations on Guam.

### Windbreaks

Windbreaks may be needed on some sites to reduce plant stress from trade winds and damage from storm winds. The dominant winds on Guam are the trade winds. From November to April, they blow from the northeast at approximately 70 degrees. From May to October, the winds are out of the southeast at approximately 95 degrees. During the rainy season there is often a breakdown of the trade winds, due to westerly-moving storm systems which result in winds coming out of the northwest at approximately 290 degrees. Refer to **[Figure 2.6]** for more information

The constant flow of the trade winds causes a higher water demand from your crop because of the moisture loss from the surface of leaves and soil. Winds may bring salt spray from the ocean and may damage flowers, leaves and stems of your crop. A windbreak is most effective if oriented within 45 degrees of perpendicular to the prevailing wind and if it allows about 20–50% of the wind through. Windbreaks reduce wind speed for a distance of about 10 times their height downwind and 1 to 3 times their height on the windward side. Large barriers such as trees, buildings, and hills can offer some protection from high winds from typhoons and tropical storms but they may also contribute to turbulence over your crop area.




## Site Preparation

### Soil tillage

Soil tillage should follow site clearing. The objectives of soil tillage are to prepare a seedbed, incorporate soil amendments and organic residues, clear weeds, and possibly to contour the soil. The type and depth of tillage practices recommended for Guam varies greatly. The shallow limestone soils of northern Guam should not be tilled more than a few inches deep and never into the bedrock. The volcanic soils of southern Guam poses less of a risk from tillage; however due to their shallow topsoil, care needs to be taken not to till so deep as to bring subsoil to the surface. Contouring the soil is used to improve drainage, control erosion, and to provide a bed for irrigation lines. Depending on the equipment available to you, several tillage operations can be done. Initial plowing is usually done with a moldboard plow or disc plow. Rototilling can be done with a small rototiller or a tractor-mounted rotovator. A disc is often used to break up heavier clods and prepare a uniform seedbed. Rototillers are also often used on Guam for cultivating weeds between the planted rows during the growing season. Raised ridges, beds, or hills can be beneficial as they improve drainage and increase soil aeration and often increases the root zone. Moisture is conserved during the dry season by planting in furrows. Unexposed military ordnance from WWII are still found in the soils of Guam so care should be taken whenever new land is to be put into production.

A drawback to frequent use of tillage is destruction of soil structure, increased compaction, spread of soilborne plant pathogens, and greater soil erosion. To lessen compaction, tillage operations should be avoided when the soil is wet. In addition, rototilling a soil when it is very dry can shatter soil aggregates which are important for good root growth. To minimize the detrimental effects of soil disturbance, some growers follow a practice of minimum or conservation tillage. This practice reduces the frequency of tillage and tries to maintain crop residues on the soil surface. Difficulties with this practice are the increased need for pesticides to control weeds and increased insect problems.

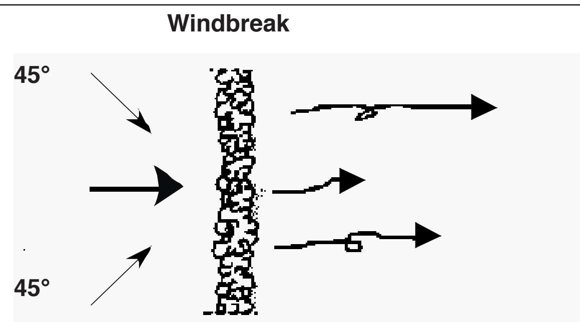
### Weed Control

Weed control needs to begin early. Tillage alone will reduce weeds but it may not be as effective as other weed control methods such as spraying of herbicides and/or the use of mulches. Physical methods of weed control include use of organic or polyethylene plastic mulches. A mulch is applied to the soil surface to prevent weeds from emerging and has the additional benefits of increasing soil moisture retention and reducing erosion. Plastic mulches also have the additional benefit of reducing leaching of soluble nutrients during heavy rains. Aluminum colored plastic reflective mulch discourages early aphid infestation. Special equipment is available for laying down plastic mulches over the seedbed or rows. Application rates of organic mulches, such as grass, shredded paper, and crop residues will depend on the physical properties of the material. Under Guam's environmental conditions, physical degradation of these materials can be rapid, and, therefore, their effectiveness should first be tested before they are used on a large-scale. If you do not use mulch to keep the weeds down, you should till the soil lightly between rows with a rake, hoe, wheeled cultivator, or rotary tiller. This light tilling should be no deeper than 1 to 2 inches. Refer to **Chapter 15: Weeds** for more information on weed control.

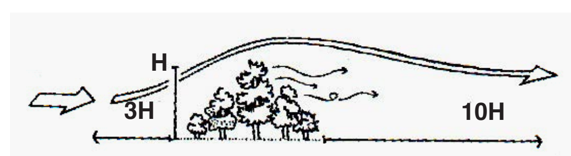
In Hawaii, tomato plants produced a higher yield when grown on vetch mulch (legume cover crop) than on plastic, paper or no mulch.

### Windbreaks

Windbreaks will need to be established in exposed sites. Even the normal occurring trade winds which blow easterly to northeasterly across Guam can reduce yield. Wind damage is caused by the drying effects of wind on leaves and flowers and the physical abrasion that occurs when plant tissue rub against each other or against the soil. If wind is a problem then physical barriers can be erected perpendicular to the direction of the wind. Several objects can be used as windbreaks, including a row of trees, hedges, tall grasses, or a wall of shade cloth or plastic secured to rebar. If you plan to use a living windbreak, then be sure to plant the windbreak in advance of planting your crop so that the windbreak will be established well before planting.




**Plant a windbreak and save on your water bill.** (Elevitch, C.R. and K.M. Wilkinson, eds. 2000. *Agroforestry Guides for Pacific Islands*)




**The taller the windbreak, the greater the protection.** (Elevitch, C.R. and K.M. Wilkinson, eds. 2000. *Agroforestry Guides for Pacific Islands*)

If you do not plan to use a windbreak, you can still reduce damage by row orientation. In a bell pepper trail on Guam in 1983, plants which were oriented parallel to wind direction produced 66% of the fruit as high quality, while those which were oriented perpendicular to the wind direction produced 71% of fruit as high quality.

## Planting and Cultivation

Plants are propagated by direct field seeding or by transplanting. Although infrequently done, indeterminate cultivars of tomato can be vegetatively propagated from stem cuttings. Stem layering in which portions of an attached stem are covered with soil, is a propagating method occasionally used with eggplants. Adventitious roots forms at the nodes, and once rooted, stems are cut free and can be used as transplants. Direct field seedling is difficult with eggplant, pepper, and tomato because the seeds are small and young seedlings are fragile. Seeds are sometimes coated to produce seeds of uniform size and shape for use in precision planters. Seeds are also coated with various products to reduce damping off diseases and/or to improve seedling health. Transplanting, the preferred method on Guam, is the transfer of seedlings from a seedbed to the field. By germinating the seeds in a seedbed, optimum conditions for germination can be easily maintained resulting in good seed germination and healthy seedlings.

### Direct Seeding

Direct seeding may not be cost effective because of the increases cost associated with the surplus seed requirement and increased labor associated with preparing and maintain field soil in a condition which would be suitable for seed germination. After germination, labor is needed to remove surplus plants. If plants are overcrowded, uniformity of fruit set and size will be affected. A method called plug planting is a variation on direct seed planting and doesn’t require seedling thinning. In this method, seeds are mixed in a medium containing vermiculite, peat moss, or other material. A portion of this mixture, 3 to 7 seeds, is placed at a precise spacing into the field. The mulch-like medium is helpful in supporting early seedling growth.

### Transplants

Transplants remain the popular means of propagation for eggplant, pepper, and tomato on Guam. Efficient use of land, early weed control, and less damage from diseases and pests are some of the benefits of transplanting. The main disadvantage is the cost of handling the transplants. At planting, transplant roots may be bare or protected in a small root ball of artificial soil. Bare rooted transplants are more susceptible to transplant shock. For transplants, seeds are planted 6 mm (0.25 inches) deep in cups (2 seeds / 6 oz cup) or trays (2 seeds / 5 cm [2 inches] square) containing a synthetic potting soil mix. Separate cell trays or separate single containers are less stress-imposing to seedlings than open trays or flats. When a seedling grows in its own compartment, there is minimal root disturbance when the seedling is removed for transplanting. Use a synthetic potting soil mix to fill containers. If it is not available, use a mixture of one part compost, one part sand, and one part garden soil. Commercial peat pellets can also be used. Peat pellets are shipped compressed and dried and are about 0.25 inches (0.64 cm) in height and 1.75 inches (4.45 cm) in diameter. When water is added to a pellet, it swells to approximately 7 times its original size and is then ready to receive the seed. Plant a few extra seeds in case some do not germinate and in order to have a few extra transplants in case some die after being transferred to the field.

**To reduce transplant shock it is recommended that transplants be produced in compartmentalized trays, transplanted to the field in late afternoon, and irrigated afterwards.**

Avoid conditions that cause root entanglement. Conditions that favor root pruning from roots growing beyond their container and drying out should be avoided if the plants are to be transplanted into deep soil. When a plant’s taproot is pruned off, the plant will develop a shallower root system. When field soils are shallow or when water is mainly supplied by irrigation, air-pruning of the roots should be encouraged. To encourage air-pruning, use containers with drainage holes. Taproot air-pruning of seedling is a feature of the Speedling seedling trays.

After the seeds are planted, daily care of the seedflats, seedcups, or peat pellets is very important to insure good germination and emergence. The planting medium must be kept damp. How often to water depends on placement of the containers. Placing containers in the shade, loosely covering them with plastic, or stacking are all methods that can be employed to reduce moisture loss and watering frequency. Some growers stack their seedflats and then cover the top one with plastic. Space is provided between the trays for seedling emergence and air movement.

After emergence, thin the seedlings, expose them to sunlight, water daily, and begin applying fertilizer. If air pruning of the roots is desired, raise the container off the ground by 15 to 20 cm (6–8 inches). The plants should be thinned to one per cup, pellet, or tray cell by snipping-off the least desirable ones. The quicker the seedlings can be exposed to full sunlight, the better. The seedlings should be watered moderately, once or twice a day. Overwatering should be avoided because it tends to make the seedlings soft and very susceptible to damping-off. Watering should be done between early and mid-morning to insure that the surface of the planting medium and leaves of the seedlings are dry before nightfall. This reduces the likelihood of fungal or bacterial diseases developing during the night when relative humidity is high. Application of water soluble, complete fertilizer, such as 15-30-15 at 1 tablespoon per gallon, 1–2 time per week will provide adequate nutrients for good seedling development.

### Field Ready Transplants

From various research studies in Florida, tomato transplants of 2 to 13 weeks can produce comparable yields. On Guam, 3 to 5 week old eggplant, pepper, and tomato transplants are recommended. Eggplants are ready for transplanting when they have 4 to 5 leaves which generally takes 4–5 weeks. An ideal eggplant transplant is young, 8–12 inches (20–30 cm) tall, does not exhibit rapid vegetative growth, and has no fruits, flowers, or flower buds. The ideal tomato transplant has 3 to 5 true leaves, no flower buds, no signs of disease, and has a stocky growth habit. Seedlings should be "hardened" 7 to 14 days prior to transplanting. This can be done by gradually changing the transplants' environment to match that of the field. The frequency of watering and fertilization is reduced during this period. Any procedure that restricts the growth of the transplants will increase hardiness. A day before transplanting, the planting medium should be watered thoroughly with a high phosphate water-soluble fertilizer to reduce transplant shock and to facilitate pulling of the seedlings. A good transplant solution to use is 1 tablespoon of 10-52-17 per gallon of water. In addition to "hardening" to reduce plant stress, transplant in the late afternoon into moist soil and when the winds are calm. Do not plant into dry soils because the field soil will act as a wick and pull moisture from the transplant's growing medium. Irrigate with 0.3–0.5 inches (0.76–1.27 cm) immediately after transplanting to settle the soil around the roots. Field spacing depends on the size of cultivation equipment and cultivars. Large bush types are spaced further apart than dwarf types. For more information, refer to **[Appendix I: Eggplant, Pepper, and Tomato Production Summary]**.

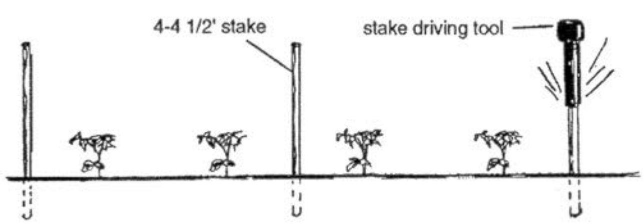
Younger transplants are generally more capable of rapid establishment because growth resumes sooner and will usually outyield older transplants. In situations where the transplant's new environment may be hostile, an older transplant having greater food reserves may be better able to survive.

Eggplant should be planted at the same depth that they were in the seedling tray. Young tomato and pepper transplants can be planted up to their cotyledonary leaves. This reduces problems from wicking moisture away from exposed potting medium and reduces wind damage for the first 30 days. Tall, leggy or pot-bound eggplant or pepper transplants should not be planted. Plant tall, leggy tomatoes on their sides 3 to 4 inches deep instead of vertically in a deep hole. Adventitious roots will form at the nodes along the buried stem. Tap-root air pruning, which is a feature in the Speedling system, encourages lateral root development and thereby facilitates removal of the plant with minimal soil/root disturbance at transplant.

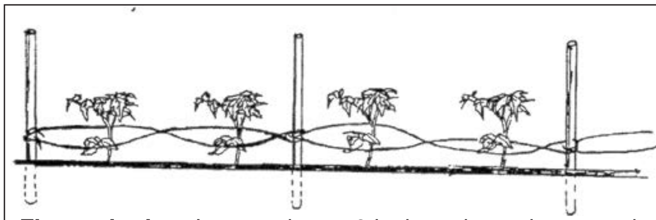
### Staking, Trellising, and Caging

Staking, trellising and caging are commonly practiced  by tomato growers and less commonly by eggplant and pepper growers. One of the reasons for staking plants is to keep the fruit off the soil and thereby reducing the occurrences of fruit rots. Also staking allows the foliage of the plant to dry more quickly which reduces foliage diseases during the rainy season. Dwarf varieties of eggplant and pepper do not require staking unless they are under a heavy fruit load. Peppers tend not to produce more fruit then they can support. Large indeterminate plants may require their own individual stake. Lee's plum and Royal Guam tomato varieties do not need individual stakes because they are of a small bush determinate type and can be easily support by wires between support poles if soil contact is to be avoided.

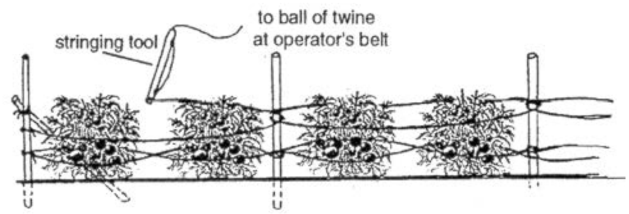
One method of staking consists of driving 1 inch x 1 inch x 4.5 foot (2.54 cm x 2.54 cm x 1.37 m) stakes after every second plant. Twine is stretched and wrapped around each stake and then tied off at the end stakes. Short pieces of twine are tied to the plant where support is needed then attached to the twine stretched between the stakes. The twine should not be too tight as it may cut into the stem as the plant's stem grows thicker. As the plant grows, extra rows of twine are added to the stakes. Wire cages (18–24 inches (45.72–60.96 cm) in diameter) made of reinforcing wire provide excellent support for tomato plants. Stake the cages down to prevent toppling over. The use of cages makes pruning and suckering of tomato unnecessary. Regardless of the support system you use, keeping plants in an upright position increases yield and aids in harvesting and controlling diseases and pests.




**Staking:** Drive 4- to 4-$^1/_2$ foot stakes about 12 inches into ground midway between plants. Note use of galvanized pipe for driving stakes manually.



**First stringing:** Locate about 10 inches above the ground when plants are 12 to 15 inches high. Note weave between plants and loop around stakes. Keep twine tight.




**Second stringing:** Locate about 6 inches above first twine when plants are 18 to 20 inches high. Note stringing tool.

**Tie the plant to the stakes with a soft cord or strip of cloth. Tie the cord to the stake and then around the plant. Pass the cord under a leaf stalk to give more support.**

Source: Growing Tomatoes in the Home Garden. Louisiana State University, Cooperative Extension Service. Pub. 1902.

Pruning is the process of removing unwanted branches or flower stems. Indeterminate tomato plants should be pruned to a single stem by removing the suckers growing in the forks of the leaf petiole and stem. You should prune up the plant until the second or third flower cluster is reached. Pruning balances vegetative growth with fruit production and enhances earlier and larger fruit. By pruning and using plant supports, plants can be trained to produce fruits which are easy to pick with a minimal amount of bending-over. Cutting the plant just above the fourth cluster will hasten maturity.

Branches of eggplants can be pruned to almost a bare plant in order to stimulate new growth or to reduce damage from an approaching typhoon. Removing old stems will also eliminate pests and diseased leaves. Eventually, the plants will develop flowers and fruits. Plants maintained for long periods of production may require trellising to support the long branches with heavy fruit loads. In Brazil, after eggplant has produced 20–30 fruits and the plantation looks old, the plants are cut to a height of 30 cm. The cut branches are removed from the site and the plants are fertilized.

In bell pepper, pruning off the growing tip will accelerate the growth of lateral branches and delay flowering. Produce bushy pepper plants by cutting off the terminal bud one week before transplanting. Better results can be achieved by waiting until after transplanting and pruning above the first branch.

### Producing and Storing Seeds

Producing and Storing Seeds is easy. It is important to use open-pollinated varieties (not hybrids) for seed production to ensure the seedlings will look like the parents. Harvest from healthy disease-free fruits and discard any seeds which appear abnormal. Seeds can be dried on paper towels under light bulbs (3 to 4 days), in a warm oven 100° F (37.78° C) for 6 hours, or outside in indirect sunlight, if the humidity is low. Once seeds are adequately dry, store in small, sealed glass jars or zip lock bags in a refrigerator. Never use a microwave oven to dry seed.

For tomato, fruits should be thoroughly ripened on the vine. Cut the tomatoes open and remove the seeds by squeezing or spooning out the seed containing pulp into a nonmetal container such as a drinking glass or jar. Let the container stand at room temperature for two days. This allows time for the removal of the seed's gelatinous coating through the process of fermentation. After two days of fermenting, rinse the seeds with water several times until seeds are cleansed and completely free from pulp residue. Place the seeds on paper towels and dry.

Pepper fruits should be allowed to fully ripen on the plant. Most peppers are red when fully ripened. Cut the pepper in half and scoop the seeds onto a piece of paper towel. Spread out the seeds and allow to dry.

Eggplant fruits should be allowed to ripen to the point that browning and shriveling occurs; this is well past the normal harvest stage. Allow fruits to further ripen by placing in a container for one week at room temperature. Split open, remove the seeds and wash thoroughly to remove the pulp. Place on paper towel to dry. Moist seeds will begin to germinate over night; so dry the seeds quickly.

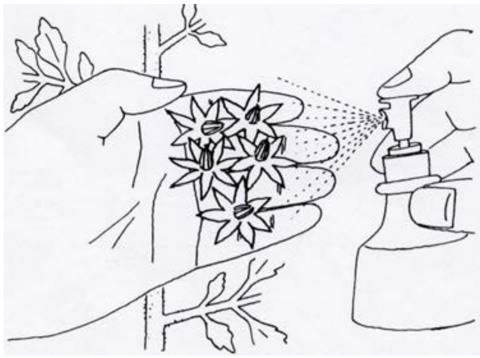
### Typhoon Preparations

Typhoon preparations will reduce losses. Typhoons are inevitable on Guam and usually result in total destruction of eggplant, pepper, and tomato crops. Commercial operators are best advised to replant rather than try to salvage severely damaged plants. However, typhoon severity varies so by following the following preventive measures listed below a total loss may be avoided.

1. Harvest all usable fruits. Remember, fruits can be used in their green or unripe stage.
2. Eggplant and pepper can be pruned to 2–4 branches and 1–1.5 feet tall.
3. If practical, lay trellised crops on the ground.
4. If flooding or erosion is a concern, provide an avenue for water to drain. Avoid diverting water where it may damage a neighbor's yard or property.

### Synthetic Plant Growth Regulators

Synthetic plant growth regulators (PGRs) can be used to overcome bud drop, poor pollination and poor fertilization. These conditions develop when tomatoes are grown under high humidity and high night temperatures above 22° C (72° F). Spraying one of the PGRs such as 4-chlorophenoxyacetic acid (CPA) improves fruit set of tomatoes. CPA is also used to promote eggplant fruit set. As a general rule, CPA is applied at the concentration of 50 mg/liter on flower clusters when they are in bloom. This treatment continues at 7–14 days intervals. Do not repeat spraying on the same flower cluster. Although CPA improves fruit set, increases fruit size, and induces early fruits, it may also produce puffy fruit at high concentration. In trials on Guam during the wet season of 1985, tomatoes treated with CPA at concentrations of 30–75 ppm resulted in increases in the number of fruits per plant, market fruit and total fruit yield.



Wear gloves when applying chemical sprays.

### Fertilization and Liming

As discussed in **Chapter 3: Production - Site Selection**, a good fertilization and lime plan for any crop starts with an analysis of the soil. Soil with a pH below the recommended level **[Table 3.4]** should be amended with lime. Many soils in the humid tropics below pH 5.5 have high exchangeable aluminum which may have toxic effects on plant root growth. The most common soil amendments for increasing soil pH are called agricultural liming materials. The effectiveness of liming material is determined by its chemical composition and the fineness of the particles. Soil with a pH above the recommended level **[Table 3.4]** should be amended with organic material or sulfur or ammonium-based fertilizers. If the soil is calcareous (limestone parent material), soil amendments to adjust soil pH may not be economically feasible.

Nutrient recommendations are based on soil test results, crop selection, fertilizer application methods, soil type, and field history. Analysis of plant tissue from a prior healthy crop is very helpful in diagnosing soil nutrient problems particularly micronutrient deficiencies such as iron (Fe) and manganese (Mn).

Other factors which will affect the amount of fertilizer to apply include the method of fertilizer application and the type of fertilizer or organic amendment used. There are several methods of applying fertilizer. For phosphorus (P) fertilization, the method that is recommended for Guam is banding (localized placement of the fertilizer in a band). Banding lessens the chance that P will be bound by the soil and made unavailable to the plant. Place fertilizer in a band about 8 cm (3 inches) below seeds and 10–13 cm (4–5 inches) below transplants. If the band is placed too close, seedling roots can be damaged. If drip irrigation is used, place band between the seed-row and the drip-line. To prevent burning the plant, exercise care at all times so that the fertilizer does not come in contact with leaves, stems, and roots. In broadcasting (uniformly distributing the fertilizer over the field), the fertilizer needs to be worked into the soil prior to planting.

Nitrogen (N) fertilizer applications must be made throughout the season because it readily leaches out of the root zone. Depending on the soil, potassium (K) will also leach; therefore, as a general recommendation, the crop's N and K requirements should be divided among 2–3 applications. The number of applications can also be reduced if a controlled-release fertilizer is used. These fertilizers are generally more expensive than conventional ones. Results from an experiment indicated that nitrate nitrogen from conventional fertilizer is held in most Guam soils for about 9 to 10 weeks with the majority of it being lost to leaching within 4 weeks. When used in Guam's Akina silty clay soil (pH 5.0), controlled-release fertilizer allowed nitrate nitrogen to be released to the soil 5 weeks longer than when water soluble fertilizer was used. No benefits from controlled-release fertilizers were noted on Yigo silty clay (pH 7.8) or Guam cobbly clay (pH 7.8).

Other application methods include foliar sprays (spraying of the fertilizer on the leaves) and fertigation (mixing fertilizer by the irrigation water). These methods vary in efficiency with which they provide certain nutrients to the plant. For example, foliar spraying of microutrient fertilizers is recommended for deficient plants in alkaline soils. Application of micronutrients to the soil is best accomplished by adding a chelated form of the micronutrient or an organic manure. Micronutrients, if applied as salts, are often changed to forms which are unavailable to the plant due in part to soil pH and soil components. For example, if the inorganic iron salt, ferric sulfate, is added to the calcareous soils of Northern Guam, much of the iron changes into a form which is unavailable to the plant.

Many types of fertilizers and organic amendments which are suitable for use with eggplants, peppers, and tomatoes are available on Guam. The fertilizer analysis is indicated on the label as three numbers such as 16-16-16. These indicate the % nitrogen (N), % phosphorus pentoxide ($P_2O_5$), and potassium oxide ($K_2O$) in the fertilizer material. Fertilizer recommendation are usually reported in these same terms. To determine how many pounds of actual fertilizer to apply, divide the pounds of N, $P_2O_5$, or $K_2O$ by the appropriate fertilizer analysis term. For example,

For 150 lbs (168 kg) N, you should apply 150 ÷ 0.10 = 1,500 lbs of (680.4 kg) **10**-30-20 fertilizer.

For 300 lb (136 kg) $P_2O_5$, you should apply 300 ÷ 0.30 = 1,000 lbs (453.6 kg) of 10-**30**-20 fertilizer.

For 220 lbs (100 kg) $K_2O$, you should apply 220 ÷ 0.20 = 1,100 lbs (499 kg) of 10-30-**20** fertilizer.

Yields generally increases with fertilizer application **[Table 3.8]** but not always. In a tomato trial on Guam clay (9.7% organic matter), it was reported that 67.3 kg N and 134.5 kg N/ha (60 lb N and 120 lb N/acre) treatments resulted in the same yield. In 1982, it was reported that tomato treated with 50 kg N/ha (44.6 lb N/acre) had a higher yield than 100 kg N/ha (89.2 lb N/acre).

**Table 3.8.** Response of Solar Set tomato to nitrogen applications.

| Nitrogen | Market yield/plant |
|---|---|
| 50 lb/acre (56 kg/ha) | 14.0 lbs (6.4 kg) |
| 100 lbs/acre (112 kg/ha) | 14.8 lbs (6.7 kg) |
| 200 lbs/acre (224 kg/ha) | 15.7 lbs (7.1 kg) |
| 400 lbs/acre (448 kgs/ha) | 17.0 lbs (7.7 kg) |
| The experiment was conducted in Guam's Pulantat soil (limestone uplands) in 1993–1994 during the dry season. | |

In yield trials on Guam on cherry tomatoes in clay soil containing 75 ppm $K_2O$, growth response at 25 kg / ha was as great as that from 50, 100 and 200 kg $K_2O$ / ha. In a similar experiment in clay soil containing 1.6 ppm $P_2O_5$, it was found that there was no substantial growth response with the addition of $P_2O_5$ when N and $K_2O$ were added at a rate of 100 kg / ha.

Organic fertilizers can be used in place of man-made fertilizers (inorganic) but they are generally low in nitrogen. Organic fertilizers improve plant growth because they add organic matter to the soil and a wide array of nutrients. In trials conducted on bell pepper on Guam, growth response of incorporation of chicken manure at 10.2 tons (10.3 metric tons) (25.1% moisture) or 12 tons (12.2 metric tons) of fresh *Leucaena leucocephala* (tangan-tangan) leaves and stems (50.9% moisture) into the soil was equivalent to the response produced by 100 kg N/ha (89 lb N/acre) from chemical fertilizer. In a 1979 experiment conducted on tomato in Inarajan, the growth response from 6 tons/ha chicken manure was less than that from 100 kg of N from ammonium sulfate $(NH_4)_2SO_4$.

Several factors may affect your selection of a fertilizer, including cost, availability, nutrient content, particle size, form, and solubility. Fertilizers which will be used in fertigation must be soluble in water. Avoid placing a large amount of solid fertilizer close to the plant due to potential salt injury. Generally, eggplants, peppers, and tomatoes can be expected to have a growth response to a fertilizer containing N-P-K. Fertilizer requirements depend on a number of factors such as farm practices, soil type, crop density, and season; therefore, fertilizer recommendations should be considered only as a guideline. The response to fertilization will be greatest at lower levels with decreasing benefits and eventual harm at excessive levels. Conservative levels of N-P-K should be used if no soil analysis data is available, such as 157 kg N, 202 kg $P_2O_5$, 157 kg $K_2O$/ha (140 lb N, 180 lb $P_2O_5$, and 140 lb $K_2O$/acre). Apply all the $P_2O_5$ and half the N and $K_2O$ at transplanting. Side dress at flowering with the remaining. For sustained production over a long period, add additional N at 22 kg/ha (20 lb/acre) every two weeks after first harvest. Apply additional fertilizer if nutrient deficiencies develop. To convert pounds of $P_2O_5$ to pounds of P, multiply $P_2O_5$ by 0.44. To convert pounds of $K_2O$ to pounds of K, multiply $K_2O$ by 0.83. Continuous application of fertilizer may lead to a buildup of P in the soil which can only be determined with a soil test. With experience and additional information, you can fine-tune your individual fertilizer requirements. When soil analysis and data are available, then the general guidelines in **[Table 3.9]** should be followed. If a heavy rain follows application, then additional fertilizer will be needed since N and K tend to leach. Supplement with additional application of N and K at 28 kg/ha (25 lb/acre) only if nutrient deficiencies develop. Excess amounts of nutrients may also lower quality or impair development.

For the home garden, a balanced fertilizer such as 10-20-20, 16-16-16 or 10-30-10 may be applied at 4.5 kg (10 lb) per 100 ft row. One pound of fertilizer is approximately equal to 1 pint. On a per plant basis, use 68 gm (2.4 oz) per plant which is approximately 5 tablespoons. Side dress every two weeks after the first harvest with ammonium sulfate (21-0-0) at 1.4–2.3 kg (3–5 lb) / 100 ft row or 28–56 gm (1–2 oz) / plant. If you use chicken manure, apply 0.23 to 0.45 kg (0.5–1 lb) per plant at transplanting and side dress with 21-0-0 if nitrogen deficiency symptoms develop.

**Table 3.9.** Granular fertilizer recommendations for eggplant, pepper, and tomato production based on University of Guam Soil and Plant Testing Laboratory results for N, P, and K.

| When Test Shows | < 9% Organic Matter | | > 9% Organic Matter | | |
|---|---|---|---|---|---|
| Add N lb/acre | 120 | | 80 | | |
| Add N kg/ha | 135 | | 90 | | |
| **When Test Shows K (ppm)** | **< 50** | **50 – 100** | **101 – 150** | **151 – 190** | **> 190** |
| Add $K_2O$ lb/acre | 180 | 125 | 50 | 20 | 10 |
| Add $K_2O$ kg/ha | 202 | 140 | 56 | 22 | 11 |
| **When Test Shows K (ppm)** | **< 50** | **50 – 100** | **101 – 150** | **151 – 190** | **> 190** |
| **For High Clay Soil** | | | | | |
| Add $P_2O_5$ lb/acre | 200 | 180 | 160 | 100 | 20 |
| Add $P_2O_5$ kg/ha | 224 | 202 | 179 | 112 | 22 |
| **For Low Clay Soil** | | | | | |
| Add $P_2O_5$ lb/acre | 100 | 80 | 60 | 25 | 10 |
| Add $P_2O_5$ kg/ha | 112 | 90 | 67 | 28 | 11 |
| **Unknown clay level** | | | | | |
| Add $P_2O_5$ lb/acre | 180 | 150 | 130 | 90 | 15 |
| Add $P_2O_5$ kg/ha | 202 | 168 | 146 | 101 | 17 |

- Add 10% more fertilizer if applied by broadcasting.
- Apply all $P_2O_5$ and half the N and $K_2O$ at transplanting, side dress at flowering with the remaining.
- For sustained production over a long period, add additional N at 22 kg/ha (20 lb/acre) every two weeks after harvest. Apply additional fertilizer if nutrient deficiencies develop.
- To convert lb/acre to lb/100-ft row with 100 cm spacing, multiple lb/acre by 0.008. For 130 cm row spacing, use (0.01). For 130 cm row spacing, use (0.01). For 200 cm rows, use (0.015). For example, *(150 lb/acre) x (0.008) = 1.2 lb/100-ft row for rows spaced 100 cm apart.*
- Organic matter determined by the Walkley-Black method; phosphorus extracted with 0.5 M sodium bicarbonate (Olsen method); potassium, calcium and magnesium by 1 N ammonium acetate.
- High clay refers to soil with a textual class name of clay. All others are referred to as low clay.

## Nutrient Symptoms Resulting from Deficiencies and Excesses

**Table 3.10** Nutrient symptoms resulting from deficiencies and excesses.

| Nutrient Available Forms | Symptoms |
|---|---|
| **Nitrogen** (N)<br>$NO_3^-$<br>$NH_4^+$ | **Deficiency:** Leaves are yellow green with lower leaves being affected first. Plant is spindly in appearance with thin and hard stems. Fruits are undersized. On tomato, leaflets are small and erect, and the major veins look purple. Tomato flower buds turn yellow and drop off. Nitrogen deficiency is more likely to occur in sandy soils with low humus and during periods of high rainfall. It can temporarily occur when an undecomposed high carbon plant material such as straw is mixed with the soil at the time of planting. Low nitrogen contributes to increased severity of tomato mosaic. In bell pepper, flower initiation will be delayed.<br><br>**Excess:** Growth is restricted and the younger leaves are small and dark. Root tips turn brown and die back. Ammonium ($NH_4^+$) toxicity causes yellowing of tomato leaves and may result from improper use of organic or ammonium fertilizers. Excess nitrogen can cause flower drop in bell pepper. The problem is most severe on sandy soils that have been allowed to become too dry. Succulent tomato plants which result from excess nitrogen and low potassium tend to be more susceptible to growth cracks. Soil can be flooded (leached) to remove excess nitrogen. |

| Nutrient Available Forms | Symptoms |
|---|---|
| **Phosphorus** (P) $H_2PO_4^-$ $HPO_4^{2-}$ | **Deficiency:** Stems are thin and shorted but clear symptoms are absent unless deficiency is severe in which case the leaves develop a purple coloration. The purple coloration starts on the underside of the leaf and includes the veins. On tomato, the older leaves may turn yellow, develop scattered brownish purple dry spots, and drop prematurely. More likely to occur on acid soils and low poorly drained iron-rich (phosphate-fixing) soils.<br><br>**Excess**: Excesses may cause micronutrient deficiencies of Mg and Fe. Phosphorus may build up in soils after years of cultivation if fertilization levels are not based on soil test results. |
| **Potassium** (K) $K^+$ | **Deficiency:** Older leaves develop gray or tan areas near the leaf edge (margin) with yellowing between the larger veins. The leaflets of older tomato leaves develop scorched and curled edges. Symptoms eventually develop in young leaves with older leaves dropping prematurely. The plant is stunted with small leaves. In tomato uneven ripening of the fruit can be expected with increased susceptibility to gray mold. May leach excessively on light soils. In bell pepper, flower initiation will be delayed.<br><br>**Excess:** Growth is reduced and any deficiency is intensified. Small excesses can be corrected by a period of liquid nitrogen application. |
| **Magnesium** (Mg) $MG^{2+}$ | **Deficiency:** Initially, older leaves show yellowing between the veins followed by younger leaves. The entire leaf may become yellow before dropping. Low soil Mg is most common on sandy soils due to leaching. High potassium may induce Mg deficiency if the ratio of K to Mg in the soil exceeds about 4:1. Associated with poor soil structure, poor drainage, or root pathogens. Deficiency occurs on calcareous loam soils.<br><br>**Excess**: Potassium deficiency symptoms may occur if Mg levels are much higher than K. More likely to occur on soils with a pH above 6.7. |
| **Calcium** (Ca) $Ca^{2+}$ | **Deficiency:** Youngest leaves near the growing point turn pale green or yellow and then die. Deficiency can occur in high organic soils, very acid soils, in high potassium soils, and is usually associated with manganese toxicity. Calcium deficiency in the fruit produces blossom-end rot symptoms. Refer to Chapter 12, Plant Diseases, for more information.<br><br>**Excess:** Calcium carbonate (lime) increases soil pH, and this can induce deficiencies of iron and manganese. It is not practical to reduce the pH of soils containing high amounts of free lime. |
| **Manganese** (Mn) $Mn^{2+}$ $Mn^{4+}$ | **Deficiency:** Pale green or yellowish areas between veins appear uniformly over the leaf, giving a mottled appearance. Symptoms are first seen on the younger leaves. In tomatoes, the main stem may develop brown streaking. The availability of soil manganese is reduced above pH 6.7. Over-liming can induce symptoms particularly on sandy soils and organic soils.<br><br>**Excess**: Excess causes brown spots on older leaves. When soil is steam sterilized, the available Mn level increases, particularly on acid soils. |
| **Iron** (Fe) $Fe^2$ $Fe^{3+}$ | **Deficiency:** Pale yellow areas develop between the veins on the youngest leaves starting at the base of the leaves. Leaves remain small and growth becomes very slow. As deficiency intensifies, older leaves become affected and younger leaves turn yellow. This disorder differs from Mn deficiency in that the chlorosis is more intense. It occurs on soils with pH above 6.8 particularly calcareous soils. It can be induced by over-liming, poor aeration and high levels of phosphorus.<br><br>**Excess**: Excess iron does not present any problems. |
| **Boron** (B) $Bo_3^{3-}$ | **Deficiency:** Growing points die, stems are shortened, and leaves are distorted. Yellow to orange discoloration of tomato leaflets. Sandy soils and soils with a pH greater than 6.8 are more susceptible.<br><br>**Excess:** On tomatoes, excess causes brown marginal scorching and curling on the older leaves. There is quite a narrow satisfactory range between deficiency and toxicity. |

# Chapter 4 Irrigation, Fertigation, and Drainage

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Irrigation is the process of applying supplemental water to a crop for satisfactory or optimum production. Irrigation is mainly used to supplement natural precipitation in order to save a crop from dying or to maximize its yield. If salt or fertilizer accumulation is a problem, then irrigation is used to leach them from the crop's root zone

Irrigation and drainage requirements of a crop depend upon the crop, climate, season and type, and soil depth. Irrigation needs on Guam are highest during the dry season from January to May. On most shallow soils, irrigation will also be needed during the rainy season.

### Irrigation Methods

Furrow, sprinkler, and microirrigation are methods of irrigation. Furrow irrigation requires level to gently sloping fields. This method is unsuitable on uneven fields, steep slopes, and on shallow soils with high percolation rates. Overhead high pressure sprinkler systems are not be suitable in Guam's high wind environment. Moreover, these systems are only cost effective for very large farms due to their high pressure and large volume requirements. Low pressure, low flow sprinkler systems are also susceptible to effects of the high wind conditions on Guam, which adversely affect the system's distribution uniformity. The most widely used irrigation method on Guam and Micronesia is microirrigation, which is a slow, frequent, and precise application of water through small orifices or emitters directly to the root zone of the growing plants. Microirrigation includes low pressure, low flower sprinklers and bubblers, drip or trickle irrigation and soaker systems. A well designed drip irrigation system can achieve water application efficiency, a ratio of the amount of irrigation water retained in the root zone depth to the amount of water applied, in excess of 95%. This method improves water use efficiency, and is amenable to fertigation (application of fertilizer/chemical via injection equipment) and automation.

The most common drip line used for eggplant, pepper, tomato in the region are drip-tapes. Drip tapes are thin (4–15 ml thickness), collapsible, plastic tubes with small orifices and are precision manufactured. They are generally available in 1.1, 1.9, 2.3, 3.8, 5.7 L/minute flow rates per 30.5 m of tape (0.3, 0.5, 0.6, 1.0, 1.5 gal/minute flow rates per 100 feet of tape). The orifices are commonly spaced from 5–91 cm (2–36 inches) apart. The drip tapes usually operate between 8–15 psi pressure. Under high pressure, they are likely to burst. It is desirable to have two drip lines per crop row on Guam's shallow northern soils, particularly after flowering initiation. The system should be designed to meet the peak water demand of eggplants, peppers, and tomatoes which is about 0.4 inches per day. To achieve high application efficiency from drip irrigation systems, they must be designed for a specific soil and crop. A higher level of skills and maintenance is required for drip irrigation as compared to other methods.

Drip tubing may be installed on the soil surface or buried two to three inches deep. Tubing is available in various wall thicknesses ranging from 3 mils to 25 mils. Thin wall tubing is cheaper but heavier wall tubing is more suitable for reuse. Microirrigation tapes with turbulent design are generally recommended on Guam because of its hilly topography and hard water. Two turbulent tapes that are commonly used on Guam are bi-wall and typhoon. Bi-wall tape is composed of two tapes–an inner and outer. Water passes through the inner tape and into the outer tape where it exits through an emitter. In the typhoon tape, water passes through a short plastic zig-zag channel before exiting. In areas with slopes greater than 5%, emitters with flow control are highly recommended.

### Irrigation Scheduling

When and how much water to apply, is one of the most complex decisions a farmer has to perform. Scheduling depends upon three interacting factors, namely crop, soil, and climate. Most of these factors continually change with time. The crop factors include the type of crop, its stage of growth, and root growth characteristics. The soil factors are soil type, depth, and water holding capacity. The rainfall distribution pattern, daily air temperature, relative humidity, wind speed, and solar radiation are some of the climatic factors.

The shallower the soil and the lower the level of clay, the more frequent water needs to be applied. The clay component in soil is able to hold more moisture than sand; and the thicker the clay layer, the more water the soil can hold before it needs to be recharged by rain or irrigation. For example, if your soil is Guam cobbly clay **[Plate 1-4]**, 1 cm of soil (35% clay) after being thoroughly watered will provide 1.8 mm of water while a 40% Guam cobbly clay soil will provide 2.4 mm of water. One centimeter of soil is not very much so you would have to soak the soil four times a day to provide 9.6 mm of water. On the other hand, if your 40% clay soil is 10 cm thick, the available moisture would be 24 mm and you would only have to soak the soil once every 2-$^{1}/_{2}$ days. It is recommended that you do not deplete more than 50 percent of the available water before irrigation; with this in mind, you should water crops grown on Guam every day. In addition to clay, silt and organic mater are also able to hold substantial amounts of water. Contact your Cooperative Extension Service for information regarding the available water capacity for your particular soil.

The combined loss of water by evaporation from the soil and transpiration from leaves is called evapotranspiration (ET). Peak ET rates for peppers are about 0.2 inches per day. The shallower and sandier the soil, the more frequent water must be added to the soil to replenish what is being removed. Clay soils may hold as much as twice the amount of water as sandy soils. To determine the percentage of silt, clay, and sand in your soil, have a soil texture analysis done. The depth of the soil can be determined by digging holes in your field at various locations.

Most crops require a constant supply of water to obtain maximum yield and high quality produce. Even periods of slight water stress during critical stages of growth **[Table 4.1]** can dramatically effect yield and quality; refer to **Chapter 2: Growth and Development** for more information on the importance of adequate watering

**Table 4.1.** Critical growth stages which are impacted by water stress conditions.

| Crop | Critical Stage |
|---|---|
| Eggplant | Flowering and fruit enlargement. |
| Pepper | Transplanting, fruit setting, and developing. |
| Tomato | Flower, fruit setting, and enlargement |
| • Nonnecke, I.L. 1989. Vegetable Production | |

Roots must be able to pull water from the soil in order to keep the plant alive. The tighter the water is held by the soil, the more difficult it is for the plant to extract it. Clay soils hold moisture tighter than sandy soils; therefore, a clay soil may feel moist to the touch and still be too dry for good crop production. How tightly water is being held by a particular soil can be determined by several methods. The simplest way is by feeling the soil. Take a handful of soil a few inches below the soil surface in the irrigation wetting one or from the crop's active root zone, then try to form a ball. If you cannot form a ball, your crop is experiencing water stress and needs to be watered immediately. After forming a ball, try to form a ribbon by squeezing the soil between your index finger and your thumb. If you cannot form a ribbon, your crop needs to be watered to avoid water stress. If you are able to form a ribbon of soil and are able to squeeze water from it, the soil is too wet and irrigation should be stopped immediately. Soil with an ideal level of moisture can be formed into a nice ribbon and will feel moist and cool. How easily a soil forms a ball and ribbon depends on soil texture as well as soil moisture. To get a sense of how malleable a specific soil is under moisture conditions (soil capacity), take a handful of soil about an inch below the surface after a heavy rain and after the soil has had a chance to drain thoroughly (approximately 12 hours). Other methods that can be used to gauge soil moisture involve tensiometers, evaporation pan and/or rain gauges.

A soil tensiometer is an effective, inexpensive device used to measure soil moisture tension. Tensiometers measure in centibars. Centibars are units used to measure the force or energy with which water is held in soil. Flooded soil would will have a reading of 0 and soil that has been allowed to drain will have a reading of 10–33 centibars depending on the soil type. To protect against failure and erroneous readings, tensiometers should be located about

15 cm (6 inches) deep and 15 cm (6 inches) from the plant base, but not under an emitter and not in rocks. The soil moisture tension for eggplants, peppers and tomatoes should be kept between 10–25 centibars. Readings should be taken daily and increased in frequency if readings go above 25 centibars.

Basing irrigation on rainfall is more reliable on deeper soils (greater than 25 cm (10 inches)). During the wet season, it is recommended that a drip system with 30.5 m (100 ft) laterals and with 0.46 m (18 inches) orifice spacing be turned on once a day for a period of one hour at a flow rate of 53.76 L per hour (0.24 gal/minute) if the three-day average rainfall is less than 1.27 cm (0.5 in). If the four-day total includes a day with more than 5.08 cm (2 inches) of rain or the irrigation system had been turned on during the previous four days, the system need not be activated. If water stress symptoms develop, increase duration to 2 hours. During the rainy season you should expect to supply between 5.08–7.62 cm (2–3 inches) of water per planting. For tomato, expect to apply 1 to 2 inches per week during the dry season.

During the dry season, the amount of supplemental water will increase dramatically. Determine how much water to apply by subtracting the total rainfall, determined by a rain gauge, in the last 24 hours from the average daily water requirement of the crop. On Guam, a daily requirement of 0.63–1.27 cm (0.25–0.5 inches) should be used. A tenth of an inch of rain is equivalent to 25,350 L/ha (2,715 gal/acre) of water. During the dry season, the water requirement should be split into 2 applications per day if the soil is shallow.

Eggplants are more tolerant to drought that tomato and bell pepper. However, lack of water will cause lower yields, and the fruit to become hard and develop a bitter taste. Typically, a 1-$^{1}/_{2}$ gallons (5.7 liters) of water or approximately 9,000 gallons (34,068.7 liters) of water per acre a day will be adequate for good plant growth and high yields. An extended period of water stress will retard plant growth and will invite insect and disease problems. The recovery of weakened plants will be very slow with very few and poor quality fruits procuced. On the other hand, they are sensitive to water logging. Poorly drained soil should be avoided.

In container experiments on Guam, it was determined that eggplants use about 2 liters (0.5 gallons) of water per day and peppers about 0.8 liters (0.2 gallons) per day. The application of 2.27 liters (0.6 gallons) per plant every three days was adequate for production of bell pepper on Guam when grown in deep soil.

### Drainage

Drainage is the process of removing excess water and/or salts from the root zone of a crop to assure its survival and optimum growth. Eggplants, peppers, and tomatoes not only need water and nutrients in the soil for proper plant growth but also an adequate supply of oxygen. Under waterlogged conditions, the water puddling on the soil surface restricts oxygen to the roots. To create conditions in the soil under which plants can obtain adequate amounts of oxygen, drainage is needed. Plants cannot withstand waterlogging for more than 24–72 hours. Some plants, like rice, are able to transport oxygen or oxidized compounds from the leaves to the roots, enabling them to grow successfully in standing water.

Drainage is not a problem on most shallow soils overlying coral reef limestone in the northern part of Guam. However, improved drainage may be needed during the rainy season on low-lying, clay soils located in Guam's southern watersheds. Poor drainage inhibits root growth by reducing oxygen, increasing root rots, and interfering with cultural operations.

### Fertigation

The process of applying fertilizer to a crop via an irrigation system is called fertigation. Many farmers, who invest in drip irrigation to make a profit, find the additional cost of fertigation equipment worth the investment. One advantage is that fertilizer is added only in small amounts. Therefore, there is no waste if the crop is harvested early and very little is lost from heavy rains.

Fertigation is generally used as a fertilizer sidedress method to add additional N and K. Apply all the required P, 10% of the required N and 50% of K at transplanting. The remaining N and K can be applied by fertigation. The nitrogen fertilizer is injected into the system at a rate of 5–20 lbs per week. Apply at least 1,000 gallons (3,785.4 liters) of water

/ acre with the fertilizer. Start the fertigation one week after transplanting and continue weekly until a week before the end of harvest.

Under certain situations, fertigation may be the only method suitable for applying fertilizers in a timely manner. Fertigation can be used when fields are too wet for workers or equipment to enter and is generally cheaper because it has lower equipment, maintenance and operational costs than does using traditional fertilizer application equipment. Fertigation is ideally suited for small farm situations on Guam and Micronesia where drip irrigation is used. Equipment used for fertigation can easily be added to any existing drip irrigation system.

The main limitation of fertigation is that only fertilizers that are completely water-soluble can be used because the particles of insoluble or partially soluble fertilizers can clog up the small orifices of the drip lines. Avoid the use of phosphorus fertilizers because they have low solubility and may react with calcium in Guam's water to plug the emitters.

**Equipment requirements and procedures** vary with the needs of the grower. A fertigation system's versatility depends on the injector, and environmental safety can be ensured by the use of a backflow preventer. A fertilizer injector enables the fertilizer to enter the irrigation line. There are many different kinds of injectors available on the market. They vary in size, capacity, allowable application rate, power requirements, and the principle of their operation. The two main types, suitable for small farming situations of this region, are venturi injectors (example: Mazzi injectors) and water-powered injectors (example: Dosmatic Plus and Dosatron). Venturi injectors are simpler and cheaper, but water-powered injectors offer more flexibility in usage and range of application rate. An additional source for more details on your specific injector may be found in the manufacturer's literature. To reduce the possibility of line plugging, place a line filter before the fertilizer injector **[Figure 4.1]**.

A backflow preventer, a device that allows water to flow in a forward direction only, is a must for fertigation. This is needed to prevent contamination of a water source or the water distribution system from chemicals going back into the water supply lines. If your drip irrigation system does not have a backflow preventer, it must be installed before starting fertigation.

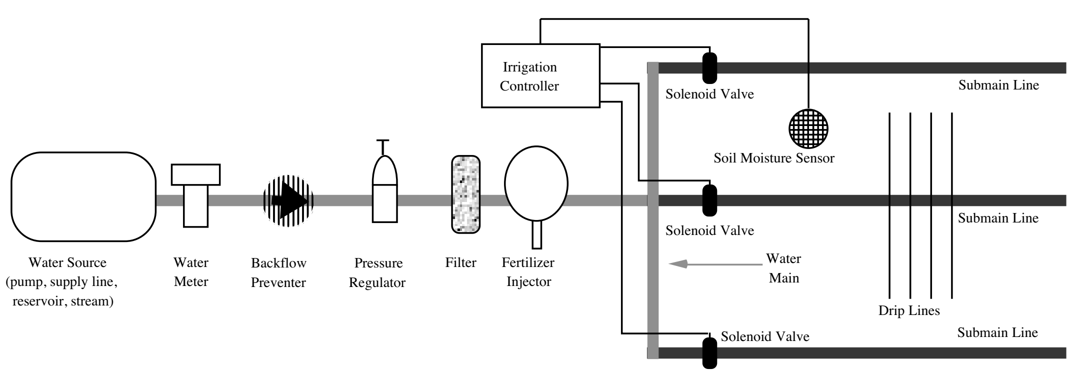



**Figure 4.1.** Schematic of a recommended drip fertigation system layout for Guam and Micronesia.

The following is a brief general procedure outlining what needs to be done in order to apply fertilizer uniformly, and prevent clogging of the drip lines.

1. **Prepare the stock solution.**
2. **Prime the drip lines** to operating pressure. Priming time will vary depending upon the distance to the farthest point in the field.
3. **Set the injector** to the desired proportion of stock solution to water and pressure test the injector.
4. **Start injecting.** When the entire stock solution has been injected, dip the suction tube in a container containing water. Let it run for about 5 minutes to rinse the suction assembly and injector.
5. **Flush the system**. Let the system run for a long enough time to flush the fertilizer from the farthest end of drip lines. This practice is important to enhance the uniformity of fertilizer application over the field. It also significantly reduces clogging of drip lines by removing chemicals that may otherwise precipitate or crystallize in the emitter pathways and eventually block these pathways.
6. **Flush the lines** with 10 to 50 ppm chlorine solution if a decrease in flow rate is detected.

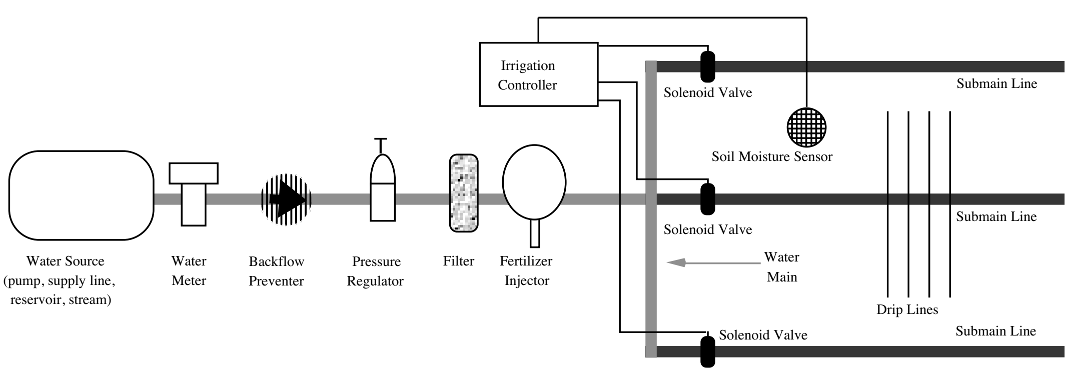



**Figure 4.1.** Schematic of a recommended drip fertigation system layout for Guam and Micronesia.

# Chapter 5 Harvest and Postharvest Handling

**Mari Marutani, Horticulturist**
**Robert L. Schlub, Extension Plant Pathologist**

On Guam, tomatoes, eggplants, bell peppers, and most hot peppers are sold as fresh-market produce. Occasionally, hot peppers are processed and sold pickled, preserved, or dried. Knowing when to harvest and how to harvest are key factors in determining the quality of produce which will reach the consumer. In this section, the general principles of harvest and postharvest practices of tomatoes, eggplants, and peppers are discussed.

### Harvest Time

Harvest time is determined by environmental conditions, cultural practices, market preference, and by crop and cultivar selection. Generally, fresh market fruits of tomatoes and peppers are harvested when physiologically mature. Both mature green and fully-colored fruits are physiologically mature when their seeds are capable of germinating. Eggplants are consumed while immature and before seed enlargement. Eggplants may be brought to market at half the full market size. Both cherry and regular tomatoes can be harvested after 60–70 days from the date of transplanting in the field. Long and pear-shaped eggplants are typically harvested after 55–65 days from transplanting, while round eggplants are generally harvested in 65–70 days. You can harvest bell peppers about 50–60 days from transplanting. The first harvest of hot peppers usually occur 60–70 days from transplanting.

On Guam, these crops are harvested by hand. Harvest time is generally determined by a maturity index **[Table 5.1]**. Fresh market tomatoes are harvested at the mature green to full-color stage. The appropriate harvest index to use depends on how the fruits are to be stored and how they will be used. For example fully ripened tomatoes have a very short shelf life. Usually on Guam, tomatoes are harvested at color break, when pink starts showing at the blossom end. Color development proceeds as tomatoes ripen during storage.

**Table 5.1.** Maturity indices of tomato, eggplant and peppers*

| Crop | Index |
|---|---|
| Tomato | Seed slipping when fruit is cut, or color turning pink. |
| Eggplant | Desirable size reached but still tender (overmature if color dulls or changes or seeds are tough). |
| Bell pepper | Dark green color turning dull or red. |
| Hot pepper | Green color turning red or full color development. |

* From AVRDC 1990; Rubatzky and Yamaguchi 1997.

Eggplants can be harvested as immature fruit. Some consumers prefer very young fruits. Desirable fruits will have a high gloss to the skin. If you push in on the fruit, it should not spring back. Fruits that are dull, spongy, and contain hard or brown seeds are overmature.

Bell peppers are usually harvested at the mature green stage. Red, yellow or orange colored bell peppers and hot peppers are harvested when color is just turning from green or even when full mature color has developed. When to pick depends on how the produce will be stored. Hot peppers are cut from the branch with some stem remaining attached to the fruit.

### Postharvest Losses

Postharvest losses of tomatoes, eggplants, and peppers are caused by fruit deterioration after harvest. The decline in fruit quality occurs as a result of natural physiological and biochemical processes initiated at the time the fruit is picked. The change in chemical composition of fruits tissue cells takes place immediately after harvest. Examples of changes in tomato fruit physiological characteristics (fruit color, firmness, and respiration) and biochemical characteristics (pH, ascorbic acid, and ethylene) are presented in **[Figure 5.1]**.

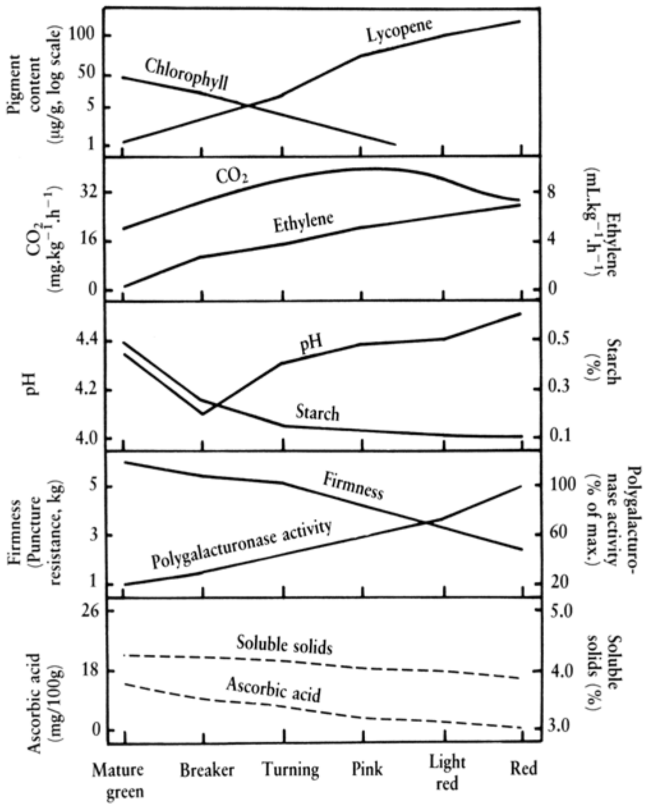



**Figure 5.1.** Some physio-chemical changes that occur during the ripening of tomato fruit. (Adapted from Rick, C.M. The Tomato Sci. Am. 239 (2): 66–76; 1978).

Tomato, eggplant, and pepper fruits are mainly water ranging from 88% for chili peppers to 94% for red tomatoes. Water loss from fruit tissues results in loss of firmness, wrinkling, and in the development of dull coloration. Fruits should be harvested at maximum water content. Maximum water content can be ensured by harvesting early in the morning, after irrigation, when relative humidity is high, and when light intensity is low. However, wet fruits should not be harvested because it contributes to storage rot.

As the living cells of fruit tissues continue to respire, there is a breakdown of starch, sugars, and organic acids into simpler molecules such as carbon dioxide. The products of respiration also include water and energy. Since many metabolic changes occur when respiration takes place, respiration rate can be used as a means to determine the general metabolic activities of fruit tissues. Immature fruits have a higher respiration rate per unit weight than mature fruits. A sudden increase in the respiration rate of a harvested tomato coincides with fruit ripening. These types of fruits are called climacteric; tomato and hot pepper belong to this category [Table 5.2]. The respiration pattern can be used as an indicator of produce storability. Keeping postharvest losses to a minimum is achieved by altering the postharvest environment.

**Table 5.2.** Respiratory behavior of tomatoes, eggplants, and peppers during ripening, and internal ethylene production, and responses to ethelyne.

| Crop | Respiration behavior | Ethelyne production | Exposure to ethelyne |
|---|---|---|---|
| Tomato | Climatcteric | High | Color development<br>Ripening<br>Softness |
| Eggplant | Non-climacteric | Very little | Hasten senescence<br>Browning<br>Loosing of calyx<br>Abscission of calyx |
| Bell pepper | Non-climacteric | Little | Hasten senescence<br>Color changes |
| Chili pepper | Climacteric | Some | Hasten senescence |

Ethylene production is another change that occurs during fruit maturation. The internal ethylene production is one of the major physiological and biochemical changes of fruit ripening of tomato [Table 5.2]. Although eggplants and peppers produce little ethylene, exposure to ethylene is a cause of postharvest loss. Many effects associated with senescence of tissues are triggered by ethylene. Separation of produce from ethylene-producing commodities is recommended to reduce loss of marketable fruits. Peppers and eggplants should not be packed with tomatoes.

Physical damage of produce during harvest, transportation, washing, sorting and packaging is detrimental since it increases water loss, pathogenic decline, ethylene production, and rapid senescence. Removal of damaged fruits is essential not only for quality control of produce, but also for prevention of the detrimental effects of injured fruits acting on other marketable fruits.

Since tomatoes, eggplants and peppers are warm-climate crops, they are very sensitive to low temperature. Injuries caused by low but non-freezing temperature is called chilling injury, which can occur during storage. Typical symptoms of chilling injury are surface pitting, premature loss of firmness, and a tendency for fruit decay. Fungal pathogens such as Alternaria often hasten deterioration of produce when in association with chilling injury. Additionally, in the case of tomatoes, chilling injury causes poor color development and improper fruit ripening **[Table 5.3]**.

Pathological decay may start during the growing period, at harvest, and any stages of postharvest handling. Physical injury of produce allows pathogenic microorganisms to enter the fruit tissues, hastening decay. Adverse environmental conditions during storage also greatly increase the possibility of postharvest deterioration. Losses can occur even after consumer purchase.

## Harvesting and Postharvest Handling Practices

### Harvesting

Maturity indices are used to determine when fruits are to be harvested; either for immediately sale or for storage. Harvested tomatoes, eggplants, and peppers should be protected from exposure to sun and wind during and after harvest to reduce respiration rate and water loss; Guam's tropical climate makes this a critical issue. Sunscorch or sunscald is heat or intensive light injury that occurs before or after harvest. Green mature tomatoes are especially susceptible to heat injury. This is caused by sudden disruption of photosynthesis by excess heat, resulting in tissues weakening and subsequent infection by fungal pathogens. Under continuous

**Table 5.3.** Harvest stage, recommended storage condition, lowest safe storage temperature, storage life, and chilling injury descriptions for tomato, eggplant and pepper.*

| | Recommended Storage Condition | | | |
|---|---|---|---|---|
| **Harvest Stage** | **Temperature** C° (F°)** | **Relative Humidity (%)** | **Storage life** | **Appearance when stored below safe temperatures** |
| **Tomato** | | | | |
| Mature green | 14–21 (58–70) | 85–95 | 1–3 weeks | Pitting<br>Alternaria rot<br>Poor color development<br>Softening |
| Firm red fruit | 9–13 (48–55) | 85–95 | 4–7 days | Pitting<br>Alternaria rot<br>Softening |
| **Eggplant** | | | | |
| Immature fruit | 8–15 (46–59) | 90–95 | 1 week | Surface scald<br>Blackening of seeds<br>Pitting<br>Alternaria rot |
| **Bell pepper** | | | | |
| Mature green | 7–13 (45–55) | 85–90 | 3–5 weeks | Pitting<br>Rot<br>Softening |
| Ripe colored | 5–7 (41–45) | 90–95 | 2 weeks | Pitting<br>Rot |
| **Hot pepper** | | | | |
| Full colored | 5–7 (41–45) | 90–95 | 2 weeks | Pitting<br>Alternaria rot<br>Cladosporium |
| Dry | 0–10 (32–50) | 60–70 | Indefinite with loss of taste over time | No damage at low temperature and low humidity |

* Table composite of several sources.

** Temperatures are used only as a guide. Fruits should be checked for low temperature damage while in storage.

high temperature after harvest, green mature fruits fail to ripen or develop color. Selection of cultivars with bushy foliage may provide a cooler environment to developing fruits. Prompt reduction of fruit temperature after harvest can prevent heat injury of produce.

**Sorting:** Removal of damaged and misshapen fruits is essential in maintaining quality control of produce, because physically damaged fruits produce higher levels of ethylene which will hasten ripening of other stored fruits. Sorting is also necessary to provide what consumers want; tomatoes, eggplants, and peppers without infection and uniform in size and shape.

### Cleaning

Any soil or organic particles should be removed from produce. Fruits can be washed with water but rubbing gently with a rag or brushing with a soft brush is preferable, since exposure of fruits to water accelerates decay. Wash water temperature should be ambient. Cold water increases the chance of pathogens enter and infecting fruits. In the case of tomato, wash water should be 10° F higher than the highest tomato pulp temperature. Fruits should not be left in the water for more than 2 minutes. If fruits are not washed in running water, then the water should be changed often. Re-used water may contain fungal spores and bacteria. Chlorinating the wash water will also minimize the spread of pathogens. Use 1 quart of bleach per 100 gallons of water (150 ppm). Dump wash water and thoroughly clean daily.

### Storage

Proper storage delays senescence of plant tissues. It minimizes water loss, respiration rate, and disease development. Temperature and relative humidity are the two main factors affecting the storage life of produce. Recommended storage temperature and relative humidity varies depending on type of crop, cultivars, harvest stage, and harvest time. Green fruits of tomato and pepper are more sensitive to chilling injury than the more matured colored ones. The general storage condition guidelines for tomatoes, eggplants, and peppers are listed in **[Table 5.3]**.

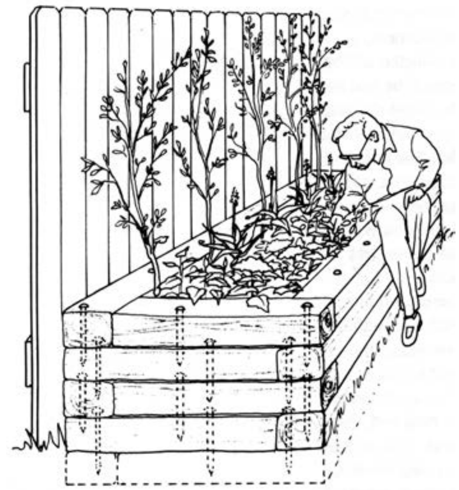
### Packaging

Two main functions of packaging are to assemble the produce into convenient units for handling and to protect the produce from mechanical injury during storage, transportation, and marketing. Packaging materials for tomatoes, eggplants and peppers include cardboard, plastic, and less commonly wooden containers. These packaging materials must have sufficient strength to protect the produce from mechanical damages, be free of any toxic chemicals, be easy to use and dispose of, and allow for a rapid cooling of the produce. At retail markets, eggplants and peppers are often packaged in small plastic bags for consumer convenience. However, some consumers prefer to select their own tomato and eggplant fruits.

# Chapter 6 Container Gardening and Horticultural Therapy

**David Nelson, Extension Assistant**
**Robert L. Schlub, Extension Plant Pathologist**

From Texas A&M University



From The Enabling Garden: Creating Barrier-Free Gardens.

If you want to grow eggplant, peppers, or tomatoes and your space is limited you may want to consider container gardening; consider the possibility of raising fresh, nutritious, homegrown vegetables in containers. A windowsill, patio, balcony, or doorstep can provide sufficient space for a productive mini-garden.

Some other reasons for container gardening are:

- Your time for gardening is limited.
- Your mobility is limited to working above ground level.
- Soil-borne diseases, nematodes or poor soil conditions can be easily overcome.
- Your gardening site is unsuitable for growing the plants you want to grow because of poor drainage, soil conditions, or too much shade or sun.
- You have a desire to be a creative garden artist!

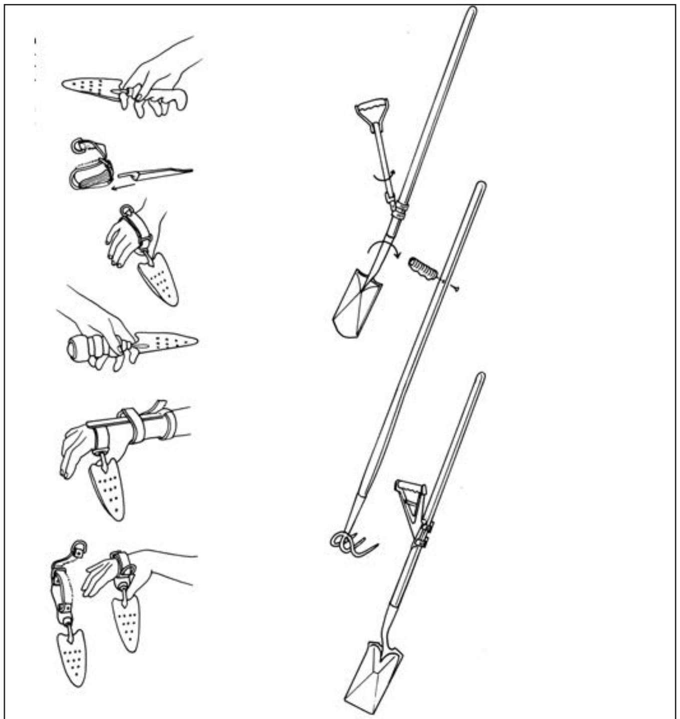
**Disadvantages to container gardening:**

- Higher maintenance requirements of watering and fertilizing the plants.
- Higher cost per plant.

### Gardening for Health

Gardening is a healthy activity that everyone can enjoy. It is known that gardening both indoor and outdoor are beneficial to its participants in that it provides both relief psychologically as well as physically. The healthy benefits of working with plants have given rise to the use of plants and planting as a form of therapy. Horticultural Therapy as it is called, is a relatively new field that is being used to aid people physically, mentally, and even socially when applied properly.

If you or someone you know is unable to enjoy conventional gardening because of a disability, then consider using adaptive tools and gardening methods. An example of an adaptation to the typical garden setting is the use of raised beds or containers for those who cannot work with plants at ground level. Another example is the use of wider pathways for persons in wheelchairs. Examples of tool adaptation include special trowels and hand rakes with padded handles or special braces for people with limited gripping ability. Long handled shovels and hoes help people with limited bending or back problems. In addition, there are shovels with a special



From The Enabling Garden: Creating Barrier-Free Gardens.

extra handle located near the head of the shovel that increases the leverage the user gets; this is particularly beneficial for persons that are too weak to use a normal shovel.

## Getting Started

### Crop Selection

Eggplants, peppers, or tomatoes are ideally suited for growing in containers. Variety selection is extremely important. Most varieties that do well when planted in a yard garden will also do well in containers.

Suggested varieties for container gardening:

**Tomatoes**: Roma, Spring Giant, Lee's Plum, Season Red

**Eggplant**: Black Beauty, Long Tom, Short Tom

**Peppers**: Yolo Wonder, Keystone Resistant Giant, (Hot) Red Cherry, Jalapeno, Local Hot Pepper (Doni Sali)

### Growing Media

Synthetic "soils" are best suited for vegetable container gardening. These mixes may be composed of sawdust, wood chips, peat moss, perlite, vermiculite or almost any other type of media. Regardless of which mixture is used, it must be free of disease and weed seeds, and it must hold moisture and nutrients but drain well and be lightweight. Many synthetic "soils" are available from garden centers, or one can be prepared by mixing horticultural grade vermiculite, peat moss, limestone, super phosphate, and garden fertilizer. To 1 bushel each of vermiculite and peat moss, add 10 tablespoons of limestone, 5 tablespoons of 0-20-0 (super phosphate) and 1 cup of garden fertilizer such as 6-12-12 or 5-10-10. Mix the material thoroughly adding a little water to reduce dust. Wet the mix thoroughly prior to seeding or transplanting.

From Texas A&M University

### Containers

Almost any type of container can be used for growing vegetable plants. For example, try using bushel baskets, drums, gallon cans, tubs, or wooden boxes. The size of the container will vary according to the crop selection and space available. For most vegetable crops such as tomatoes, peppers, and eggplant, you will find 5-gallon containers are the most suitable size. They are fairly easy to handle and provide adequate space for root growth. Even feed sacks filled with media work well. Regardless of the type or size of container used, adequate drainage is a necessity for successful yields. It is advisable to add about 1 inch of coarse gravel in the bottom of the container to improve drainage. The drain holes are best located along the side of the container, about $^1/_4$ inch to $^1/_2$ inch from the bottom.

### Fertilization

The easiest way to add fertilizer to plants growing in containers is by preparing a nutrient solution and pouring it over the soil mix. There are many good commercial fertilizer mixes available. To make nutrient solutions, follow the directions on the label.

To make your own nutrient solution, you must first make a base solution by dissolving 2 cups of a complete fertilizer such as 10-20-10, 12-24-12 or 8-16-8 in 1 gallon of warm tap water. To make the nutrient solution, mix 2 tablespoons of the base solution in 1 gallon of water. It is the nutrient which you pour around the plants.

Plants, depending on size and condition, need to be watered and fertilized. If you use transplants, begin watering with the nutrient solution the day you set them out. If you start with seed, apply only tap water to keep the soil mix moist enough until the seeds germinate and the plants emerge. Then begin using the nutrient solution.

The plants should be watered with the nutrient solution about once a day. While the frequency of watering will vary from one crop to the next, usually once per day is adequate. Should the vegetable make a lot of foliage growth, twice a day may be necessary.

**From The Enabling Garden: Creating Barrier-Free Gardens.**

Less water will be needed during periods of slow growth. Occasionally, it is a good idea to water with a nutrient solution containing minor elements. Use a water-soluble fertilizer containing iron, zinc, boron and manganese, and follow label directions.

### Watering

Proper watering is essential for a successful container garden. Generally, one watering per day is adequate. However, poor drainage will slowly kill the plants as the mix becomes waterlogged and plants will die from lack of oxygen. At least once a week, it is advisable to leach all the unused fertilizer out of the soil mix by watering with tap water. Add sufficient water to the container to cause free flow from the bottom. This practice will prevent any buildup of injurious materials in the soil mix. If at all possible, avoid wetting the foliage of plants since wet leaves favor plant diseases. Always remember that each watering should be done with the nutrient solution except for the weekly leaching with tap water.

**David A. Nelson**

### Light

Nearly all vegetable plants will grow better in full sunlight than in shade. However, leafy crops such as lettuce, cabbage, greens, spinach, and parsley can tolerate more shade than root crops such as radishes, beets, turnips, and onions. The root vegetables can stand more shade than those which bear fruit, such as cucumbers, peppers, tomatoes, and eggplants. One advantage to container gardening is mobility. Container gardening makes it possible to position the vegetables in areas where they can receive the best possible growing conditions.

**David A. Nelson**

# Chapter 7 Nutrition and Recipes

**Rachael T. Leon Guerrero, Ph.D., R.D.**

It seems that almost every year, scientists find more evidence which support the importance of including more fruits and vegetables in our daily diets. In fact, many national health organizations are recommending that everyone should follow a more 'plant-based' diet. A 'plant-based diet' is a diet that emphasizes vegetables, fruits and grain products. This is very different from the usual diet of most Guam residents, where meat and other animal sources are the main emphasis of meals.

A plant-based diet is not necessarily a vegetarian diet. However, following a plant-based diet means that most of each meal should be made up of plant foods including: vegetables and fruits (like eggplants, tomatoes, and peppers); grains (like rice, titiyas, bread, noodles, pasta, and cereal); tubers and roots (yam, taro, potatoes, and sweet potatoes); and legumes (such as beans, peas, and lentils).

### Reasons for a plant-based diet

Here are just a few reasons why we should all eat a plant-based diet, which contains lots of vegetables and fruits:

1. Plant foods tend to be low in calories and fat. This makes it easier to balance our food intake with our activity level so we do not gain weight.
2. Plant foods – including eggplants, tomatoes, and peppers — are rich in dietary fiber. Most of us do not get enough dietary fiber, which is unfortunate because dietary fiber has many health benefits:
    - It actually helps to decrease blood cholesterol levels, which in turn reduces the risk of atherosclerosis, heart disease, and stroke.
    - It keeps your digestive tract running smoothly.
    - It also protects against cancers such as colon, rectum, breast, and prostate cancers.
3. Plant foods – including eggplants, tomatoes, and peppers — are rich in antioxidant nutrients like vitamins C and E, beta-carotene, and other carotenoids. Antioxidants cleanse the body of damaging free radicals, which cause molecular damage to healthy cells. Antioxidants protect our cells from damage by these cancer-causing agents, halting the earliest processes that can lead to cancer. Antioxidants also protect against heart disease, stroke, arthritis, asthma, and cataracts. Antioxidants may also protect against degeneration of brain cells as we age.
4. Plant foods – including eggplants, tomatoes, and peppers — are rich in phytochemicals. Phytochemicals are substances found in plant foods like vegetables and fruits, and act like antioxidants. Although they are not nutrients like vitamins and minerals, scientists believe these plant chemicals show much promise in the prevention of cancer (especially liver), heart disease, and stroke.
5. Plant foods – including eggplants, tomatoes, and peppers — have the right combination of minerals and possibly other 'elements' to reduce blood pressure. This is especially true if a plant-based diet is combined with calcium rich dairy products.

### Nutritional Value

Health experts agree that everyone needs at least five servings of fruits and vegetables per day. A serving of fruits or vegetables is equal to just one medium sized fruit (like an apple); one-half cup of chopped tomatoes, eggplant, or peppers; or 1 cup of green leafy vegetables.

Although eggplants are not particularly rich in nutrients such as vitamins A and C, iron, or calcium, they are still a good choice when following a plant based diet. Eggplants are low in calories and fat, and are high in dietary fiber. Consuming eggplants on a regular basis will help meet the recommended five daily servings of fruits and vegetables.

**Table 7.1**. Nutrient content of eggplant, tomato, and bell pepper.

| | Eggplant (1 cup raw) | Tomato (1 cup raw) | Bell Pepper (1 cup raw) |
|---|---|---|---|
| Calories | 28 | 52 | 26 |
| Total Fat | 0 g | 0.8 g | 0 g |
| Saturated Fat | 0 g | 0 g | 0 g |
| Cholesterol | 0 mg | 0 mg | 0 mg |
| Protein | 1 g | 2 g | 1 g |
| Carbohydrate | 7 g | 11.5 g | 6.5 g |
| Dietary Fiber | 2 g | 3 g | 1.6 g |
| Iron | 0.5 mg | 1.1 mg | 0.46 g |
| Calcium | 30 mg | 12 mg | 10 mg |
| Vitamin A | 58 IU | 1,532 IU | 632 IU |
| Vitamin C | 2 mg | 48 mg | 90 mg |

Tomatoes are a rich source of vitamin A. Vitamin A is important because it is involved in regulating the immune system, bone and tooth growth, reproduction, hormone synthesis and regulation, skin health, and vision. Vitamin A (as beta carotene) is also an antioxidant.

Bell peppers are a rich source of vitamin C; just 1 cup supplies more vitamin C than the average person needs in one day. Vitamin C is important because it acts as an antioxidant; it strengthens the body's resistance to infection; it helps the body absorb iron; it is involved in amino acid metabolism; and it is intimately involved in collagen synthesis and wound healing. Bell peppers are also a rich source of vitamin A.

Bell peppers are not indigenous to Guam or the Marianas Islands. However, local residents have discovered many ways of using them in many recipes. Sliced bell peppers are indispensable additions to several dishes including chop steak, sukiyaki, tempura, and Chamorro bisteak. The leaves of the bell pepper plant, which are rich in vitamins A and C, can also be used in recipes calling for cooked 'leafy greens'.

## Preparation and Preservation

### Eggplant

Fortunately, eggplants are available year-round. Therefore, when choosing eggplants, look for ones that are firm, heavy, smooth and uniform in color. Avoid eggplants that are poorly colored, soft, shriveled, cut, or those which show signs of decay in the form of irregular dark brown spots.

Once purchased, store eggplants at 60° F (15° C). Storing eggplants below 50° F may cause chilling injury. If eggplants are kept at room temperature, plan to use them within a week.

When cooking eggplants, some herbs that compliment the flavor of eggplants include: allspice, cayenne or red pepper, chili powder, basil leaves, herb seasoning, majoram, oregano, parsley flakes, poultry seasoning, or sage. Eggplants can be boiled (10–20 minutes), steamed (15–20 minutes), cooked in the microwave (7–10 minutes on high per lb.), or grilled (8–10 minutes, turning often until browned and tender). Other methods of cooking eggplants are included later in the 'recipe ideas' of this section.

### Tomato

When looking for tomatoes, choose ones that are well formed, smooth, well-ripened, and reasonably free from blemishes. For fully ripe fruit, look for an overall rich red color and a slight softness. Softness is easily detected by gentle handling. For tomatoes slightly less than fully ripe, look for firm texture and color ranging from pink to light red.

Once purchased, store ripe tomatoes, uncovered, in the refrigerator. Keep unripe tomatoes at room temperature, but away from direct sunlight until they ripen.

Tomatoes are extremely versatile and can be used as the main ingredient for cooking or as a flavor enhancer. Some herbs that compliment the flavor of tomatoes include: basil, bay leaves, celery seed, cloves, herb seasoning, oregano, parsley flakes, rosemary, sage, sesame seed, tarragon, or thyme. Tomatoes can be boiled (7–15 minutes) or cooked in the microwave (4–6 minutes on high per lb.). Other ways of using tomatoes in cooking are included later in the 'recipe ideas' of this section.

### Sweet Bell Peppers

When choosing peppers, look for medium to dark green color (or bright red or yellow), glossy sheen, relatively heavy weight, and firm walls or sides. Avoid peppers with very thin walls — shown by light weight and flimsy sides, punctures through the walls, and peppers with soft watery spots on the sides (evidence of decay).

Once purchased, store sweet bell peppers in the refrigerator crisper or in a plastic bag in the refrigerator; use within three to five days.

Sweet bell peppers are usually used as an ingredient in a main dish, such as stir-fired vegetables. However, peppers are very versatile and are used in many recipes.

### Roasted Pepper & Black Bean Salad

Roasted Red Bell Peppers (recipe below)
1/2 cup seasoned rice vinegar; or 1/2 cup distilled white vinegar plus 1 tablespoon sugar
1 tablespoon water
1 tablespoon olive oil
1 tablespoon honey
1/2 teaspoon chili oil
3 cans (about 15 oz. each) black beans, drained and rinsed; or 6 cups cooked (about 3 cups dried) black beans, drained and rinsed
1/4 cup minced cilantro
2 tablespoons thinly sliced green onion
salt
cilantro sprigs

1. Prepare Roasted Bell Peppers; set aside.
2. In a bowl, mix vinegar, water, olive oil, honey, and chili oil. Add beans and roasted peppers; mix gently but thoroughly. (At this point, you may cover and refrigerate until next day).
3. To serve, stir minced cilantro and onion into bean mixture. Season to taste with salt and garnish with cilantro sprigs.

Makes 6 servings. Approximate per serving: 295 calories; 16 g protein; 52 g carbohydrates; 4 g total fat (1 g saturated fat); 0 mg cholesterol; 400 mg sodium.

### Herbed Oven Dried Tomatoes

**The Art of Preserving by Jan Berry (Ten Sped Press)**

2 pounds (1 kg) ripe Roma (plum) tomatoes, halved
4 tablespoons sea salt
freshly ground pepper
1 tablespoon dried marjoram
1 tablespoon dried basil
bay leaves
black peppercorns
2 cloves garlic, cut into slivers
extra virgin olive oil

1. Scoop out the tomato seeds with your fingers, and discard, leaving the fibrous tissue intact.
2. Place the halves, cut side up, on a baking sheet lined with parchment paper.
3. Sprinkle with the salt, pepper, marjoram, and basil.
4. Place the tray in a preheated oven at 210° F for 12 hours. If the tomatoes are drying out too quickly, leave the oven door slightly ajar.
5. When the tomatoes are dry and have cooled, pack them into a sterilized jar. Add a bay leaf, a few peppercorns, and some garlic sliver. Cover with olive oil and seal.

**Note:** Make sure the oven is not too warm or the tomatoes will cook rather than dry.

Makes one 4-cup jar serving. Store in refrigerator up to three months.

### Pasta with Peppers and Parmesan

2 tablespoons corn oil margarine
2 tablespoons olive oil
2 red or green bell peppers, quartered and thinly sliced
1 clove garlic, minced
$^1/_2$ teaspoon salt (optional)
$^1/_4$ teaspoon pepper
8 ounces whole wheat or white fettuccine or other flat pasta
3 tablespoons Parmesan cheese, freshly grated

1. Combine margarine and oil in a large skillet and heat over low heat until margarine melts.
2. Add bell peppers and sauté for 5 minutes.
3. Add salt and pepper and sauté for 2 minutes. Keep warm.
4. Cook fettucine al dente according to package directions, then drain.
5. Combine hot fettuccine, sautéed pepper and cheese in a serving bowl and toss to mix. Serve at once.

Makes 6 servings. Approximate per serving: 204 calories; 3 g fat.

### Chamorro Bisteak
### by Carlos Takai

$^1/_2$ cup vinegar
2 cloves minced garlic
$^1/_2$ cup chopped onions
$^1/_4$ teaspoon black pepper
$^1/_4$ teaspoon Accent™
1-$^1/_2$ pounds sliced round round beef
achote water (for coloring as desired)
$^1/_4$ cup flour dispersed in 1 cup water
2 sliced bell peppers
salt

1. Combine together the vinegar, garlic, onions, pepper, and Accent™.
2. Marinate the beef in combined ingredients for about 30 minutes.
3. Cook meat in marinade until tender, adding a little water if the mixture dries up before meat gets tender.
4. Add achote (if desired).
5. Stir in flour & water mixture.
6. Continue stirring and cook until meat pieces are coated with the thickening.
7. Add bell peppers.
8. Season with salt to taste
9. Cook for about 5 minutes more.
10. Serve hot.

Makes 8 servings. Approximate per serving: 215 calories; 24 g protein; 10 g fat.

### Eggplant Finadene with Coconut Milk (Hot/Spicey Sauce)

**UOG Cooperative Extension Service**

8 eggplants (purple or green)
3–4 tablespoons of lemon juice
$^{3}/_{4}$ cup coconut cream
1 teaspoon salt
chopped fresh hot pepper (according to taste)

1. Rinse eggplant-remove leaves and stem. Punch three holes in each side with fork.
2. Place cake rack on top of stove on high temperature. Place eggplant on top of rack. Burn until black and soft. Turn eggplant to burn on all sides (about 2 minutes).
3. Submerge immediately in tap water to loosen skin.
4. Remove skin and place in bowl.
5. Add coconut cream, lemon juice, hot pepper, and salt. Mash into a smooth sauce.

Makes 18 servings. Approximate per serving: 45 calories; 4 g fat (3 g saturated fat); 0 mg cholesterol; 120 mg sodium; 1 g protein; 4 g carbohydrate; 5 mg calcium.

### Stuffed Bell Peppers

**UOG Cooperative Extension Services**

6 green bell peppers
1-$^{1}/_{4}$ pounds cooked meat (chicken, ham, or hamburger)
1-$^{1}/_{4}$ cups moistened bread crumbs or cooked rice
1 cup water or stock
1 tablespoon olive oil
$^{1}/_{2}$ cup onions (minced)
$^{1}/_{4}$ teaspoon salt
$^{1}/_{4}$ teaspoon black pepper
$^{1}/_{4}$ teaspoon monosodium glutamate

1. Slice off tops of each pepper. Remove seeds and parboil peppers for 10 minutes.
2. Mix minced cooked meat with moistened bread crumbs.
3. Add salt, black pepper, monosodium glutamate, melted fat, and onions.
4. Stuff peppers with mixture and place in baking pan. Add water or stock. Bake in moderate oven (375° F) for 30 minutes, basting frequently.

Makes 6 servings: Approximate per serving: 260 calories; 20 g protein; 14 g fat.

### Roasted Red Bell Peppers

1. Cut 2 large red bell peppers (about 1 pound total) in half lengthwise. Set pepper halves, cut side down, in a 10- by 15-inch rimmed baking pan.
2. Broil 4 to 6 inches below heat until charred all over (about 8 minutes).
3. Cover with foil and let cool in pan.
4. Remove and discard skins, stems, and seeds; cut peppers into strips or chunks.

### Tomatoes Florentine

6 medium tomatoes
2 tablespoons corn oil margarine
1 small onion, finely chopped
1 clove garlic, minced
1 10-ounce package frozen spinach, thawed, drained and chopped
$^{1}/_{3}$ cup 1% low-fat milk
2 tablespoons fine dry bread crumbs
2 tablespoons fresh parsley, chopped
2 tablespoons Parmesan cheese, freshly grated
salt and freshly ground pepper to taste

1. Preheat oven to 400° F.
2. Slice tops off tomatoes and scoop out half the pulp.
3. Melt margarine in a skillet over medium heat.
4. Add onion and garlic and sauté until tender.
5. Add spinach, milk, salt and pepper and mix well.
6. Spoon spinach mixture into tomato shell and place in an ovenproof serving dish or on a baking sheet.
7. Combine bread crumbs, parsley and cheese in a small bowl and mix well. Sprinkle over tomatoes.
8. Bake for 20 minutes or until heated through.

Makes 6 servings. Approximate per serving: 73 calories; 2 g fat.

### Tenactac (Beef with eggplant and coconut milk)

**UOG Cooperative Extension Service**

1-$^{1}/_{4}$ pounds flank steak, chopped or 1-$^{1}/_{4}$ pounds ground beef6–8 eggplants, parboil, sliced lengthwise
2 cups coconut milk (1 cup very thick, 1 cup very thin)
2 tablespoons lemon juice
1 small onion, minced
1 tablespoon garlic, minced
$^{1}/_{4}$ teaspoon monosodium glutamate (optional)
1 tablespoon salad oil
$^{3}/_{4}$ teaspoon salt

1. Sauté garlic and onion in salad oil.
2. Add flank steak or ground beef and simmer for 10 minutes in covered saucepan.
3. Add lemon juice and continue cooking for 20 minutes.
4. Add salt, pepper, monososium glutamate. Continue cooking for 20 more minutes.
5. Add thin coconut milk and continue cooking for 10 more minutes.
6. Add eggplant and cook for 3 minutes.
7. Add thick coconut milk and simmer for 3 minutes.
8. Remove from heat and serve while warm.

Makes 4–6 servings. Approximate per serving: 360 calories; 30 g fat; 10 g protein; 4 g dietary fiber.

### Eggplant Salsa

1 large (1-$^{1}/_{4}$ pounds) eggplant

1 large tomato, peeled and chopped

3 green onions, finely chopped

$^{1}/_{2}$ stalk celery, finely chopped

$^{1}/_{4}$ cup green bell pepper, minced (optional)

1 large clove garlic, minced

2 teaspoons corn oil or safflower oil

1 teaspoon fresh lemon juice

$^{1}/_{2}$ teaspoon salt (optional)

$^{1}/_{2}$ teaspoon freshly ground pepper

1. Preheat oven to 400° F.
2. Prick eggplant in several places with fork and place onto a baking sheet.
3. Bake until tender, turning eggplant several times.
4. Allow eggplant to cool, then peel and chop finely.
5. Gently mix eggplant, tomato, green onions, celery, green pepper and garlic into a medium bowl. Toss to mix.
6. Add oil, lemon juice, salt and pepper and mix well.
7. Cover and refrigerate for 1 hour or more to blend flavors.

Makes 12 ($^{1}/_{4}$-cup) servings. Approximate per serving: 24 calories, 2 g fat.

### Eggplant Parmigiana

**guamdiner.com**

2 medium-sized eggplants, washed and cut into $^{1}/_{2}$ inch slices
$^{1}/_{2}$ cup all-purpose flour
2 eggs, well beaten
$^{1}/_{2}$ cup bread crumbs
1 teaspoon dried oregano
6 tablespoons olive oil
1 teaspoon salt, plus more for draining eggplant
1 teaspoon freshly ground black pepper
3 cups marinara sauce
$^{1}/_{2}$ cup freshly grated Parmesan cheese
Thin slices of mozzarella or Parmesan cheese

1. Sprinkle eggplant slices lightly with salt and place on paper towels for 30 minutes to drain.
2. Mix bread crumbs and oregano on a plate.
3. Dry the eggplant slices, dust with flour, dip in beaten eggs, and cover with bread crumb mixture.
4. Heat the olive oil in a skillet over medium heat and sauté the eggplant slices until medium brown, about 5 minutes per side.
5. Place a thin coating of marinara sauce in the bottom of a baking pan large enough to hold the eggplants in a single layer.
6. Arrange the eggplant slices on the sauce, sprinkle with Parmesan cheese. Place a slice of mozzarella or Swiss cheese on top of each eggplant slice. Cover with remaining marinara sauce.
7. Bake in a 325° F oven for 20 to 25 minutes.

Makes 6 servings. Approximate per serving: 324 calories; 19 g protein; 14 g fat

### Fried Eggplant a la Schlub!
### Breaded, Fried, and Cheesed Eggplant
**Phillip Iannarelli**

eggplant
flour
eggwash (eggs with water to make a thin wash, not thick)
breadcrumbs
grated cheese
Italian seasoning
salt

1. Peel eggplant and slice in $^1/_4$ inch slices. Slice them rather thick to get a thick, creamy center. If you cut it too thin, the eggplants will be all batter and crumbs.
2. Dredge in flour, then dip in eggwash, then in breadcrumbs.
3. Fry in vegetable oil until brown.
4. Take out and drain on paper. Immediately salt them. Sprinkle on Parmesan cheese and some Italian seasoning if you wish.
5. Serve at room temperature or chilled.
6. You can add tomato sauce as an option.

### Cherry Tomato Salsa

2 cups (about 12 ounces) red cherry tomatoes, cut into halves
$^1/_2$ cup lightly packed cilantro leaves
2 fresh jalapeño chiles, seeded
1 clove garlic, peeled
2 tablespoons *each* lime juice and thinly sliced green onion
salt and pepper

1. Place tomatoes, cilantro, chiles, and garlic in a food processor; whirl just until coarsely chopped (or chop coarsely with a knife).
2. Turn mixture into a nonmetal bowl; stir in lime juice and onion.
3. Season to taste with salt and pepper. If made ahead, cover and refrigerate for up to 4 hours.

Makes about 2 cups. Approximate per serving: 12 calories (8% from fat), 0.4 g protein; 0.1 g carbohydrates; 2 g total fat (0 g saturated fat); 0 mg cholesterol; 5 mg sodium.

### Corn Beef with Eggplant
**by UOG Cooperative Extension Service**

2 tablespoon vegetable oil
2 cloves minced garlic
$^1/_2$ cup chopped onions
5 cups sliced eggplant (approximately 4 long eggplants)
1 can corn beef
$^1/_4$ teaspoon black pepper
$^1/_4$ teaspoon Accent™

1. Sauté garlic and onion (at 350° F) in a skillet until tender.
2. Add sliced eggplant and cook for 5 minutes.
3. Mix in corn beef and cook for another 3-5 minutes.
4. Add black pepper and Accent™ to desired taste.
5. Remove from heat and serve while it's hot.

Makes 6 servings. Approximate per serving: 190 calories; 10 g fat; 12 g protein; 6 g dietary fiber.

### Tomato Wedges Provencal

4 medium tomatoes, each cut into 8 wedges
$^1/_4$ cup fine bread crumbs
$^1/_4$ cup onion, finely chopped
1 clove garlic, minced
1 tablespoon corn oil margarine
$^1/_2$ teaspoon fresh basil or $^1/_4$ teaspoon dried basil
salt and pepper to taste

1. Preheat oven to 425° F.
2. Arrange tomatoes in a greased shallow baking dish.
3. Combine bread crumbs, onion, parsley, garlic, margarine, basil, salt and pepper in a small bowl and mix well.
4. Sprinkle over tomatoes.
5. Bake for 8 to 10 minute or until tender.

Makes 6 servings. Approximate per serving: 45 calories; 1 g fat.

### Spinach and Eggplant Lasagna

**UOG Cooperative Extension Service**

1 can whole tomatoes (16 ounces)
$^3/_4$ cup tomato puree
$^1/_3$ cup onion (chopped)
1-$^1/_4$ teaspoon oregano leaves
$^1/_4$ teaspoon garlic powder or 2 garlic cloves
3 cups mozzarella cheese, shredded
2 eggplants or zucchini, sliced $^1/_8$ inch thick lengthwise
$^1/_8$ teaspoon black pepper
9 lasagna noodles, medium width, uncooked
1 cup firm tofu (drained)
10 ounce package frozen spinach, cooked, unsalted, well-drained

1. Preheat oven to 375° F.
2. Break up large piece of tomatoes; place in sauce pan with puree, onion and seasonings. Bring to a boil.
3. Reduce heat and boil gently uncovered, until thickened, about 15 minutes. Stir occasionally to prevent sticking.
4. In a medium bowl, combine tofu, Parmesan cheese, garlic powder and spinach. Mix to blend well.
5. Spread one-third of tomato sauce over bottom of a 8x8 inch rectangular baking dish.
6. Cover with 3 uncooked lasagna noodles. Top with half the tofu mixture and then sprinkle with one cup mozzarella cheese.
7. Spread with half the remaining tomato sauce.
8. Add a layer of eggplant.
9. Top with another 3 noodles.
10. Spread the tofu mixture over noodles and sprinkle with 1 cup mozzarella cheese.
11. Top with remaining 3 noodles, then spread on remaining tomato sauce.
12. Sprinkle remaining 1 cup mozzarella cheese on top.
13. Cover with foil. Bake 45 to 50 minutes, or until noodles are tender.
14. Let stand 5 minutes before serving

Makes 4 servings. Approximate per serving: 536 calories; 9 g fat (3 g saturated fat); 10 mg cholesterol; 856 mg sodium; 95 g total carbohydate; 25 g protein.

### Red & Yellow Pepper Salad-Salsa

5 large yellow bell peppers (about 2-$^1/_2$ lbs. total)
1 large red bell pepper (about 8 oz.), seeded and diced
$^2/_3$ cup peeled, minced jicama
2 tablespoons minced cilantro
1-$^1/_2$ tablespoons distilled white vinegar
1 teaspoon honey
about $^1/_8$ teaspoon ground pepper (cayenne), or to taste

1. Set 4 of the yellow bell peppers upright, then cut off the top quarter of each. Remove and discard seeds from pepper shells; set shells aside. Cut out and discard stems from top pieces of peppers; then dice these pieces and transfer to a large non-metal bowl.
2. Seed and dice remaining yellow bell pepper and add to bowl. Then add red bell pepper, jicama, cilantro, vinegar, honey, and ground red pepper; mix gently.
3. Spoon pepper mixture equally into pepper shells. If made ahead, cover and refrigerate up to 4 hours.

Makes 4 servings. Approximate per serving: 90 calories; 3 g protein; 22 g carbohydrates; 0.6 g total fat (0.1 g saturated fat); 0 mg cholesterol; 7 mg sodium.

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| | | | |
|---|---|---|---|
| C. | cup | 8 oz | 236.6 ml |
| **tbsp.** | tablespoon | 0.5 oz | 14.8 ml |
| **tsp.** | teaspoon | 0.17 oz | 4.9 ml |
| **lb** | pound | 16 oz | 0.45 kg |

# Part 2. The Economics of Farming

# Chapter 8 Developing Budgets

L. Robert Barber, Agricultural Economist

## Cost and Environmental Benefits from IPM

Though the purpose of this chapter is to provide growers with the financial information and tools to develop their own budgets for solanaceous crops, it is necessary to be reminded that many farm practices have a negative impact on the environment and that minimizing these impacts are good for your budget and the environment. The best way to reduce the impact of agriculture on the environment is through the adoption of IPM practices. IPM programs are very site-specific and developed by your local extension and research personnel. IPM is based on the identification of pests, accurate measurement of pest populations, assessment of damage levels, and knowledge of available pest management strategies. The negative impact of farming is in large part due to the over use and or miss use of chemical fertilizers and pesticides. Each farm site and crop has its own potential yield, which cannot be exceeded by the application of additional amounts of fertilizer or pesticides. How much fertilizer to purchase and when to and how to apply, depends on the crops, crop spacing, water availability and soil conditions. When excess nutrients are applied to the soil it not only damages your budget but also the environment for these excess nutrients need up in the ground water and streams in Guam.

A Grower must base their application of pesticides on rational decisions derived from IPM principles and agricultural research; otherwise, the grower will need to contend with a new set of problems such as pesticide resistance pests, produce with pesticide residues, and the harming non-target organisms. As a means to aid growers in making sound pest management decisions, the concept of economic-injury level (EIL) was developed by Stern et al., 1959- "The EIL is the lowest population density of a pest that will cause economic damage; or the amount of pest injury which will justify the cost of control." In other words, there is no need for the application of a costly pesticide if the pest damage is not likely to reach EIL and there is no need for the application of a costly pesticide if the EIL is exceeded after application **[Figure 8.1]**. Contact your local agriculture extension for more information on economic threshold curves for pest in your area.

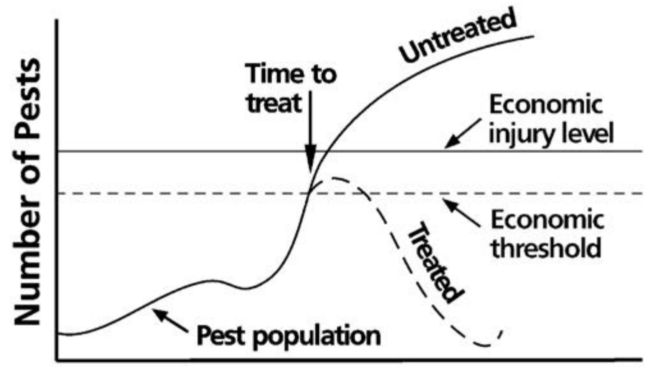



**Figure 8.1.** Pest economic injury curve. **Economic injury level (EIL)** is the lowest pest population that will cause economic damage. **Economical threshold (ET)** is the pest population level at which a control tactic should be started to keep the pest population from reaching the EIL. (The ET is also called the action threshold.) http://www.extension.umn.edu/agriculture/pesticide-safety/ppat_manual/Chapter%201.pdf

In any business activity, agricultural or other types, one of the most effective methods of increasing profits and reducing the risk of failure is good planning. A key planning tool for farmers is a crop budget. In many states, the Cooperative Extension Service provides budgets for a wide variety of agricultural enterprises. A budget is usually based on the records of top growers in the state. Such a budget can serve both as a guide to recommended production practices and serve as an estimator of production costs and profits. This tool is especially important for growers that are new to farming. But, for any grower, the most important budget to use in planning is the one that comes from the grower's own past records. The purpose of this chapter is to provide growers with the information and tools necessary to develop their own budgets for various crops.

To be useful, budgets must take into account the agricultural practices and yields of the area where they will be used. Frequently, budgets from the U.S. mainland are not directly transferable to tropical island settings, due to differences in scale and production practices. Budgets from the U.S. mainland are designed for large farms with acres as the unit of production. On Guam, it is normal for growers to have plantings that are less than one acre. A standard unit for reporting crop production adopted by the College of Agriculture and Life Sciences, University of Guam is a 100 foot row. Crop budgets can take many forms. The budget may be just a simple list of expected out-of-pocket costs for the crop or it may involve a detailed breakdown of how each farm expense is allocated to a given planting. Growers, in developing a budget, will benefit from an increased understanding of their costs regardless of the degree of detail and effort put into preparing the budget. The three major components of a crop budget are:

1. Estimated costs of the various inputs and activities involved in the production and marketing of the crop.
2. Estimated marketable quantity of crop expected to be harvested.
3. The estimated selling price for the crop.

Given these components a grower can calculate the expected net return and the expected breakeven price.

**Table 8.1.** Worksheet for use in calculating the variable cost portion of a single crop budget.

| Practices | INPUTS OF LABOR | | | INPUTS OF MATERIALS AND SUPPLIES | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Man hours** | **Wage/Rate** | **Cost** | **Item** | **Unit (example)** | **Number** | **Price per Unit** | **Cost** |
| **Field Preparation Stage** | | | | | | | | |
| Mowing | | | | Fuel | gal | | | |
| Plowing | | | | Fuel | gal | | | |
| Disk/Till | | | | Fuel | gal | | | |
| Preplant Fertilization | | | | Fertilizer | 50 lb bags | | | |
| Install Irrigation | | | | Drip Lines | 100 ft | | | |
| Other | | | | Other | | | | |
| Other | | | | Other | | | | |
| | | | | | | | | |
| Plant Seeds | | | | Seeds | lbs | | | |
| Transplant | | | | Transplants | flat | | | |
| Insect Control | | | | Insecticide | oz | | | |
| Disease Control | | | | Fungicide | oz | | | |
| Mechanical Weed Control | | | | Other | | | | |
| Chemical Weed Control | | | | Herbicide | oz | | | |
| Slug Control Pellets | | | | Pellets | lbs/box | | | |
| Install Trellis | | | | Poles | | | | |
| | | | | Net | 100 ft | | | |
| | | | | Rope/Wire | 100 ft | | | |
| Side-dress Application | | | | Fertilizer | 50 lb bags | | | |
| Other | | | | Other | | | | |
| Other | | | | Other | | | | |
| **Harvest and Marketing Stages** | | | | | | | | |
| Picking | | | | Crates | | | | |
| Washing | | | | Other | | | | |
| Sorting/Packing | | | | Boxes | | | | |
| Chilling & Storage | | | | Electricity | kw/hour | | | |
| Delivery & Sales | | | | Fuel | gal | | | |
| Other | | | | Other | | | | |
| | | **Total Labor Costs:** | | | | | **Total Materials and Supplies Costs:** | |

**Major components of a crop budget**
1. Costs
2. Quantity
3. Selling price

**A good budget begins with estimation of costs.**
1. Variable costs
2. Fixed costs
3. Selling price

## Estimating Costs

When examining production costs, growers need to understand that there are two different types of costs involved in their farming operations, variable costs and fixed costs. Many of the variable and fixed costs are for expenses that are shared by multiple crops or enterprises on the farm. These costs are known as whole farm costs, of which only a portion should be charged to a single planting.

### Variable costs

Variable costs are costs that can change during the production cycle. They are directly related to increases or decreases in production. Examples of variable costs are labor, seeds, fertilizer, and packaging materials. When making decisions on which crop to produce, the most important considerations are variable costs, expected yield, and market price. In the short run, the fixed costs will be the same no matter what the grower decides to do.

**Examples of Variable Costs**
1. Labor
2. Seeds
3. Fertilizer

For many farmers, budgeting is a new concept and frequently all the desired financial records are not available. Receipts are the beginning of a budget; therefore they must be recorded and filed. If filed by date, the date should appear each time the receipt is mentioned in a budget worksheet. To identify the cost of production in cases where records are missing, it is important to structure the process in a manner that is familiar to the grower **[Table 8.1]**. Before the various components of the table are discussed, it is necessary to point out that this is only a starting point in identifying variable costs because such a list will change with management practices and equipment.

Labor (the farmer's own or hired) is a primary input in the production process. It is also the input that the farmer can most easily document or recall. The production process should first be divided into logical identifiable stages (field preparation, grow out, and harvest and marketing). The practices occurring during each stage need to be identified. One can then determine the labor and inputs of materials and supplies for the practices at the various stages. Second, the man-hours required during each stage will determine the labor component in the budget.

The worksheet **[Table 8.1]** will provide reference points for the farmer to use in identifying the purchased inputs (materials and supplies) necessary for the production process. At a minimum, farmers must be able to cover their variable costs. If they cannot, then they may need to switch crops, change farm practices, or pull out of the market.

### Fixed Costs

Fixed costs are the expenses that remain the same, during the production period, for any level of production. Examples of fixed costs are land, equip-

**Table 8.3.** Allocating a portion of yearly whole farm costs to a single planting.

| Item | Annual Depreciation Cost AC* | Total Production Units in a Year TU | Production Unit Cost UC*** | Number of Units in Single Planting NU | Planting Cost PC**** |
|---|---|---|---|---|---|
| Tractor | $2,400 | 2,240 | $1.07 | 40 | $42.80 |
| Chilling Unit | $900 | 1,000 | $0.90 | 40 | $36.00 |
| Delivery Truck | $2,000 | 2,240 | $0.89 | 40 | $35.60 |

* Items that are not used in the production of this single crop planting.
** Since we do not depreciate variable items, AC = annual cost when variable items are used.
*** **UC = AC ÷ TU**
**** **PC = UC x NU**

ment, and insurance. Many fixed costs are more difficult to calculate than variable costs because some are spread over many production cycles or years. For example, the cost of a tractor must be spread over or depreciated over many production cycles or years.

**Examples of Fixed Costs**
1. Property Tax
2. Equipment
3. Insurance

Another consideration in estimating costs is that most fixed and several variable costs are *Whole Farm* in nature. For growers that produce different crops, costs like tractor fuel and tractor repairs, which are variable costs, or property taxes and rent payments, which are fixed costs, must be allocated among the different crops.

Some fixed costs, such as property tax or rent, are easier to calculate than others because the cost is a set annual amount. Many others, like the cost of a tractor or chilling unit, are a little more difficult to estimate. This is because the costs should be spread (depreciated) over several production periods. A major annual cost to the farm for such items is the loss in value that results from each year of use (the item's depreciation) **[Table 8.2]**.

**Table 8.2.** Example calculation of annual depreciation cost (**AC**) for three items.

| Item | Cost<br>C | Salvage Value<br>SV | Estimated Life (Years)<br>L | Annual Depreciation Cost<br>AC* |
|---|---|---|---|---|
| Tractor | $25,000 | $1,000 | 10 | $2,400 |
| Chilling Unit | $5,000 | $500 | 5 | $900 |
| Delivery Truck | $14,000 | $2,000 | 6 | $2,000 |

* **AC** = (**C** - **SV**) ÷ **L**

To calculate the annual depreciation cost (**AC**) of an item, determine the cost (**C**), its estimated life (**L**) in years, and its salvage value (**SV**), then plug the values into the equation **AC** = (**C** - **SV**) ÷ **L.**

Example: Tractor

**AC** = (**$25,000 - $1,000**) ÷ **10 = $2,400**

### Allocating Whole Farm Costs to Individual Plantings

Whole farm costs are those costs that cannot be directly charged to a single planting of a crop or agricultural enterprise. Whole farm costs can be either fixed or variable costs. These costs should be distributed among the farm's different agricultural crops. Calculating the distribution of these costs involves looking at cost of an input (equipment, land, etc.) from a whole farm perspective **[Table 8.3]**, as opposed to using only a single variable cost approach **[Table 8.1]**.

The steps used in deciding how much of each annual depreciation cost to charge to a single planting and how to calculate whole farm costs are as follows:

1. Determine the farm production unit. On Guam, most farmers would use the 100-foot row as their production unit.
2. Estimate the total number of production units (**TU**) for all crops during the year which are dependent on a particular item. For example, the tractor and truck are used for all crops (2,240 units) but the chilling unit is only used for some of the crops (1,000 units).
3. Identify the annual depreciation cost (**AC**) of an item (tractor, chilling unit, or delivery truck).
4. The farm production unit cost (**UC**) is equal to the annual depreciation cost (**AC**) of the item divided by the total production units (**TU**).
5. Determine the number of units in a single planting under consideration (**NU**).
6. Calculate the planting cost (**PC**) by multiplying the number of units in the single planting (**NU**) by the production unit cost (**UC**).

Variable costs, such as fuel for a tractor, maintenance, or electricity, can also be used in determining whole farm costs. When using variable costs, the term (**AC**) is defined as annual costs and not annual depreciation cost. Once all the costs associated with a planting have been determined, the marketable harvest and selling price must be identified to determine the profitability of the crop.

### Estimating Quantity to be Harvested

Harvest or yield estimates in the U.S. mainland are usually based on a given area such as acres. For island farmers, a harvest estimation based on the average per plant yield times the number of plants in a planting is more useful due to their small planting size, widely varied production systems, equipment, management skills, terrain, row and plant spacing.

For the island farmer, the first step in estimating harvest (**H**) is to determine the number of plants in a planting unit (**P**). To calculate the number of plants in a planting the grower needs three measurements and (**R**, **L**, **D**) and the following formula:

$$P = (R \times L) \div D$$

For example, a grower plants 10 rows of tomatoes (**R**), each row is 100 feet long (**L**), and the distance between plants in a row is 1 foot (**D**). You multiply 10 rows by 100 feet to give you 1,000 row feet. This would then be divided by the 1 foot to equal 1,000 plants in the planting (**P**).

$$P = (R \times L) \div D$$

**P** = plants in a planting unit
**R** = the number of rows
**L** = the row length in feet
**D** = the distance, in feet, between plants in a row

1,000 plants = (10 x 100) ÷ 1

The next step in calculating a grower's estimated harvest (**H**) requires an estimate of the expected yield per plant (**Y**). While both the Guam Department of Agriculture and the Guam Cooperative Extension have estimates of average plant yields for many crops grown on Guam, the best estimate to use is one based on the grower's past experiences. To calculate (**Y**), a grower records the total pounds harvested (**T**) for a planting and then divides by the number of plants in the planting (**P**).

$$Y = T \div P$$

**Y** = average plant yield
**T** = total pounds harvested
**P** = number of plants in the proposed planting

Keeping the average plant yield for several crop cycles will allow a grower to calculate an average yield per plant for the farm.

**Estimate your harvest by knowing your**

1. Number of plants
2. Yield per plant

To estimate harvest for a planting (**H**), multiply the farm's average plant yield (**Y**) times the number of plants (**P**) in the proposed planting. In estimating the harvest, a grower might want to consider previous production history and use both a high and low estimate.

$$H = (Y \times P) \div D$$

**H** = harvest for a planting
**Y** = average plant yield
**P** = number of plants in the proposed planting

### Breakeven Price

Know your breakeven price before you set your selling price. Once a grower has calculated the cost of production for a planting, an important factor to consider is the breakeven price. Any financial return above the breakeven price is profit. The breakeven price is the unit price (price per pound or box) that one must obtain in the market in order to cover the cost of production and marketing. This is a very important price to know when the grower is developing a market plan. Knowledge of the breakeven price provides a sense of security for growers in developing a marketing plan and selling price, especially if the market competition is strong and consideration is being given to lowering one's price.

The breakeven price is calculated by dividing the total cost of production by the total number of units (pounds) produced. For example, if it cost $4,194 to produce 12,600 pounds of tomatoes, the breakeven would be $4,194 ÷ 12,600 or $0.33/lb of tomatoes. If the going market price was 79¢/lb then a grower might feel comfortable dropping his price to 69¢/lb (10¢/lb below the market price) in order to capture a larger share of the market.

Growers who stay on top of their costs can rapidly adapt to changes in the market place with confidence. Knowing where the farm's most profitable opportunities are allows them to make the best use of their resources and help to ensure their success.

### Estimating Your Selling Price

The price a grower is able to obtain for his product depends on many variables, such as product quality, supply of the product in the market, and the grower's ability to negotiate. Many growers remember the prices they have historically obtained for their crops. The Guam Department of Agriculture together with the Guam Cooperative Extension collected farmer selling prices on a monthly basis for a number of years. This information is available from the Guam Cooperative Extension. The Guam Department of Agriculture maintains a list of buyers for many crops and, in some cases, the prices these buyers are willing to pay. It must be noted that historical prices should only serve as a guide and do not ensure present or future prices. Other growers and potential buyers are excellent sources of current information for the market price. Refer to **Chapter 9: Economic Assessment** for more information.

Frequently in order to make a sale, it is important to look at information other than just the market price. If there are large amounts of the crop in the market channels or if a grower is new to the market or trying to capture a larger portion of the market share, it may be necessary to sell below the market price. Use the breakeven price to determine if it is possible to lower one's selling price without suffering losses.

# Chapter 9 Economic Assessment

Robert L. Schlub, Extension Plant Pathologist

The purpose of this unit of the guide is to provide producers with market and production information which can be use in developing a crop budget. The information has been obtained over a number of years by researchers in the Agriculture Experiment Station and agents in Guam Cooperative Extension at the College of Agriculture and Life Sciences and the Guam Department of Agriculture.

### Economic Assessment for Bell Pepper

Economic assessment for bell pepper was undertaken on Guam in 1983 by Thao Khamoui and Vincent M. Russo [**Table 9.1**, **9.2**, **9.3**]. The results of their study indicated that growing the small fruit variety Express Bell in the dry season with a yield of 35,280 kg / ha can be a lucrative business, but is a risky undertaking in the wet season because of low yields (7,440 kg / ha) and increased cost associated with weed control. Variety Express Bell was nearly twice as profitable as the variety Keystone Giant; this was because 71% of its fruits were marketable compared to Keystone Giant's 42%. It was also found that the application of mulch and fungicides were cost effective.

### Guam Crop Production Survey

If you are interested in becoming a commercial farmer on Guam, it is important to learn as much as possible about the produce market. Eggplant is the most common solanaceous crop on Guam based on pounds produced and acreage planted [**Figure 9.1**, **9.2**]; however, its price has been eroding over the years. Cherry tomato may eventually replace eggplant as the top crop because its farm price has increased 4 of the last 5 years **[Figure 9.3]** in spite of increases in acreage over most of these same years **[Figure 9.2]**.

**Table 9.1.** Man-hours required per hectare for field preparation, planting and post planting activities for production of the bell pepper variety Express Bell during the dry season.[1, 2]

| Activity | Man-Hours | Cost[3] |
|---|---|---|
| **Preparation and Planting** | | |
| Mowing (T, FP)[4] | 12 | $72 |
| Plowing (T, FP) | 23 | $138 |
| Discing (T, FP) | 40 | $240 |
| Tillering (T, FP) | 40 | $240 |
| Furrowing (T, FP) | 14 | $84 |
| Laying irrigation (M, FP) | 93 | $558 |
| Laying & securing mulch (M, FP) | 266 | $1,596 |
| Planting (M, PL) | 70 | $420 |
| Replanting (M, PL) | 30 | $180 |
| **Fertilizer Application** | | |
| Manure (M, FP) | 50 | $300 |
| Commercial (M, FP) | 17 | $102 |
| Sidedress (I, PP) | 10 | $60 |
| **Pesticide Application** | | |
| Fungicides, Drench (M, PP) | 44 | $264 |
| Fungicides, Foliar (M, T, PP) | 196 | $1,176 |
| All other (M, T, PP) | 183 | $1,098 |
| **Weeding** | | |
| Pre-plant in-plot (M, FP) | 10 | $60 |
| Border (T, PP) | 20 | $120 |
| In-plot, mulched[5] | 150 | $900 |
| Equipment Recovery (M, FP) | 50 | $300 |
| **Harvesting (M, PP)** | | |
| Exp. Bell[6] | 2,100 | $12,600 |
| Totals | 3,418 | $20,508 |

1. Update of Khamoui, T. and V.M. Russo. 1983. University of Guam, College of Agriculture and Life Sciences, AES Pub. No. 31.
2. Derived from approximately 0.2 hectare experimental plot.
3. Based on wage of $6.00 per hour.
4. **M** - Manual Labor
   **T** - Tractor-Assisted
   **I** - With Existing Irrigation
   **FP** - Field Preparation
   **PL** - Planting Related
   **PP** - Post-Planting Activity.
5. If black plastic mulch is not used, increase man-hours from 150 to 1,450.
6. Five week old seedlings were planted 38 cm apart in rows which were spaced 1 meter apart.

**Table 9.2**. Cost per hectare for non-labor inputs required for production of the bell pepper variety Express Bell during the dry season.[1, 2]

| Practices/Item | Unit Price | Quantity | Cost |
|---|---|---|---|
| **Pre-plant** | | | |
| Irrigation pipe | $386/4,000 ft | 3 | $1,158 |
| Chicken manure | $50/pick-up truck load | 4.4 | $220 |
| Fertilizer 10-30-10 | $15.75/50 lb bag | 7.7 | $121 |
| Mulch | $70/2,000 ft | 7 | $490 |
| Tractor Service[3] | $55/hour | 129 | $7,095 |
| **Plant and Post Plant** | | | |
| Seeds | $90/oz | 4 | $360 |
| Irrigation water[4] | gallons | 156,000 | $156 |
| **Fertilizer** | | | |
| 46-0-0 | $13.60/50 lb bag | 3.5 | $48 |
| 0-0-62 | $13.50/50 lb bag | 7 | $95 |
| **Pesticides** | | | |
| Insecticides Dibrom | $99.45/gal | 1.8 | $179 |
| Insecticides Sevin | $65.60/10 lb bag | 10.4 | $682 |
| Insecticides Pounce | $79/1 qt | 0.5 | $40 |
| Fungicides Dithane M-22 | $58.50/12 lb bag | 7.8 | $456 |
| Fungicides Copper count | $48.50/2.5 gallons | 2 | $97 |
| Fungicides Terrachlor | $59/5 lb bag | 2.2 | $130 |
| **Other** | | | |
| Sprayers | $130 each | 3 | $390 |
| Tractor services | $55/hour | 379 | $20,845 |
| **Total** | | | **$32,562** |

1. Update of Khamoui, T. and V.M. Russo. 1983. University of Guam, College of Agriculture and Life Sciences, AES Pub. No. 31.
2. Derived from approximately 0.2 hectare experimental plot.
3. Includes fuel and repairs.
4. Total quantity for five months and cost based on two inch water meter and agricultural rates.

**Table 9.3**. Total cost, total revenue, and net revenue per hectare of Express Bell bell pepper grown on Guam during the dry season.[1, 2]

| Cost | Amount |
|---|---|
| Labor cost | $20,508 |
| Non-labor cost | $32,562 |
| Subtotal | $53,070 |
| Interest cost[3] | $1,327 |
| Total cost | $54,397 |
| Total revenue[4] | $105,840 |
| Net revenue | $53,966 |

1. Update of Khamoui, T. and V.M. Russo. 1983. University of Guam, College of Agriculture and Life Sciences, AES Pub. No. 31.
2. Derived from approximately 0.2 hectare experimental plot.
3. Based on simple interest of three months ($^1/_4$ year) at 10% interest rate ($53,070 x 0.25 x 0.10).
4. Based on $3.00 per kilogram and a marketable yield of 35,280 kg / ha. Marketable weight was approximately 70% of the total harvest weight.

**Figure 9.1.** Estimated pounds of eggplant, pepper, and tomato produced from 1996-1999.

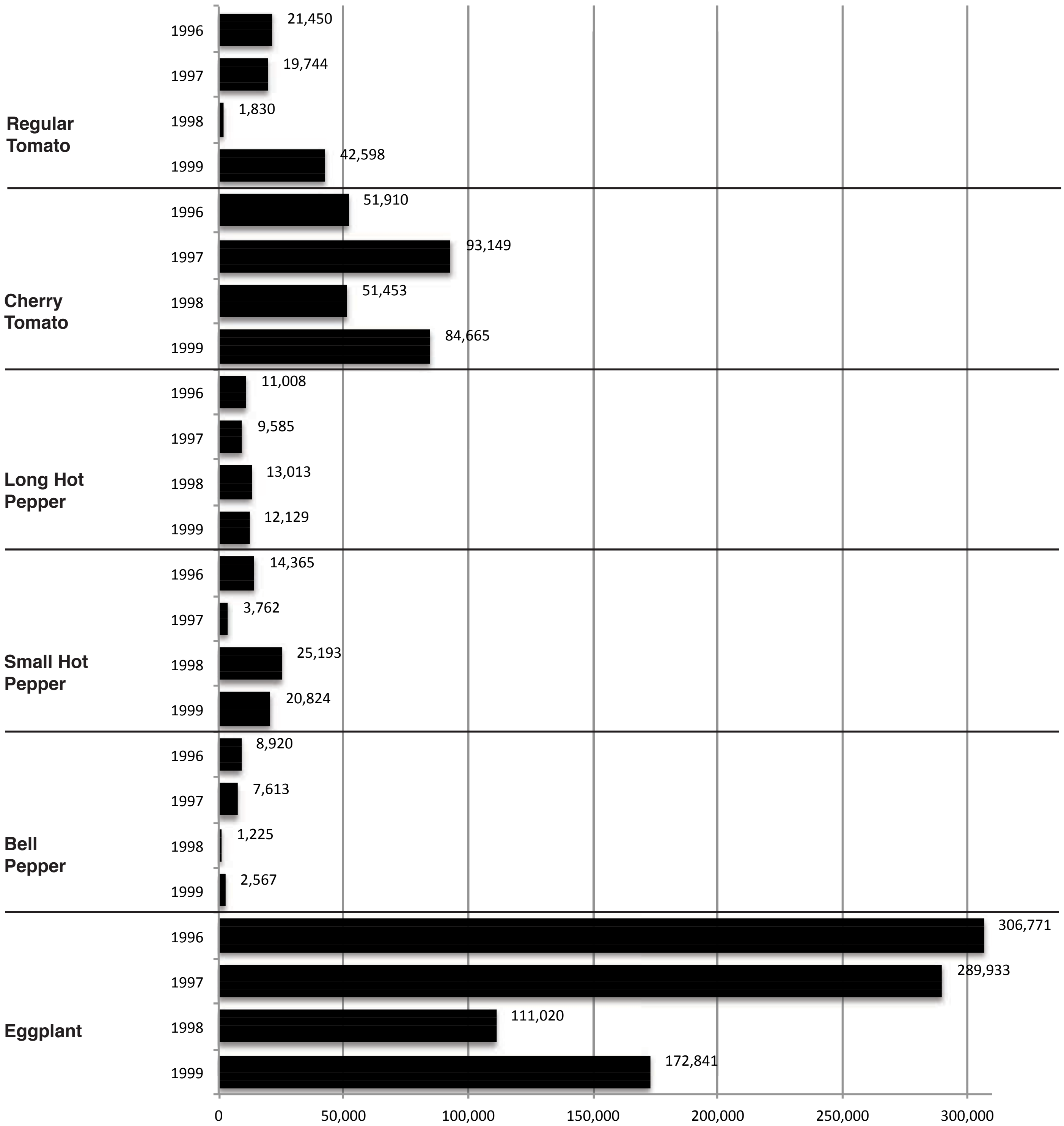


**Figure 9.2.** Estimated acres of eggplant, pepper, and tomato produced from 1996-1999.

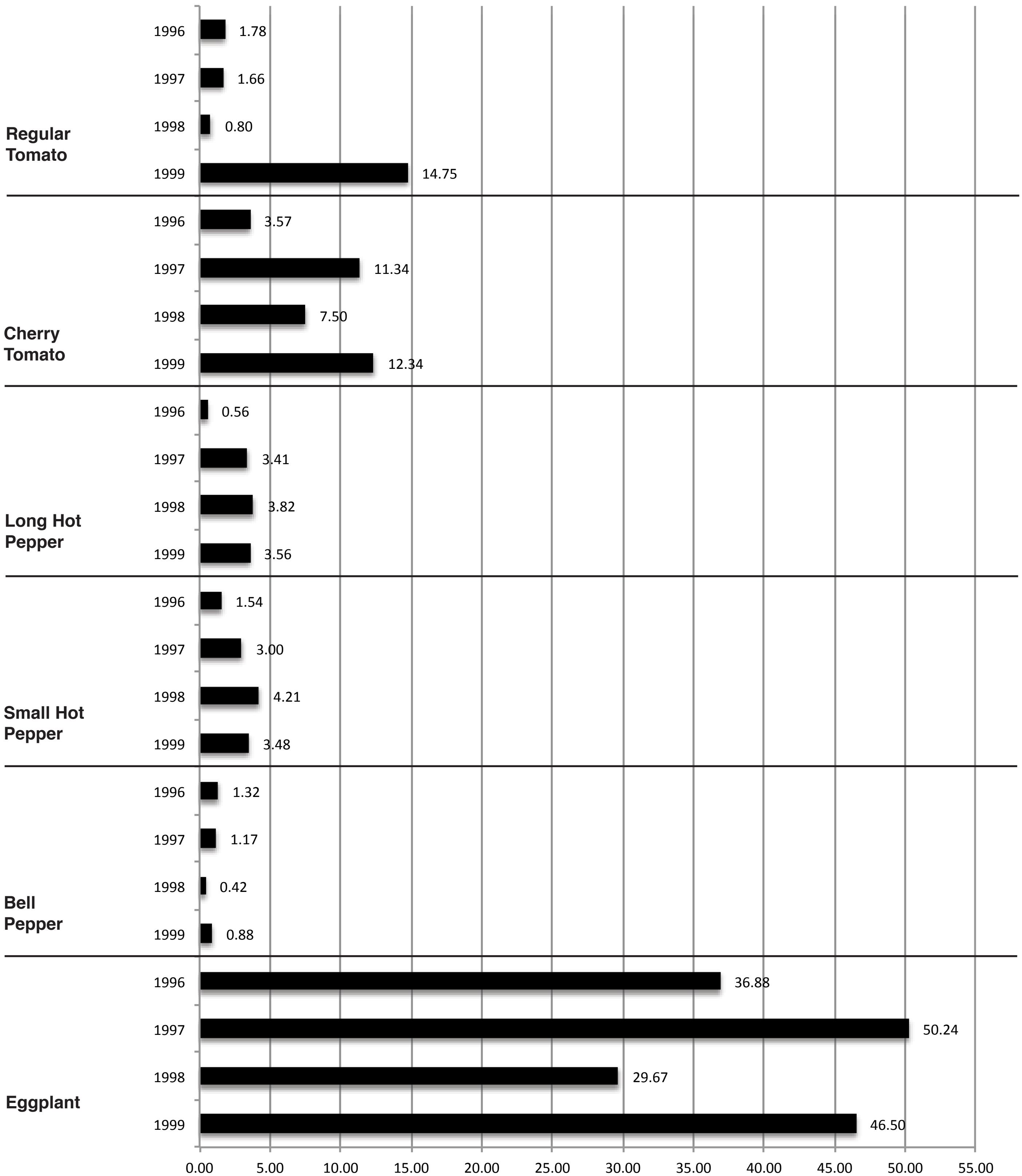
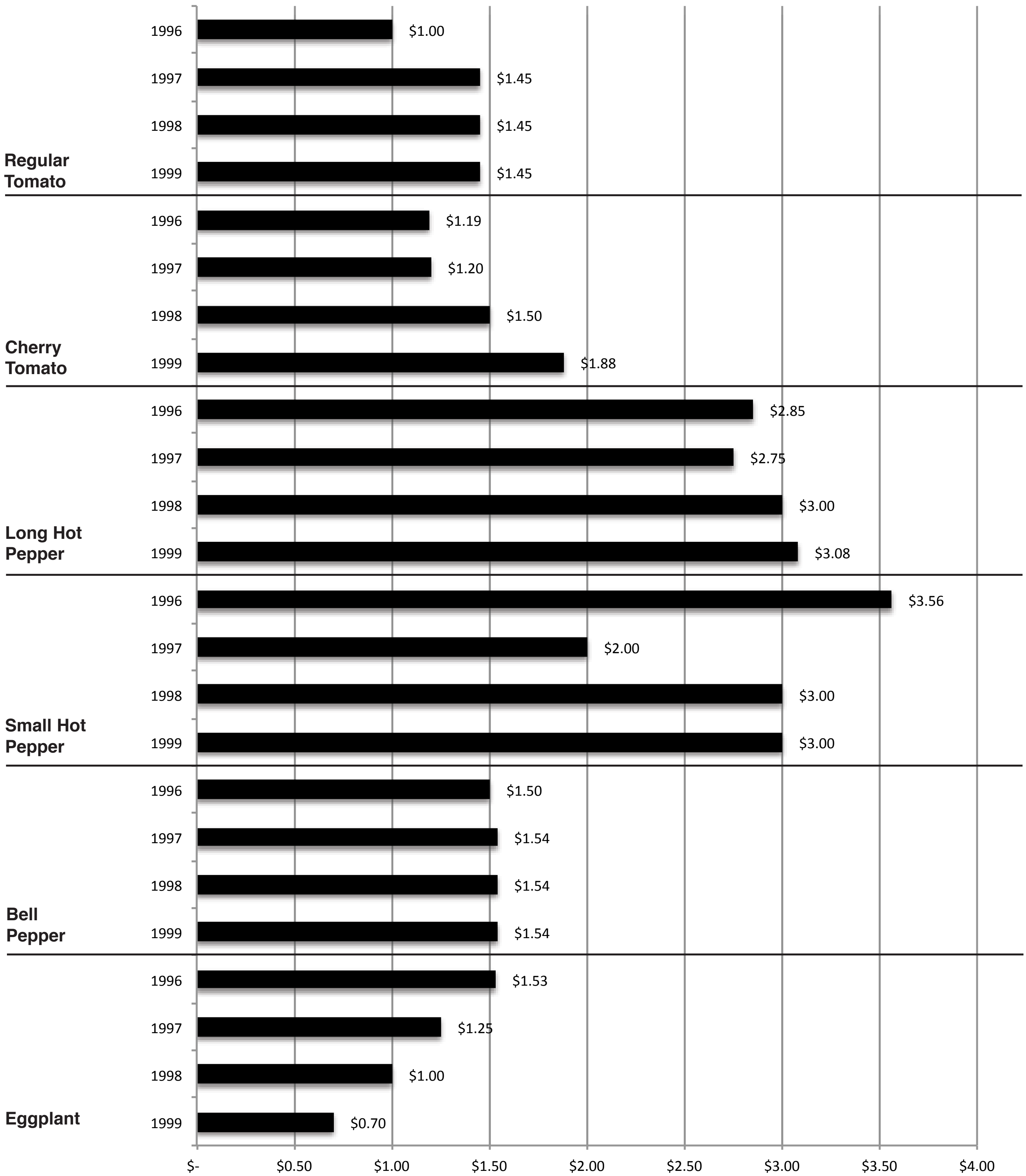


**Figure 9.3.** Average price per pound individual growers were receiving for eggplants, peppers, and tomatoes produced between 1996 – 1999.



# Chapter 10
# Financial Assistance to Guam's Farmers Provided By Guam's Agricultural Development Fund (ADF)

**Peter Barcinas, Extension Agricultural Economist**

This chapter summarizes past Guam agricultural census reports and describes the structure and support role of the Agricultural Development Fund (ADF). The ADF program is designed to help farmers and agriculture related ventures secure start-up financing at the attractive low interest rate of 4 percent. Such financing assistance provides increased options for farmers by allowing for production expansion and ancillary support and other related farm enterprises. Since the program's inception, many have benefited and have managed to operate a successful farm enterprise and owe their start to the program. The program's inherent feature of instilling good farm practices, evidenced by the adoption of basic farm plans and proper accounting of farm records is apparent in the final review because most of the loans processed are eventually certified.

In the real world of agriculture, many decisions have outcomes that take place long after the decision to commit time and resources to an agricultural enterprise was made. Outcomes range from favorable to worst-case scenarios harboring mixed feelings amongst farmers who elected to engage in an agricultural enterprise. Putting ideas to paper contributes towards minimizing risks while improving chances for reasonable success. Guam's ADF program provides farmers with the opportunity to adequately assess and understand the inherent risks found in Guam's agricultural sector and provides insight into the causes of marginal success or failure. This program provides funding to assist farmers in starting or expanding their agricultural enterprises. This unit profiles the ADF's effectiveness and contribution to Guam's agricultural sector.

### Guam's Agricultural Outlook

Guam is the largest and southernmost island in the Mariana archipelago with its limited land area of approximately 212 square miles or 54,908 hectares, or about 549 square kilometers[1] limits are placed on the level of agricultural pursuits that can be realistically sustained. A growing population, growing services industry, and the ongoing debate over land tenure issues contribute to the mix of external factors influencing the island's agricultural sector. According to the U.S. Department of Commerce, Census Bureau, Guam's population increased by 16.25 % or 21,653 up from the 1990 population figure of 133,152 to the latest count of 154,805.[2]

Guam's agriculture, once the economic mainstay prior to World War II, continues to give way to a service oriented island society. This contributes to an erosion of farm related employment stemming from the much sought after government and private sector jobs. Still, the reliance on subsistence farming as an informal source of cash persists and manages to succeed as farmers target niche markets. However, making the transition from subsistence level to commercial level production can at times be challenging without any formal technical support and farm business experience. The degree by which a farmer is successful hinges on how well the farmer adopts and integrates the right resources coupled with a basic understanding of management which includes farm business and specific skills in farm/business planning, accounting and marketing.

Despite the cash income issue, demand for locally grown produce and agricultural products remains high.[3] Institutional markets continually source their product needs to meet current servicing levels. Agricultural products not available on Guam are imported and continue to impact import substitution strategies intended to support the marketing of locally grown produce and value-added products. Erratic productions of locally grown produce and value-added products. Erratic production of local agricultural products and limited product offerings contribute to a basic logistics problem and adds to the difficulty of the local industry's ability to meet institutional demand.

## Agricultural Data Sources

Data are from the past Guam Agricultural Censuses conducted by the National Agricultural Statistical Service, United States Department of Agriculture and from information provided by the Guam Economic Development Authority and the Guam Department of Commerce. A cursory survey of past applications provides basic insights about the typical characteristics of farms ranging from established to start-up operations. All records are confidential in nature and contain proprietary information thus, limiting access to in-depth review. As a result of this effort, the gain for the certification process is the opportunity to identify areas of services that can provide key information and insights towards improving government services and program structures.

### Agriculture Census Profile

A review of agriculture census reports shows a dramatic decline in both production levels and acreage committed. The same report profiles total farms between 1940 and 1982.[4] Noted also is the corresponding drop in total area of land committed to farm operations as seen in **Table 10.1** with a marginal increases in latter periods. This perhaps can be attributed to the amended standard farm definition that was used during the 1998 Guam Agricultural census which considered a farm as any place where qualified agricultural operation occurred. In Guam, this included all places from which $1,000 or more of agricultural products were produced and sold, or normally would have been sold, during the 12-month period between July 1, 1997, and June 30, 1998. The 1993 farm definition minimum value of sales to qualify as a farm was $100.[5]

**Table 10.1.** Farms and farm acreage in Guam (1940–1997).

| Years | Number of farms | Total acres in farms |
|---|---:|---:|
| 1940 | 2,529 | 26,264 |
| 1950 | 2,262 | 10,025 |
| 1960 | 2,028 | 12,994 |
| 1970 | 1,999 | 11,582 |
| 1982 | 2,044 | 10,794 |
| 1987 | 351 | 13,134 |
| 1992 | 199 | 1,919 |
| 1997 | 201 | 2,144 |

## Market Value of Agricultural Products

The total market value of agricultural products sold was $4.3 million as compared to the previous census period of $2.6 million as shown in **Table 10.2**. This includes all vegetables, melons, fruits, nursery crops, livestock, poultry, poultry products, fish and aquaculture products. This is in contrast to the Department of Agriculture's estimated production statistics during the same period showing a dramatic decline in fruit and vegetable production. It should be noted that methodology for deriving production estimates by the Department of Agriculture may vary from that of the agricultural census criteria by active tracking of farms that may represent the bulk of consistent farms reporting farm activities.

**Table 10.2.** Market value of agricultural products.

| | 1992 | 1998 |
|---|---:|---:|
| Total sales | $2,655,980 | $4,302,396 |
| Average per farm | $13,347 | $21,405 |
| Number of farms | 199 | 201 |
| Source: 1998 Census of Agriculture Area Data | | |

Department of Agriculture statistics estimated production acreage declined by 292 acres from 486 in 1997 to 199's 194 acres.[7] The corresponding estimated yield in lbs for 1997 was 2.3 million pounds with a total dollar value of $2.3 million as compared to the significant decrease in 1998 of 1.4 million pounds and a dollar value of $1.5 million.

## Employment Profile

Current preliminary figures for March 2001 show a decline in total jobs to 60,100, with some increases in the agriculture sector from 290 to a steady 410 jobs in preceding quarters. This is in contrast to the total 290 persons out of a workforce of 64,230 in December 1998.[8] Average weekly earnings reported are $373.71 or an annual average salary of $17,938. This increase can be attributed in part to the implementation of the Chamorro Land Trust Act and ensuing agricultural land leases. This increase is also apparent in supporting employment statistics reported by the Department of Labor as well as the early retirement program with retirees opting for new ways to augment retirement income needs.

### Farm Production Expenses Profile

Typical farm production expenses are presented in **Table 10.3**. This table serves as a useful guide for farmers to appreciate the importance of developing cost estimates for their planned farm activities. It represents selected expenses and indicates the level of dependence the average farming industry experiences. The bulk of incurred expenses, $726,734, comes from hired farm labor. The second largest expense category comes from feed purchases for livestock poultry, and fish and is responsible for $526,990 worth of expenses. It is interesting to note that in the farm plans initially reviewed, references to production expenses were at best cursory, with one or two applications having complete production estimates. The need for closer review of these expenses is warranted in the application process and for proper inclusion in the farm plan.

**Table 10.3.** Selected agricultural production totals based on a pool of 70 farms.

| Item | Expenses (dollars) |
|---|---|
| Machine hire & custom work | $159,190 |
| Hired farm labor | $726,734 |
| Feed purchases | $526,990 |
| Insecticides, fungicides, herbicides | $133,236 |
| Fertilizers & manure purchased | $277,195 |
| Livestock, poultry, & fish purchased | $26,939 |
| Seed cost & seedlings | $177,012 |

* Totals for each item are derived from farm reporting expenses of at least $100 for that specific item.
Source: 1998 Census of Agriculture-Area Data

**Eggplant Example**
Yield = 8,000 lb/acre
Farm gate sales price = $1.50/lb

| Cost and Input | Cost per acre ($) | Cost per unit of output (lb)* |
|---|---|---|
| **Fixed Costs** | | |
| Vehicles | $50.00 | $0.01 |
| Machinery | $150.00 | $0.02 |
| Land Use | $500.00 | $0.06 |
| Other | | |
| Total Fixed Costs | $700.00 | $0.09 |
| **Variable Costs** | | |
| Car & truck expense | $200.00 | $0.03 |
| Chemicals | $250.00 | $0.03 |
| Custom hire (machine work) | | |
| Depreciation | | |
| Labor | $6,000.00 | $0.75 |
| Fertilizer | $450.00 | $0.06 |
| Gasoline, fuel, oil | $100.00 | $0.01 |
| Drip irrigation | $150.00 | $0.02 |
| Repair, maintenance | $100.00 | $0.01 |
| Seeds, plants | $100.00 | $0.01 |
| Utilities (water) | $200.00 | $0.03 |
| Other | | |
| **Total Variable Costs** | **$7,550.00** | **$0.95** |
| **Total Cost of Production** | **$8,250.00** | **$1.04**** |

* Based on cost calculator developed by CTAHR, Cooperative Extension Service. The calculator takes the cost per acre, divides by the units of output and rounds off the answer. Example: 50.00 ÷ 8,000 = 0.00625 or 0.01.
** The breakeven price in this example is $1.04.

### Agricultural Government Programs

On-going programs like agricultural land leases, government financing, and agricultural parks where infrastructure provide access to land areas are renewing interest in farm and agricultural related ventures. This, in part, can be attributed to the mandates of several government agencies that cater to the agricultural industry. The Guam Department of Agriculture is the lead agency overseeing a number of programs ranging from crop insurance, subsidized water rates, sale of seedlings, animal breeding services to plant protection and quarantine services. The University of Guam's (UOG) College of Agriculture and Life Sciences is an established and highly recognized source for technical and research services amongst the farming community. Through its two key units, the Agricultural Experiment Station and the Guam Cooperative Extension Service, it delivers science based and informational education to the island-wide farm community. Lastly, the Guam Economic Development Authority (GEDA) administers the Agricultural Development Fund (ADF) program through which agricultural loans may be disbursed to eligible farms. Mention of the federal programs for Guam agriculture is also warranted as they provide additional support services directly benefiting the farm community. Agencies such as the U.S. Soil Conservation Service and other affiliates like the U.S. Department of Agriculture play a key role for Guam and the region. All in all, such support networks and resources are literally at the beck and call of our farm community.

The supportive role that government plays in extending assistance to the agricultural sector is readily gauged by the level of services and programs established for the farm community and agriculture related businesses. Despite the many resources and programs available to farmers, caution is often emphasized in the case of the many government programs and research efforts initiated to address farm issues. The benefits of accessing the latest in research, methodologies, and technology harbor some misgivings about the adoption and use of the perceived "freebies" without realizing the full impact and commitment needed. Not having a clear understanding of the importance of business basics including the specifics of production and marketing systems add to the myriad of issues affecting a farm's overall ability to succeed. This is difficult to instill in the farmer the desire to incorporate safety regimes in food production systems, food safety, farm safety, and pesticide management.

### Agriculture Development Fund (ADF) Structure

The ADF program was established on August 23, 1967 by the enactment of Public Law 9-107. Bonafide farmers have ready access to low interest agricultural loans for the purpose of expanding commercial enterprises. This program specifically provides for collaboration with the Guam Department of Agriculture and the Guam Economic Development Authority (GEDA) to provide financing assistance to farmers. The overall fund administration lies with GEDA. Specifically, a fixed 4% per annum low interest loan will go towards financing start-up or expansion activities for qualified farmers and fishermen (terms ranging from five to twenty-five years.) Loan payments are amortized with 12 years being the maximum period allowed. For example, as indicated in **Table 10.4**, a $25,000 loan amortized over 10 years would require a monthly payment of $253.11. Loan processing fees also apply.

**Table 10.4.** Amortized $25,000 Loan

| **Inputs** | |
|---|---|
| Loan principal amount | $25,000 |
| Annual interest rate | 4% |
| Loan period in years | 10 |
| Base year of loan | 2002 |
| Base month of loan | 1 |
| **Key figures** | |
| Annual loan payments | $3,037.32 |
| Monthly payments | $253.11 |
| Interest in first calendar year | $962.22 |
| Interest over term of loan | $5,373.20 |
| Sum of all payments | $30,373.20 |

Additionally, Public Law 19-19 Section 12 further refined this process by creating the Agricultural Development Fund Loan Program. This, in part, expands the collaboration outside GEDA and allows the University of Guam's College of Agriculture and Life Sciences to provide technical and extension servicing in the development of locally produced agriculture products.

### Eligibility

Eligibility is limited to individuals, corporations and partnerships that engage in commercial agricultural related businesses to include aquaculture, horticulture, and closely related areas.

### Use of Loan Funds

The ADF loan program authorized use of funds includes the following specific categories listed in Table 10.5. The prohibited uses of the ADF Loan program include funds towards the purchase of real estate property for speculation or investment, to payoff delinquent credit obligations, or for any illegal activities.

**Table 10.5.** Authorized fund uses

| |
|---|
| • Acquisition of equipment and machinery |
| • Augment working capital |
| • Raw materials inventory |
| • Farm supplies |
| • Capital improvements |
| • Contract services to clear farm land |
| • Irrigation |
| • Infrastructure |
| Source: GEDA's ADF Program Brochure |

### ADF Review Process

For ADF loan eligibility, bona fide farmers must submit an application that is routed for review and comment by the Department of Agriculture and the Guam Cooperative Extension Service, University of Guam, College of Agriculture and Life Sciences. Specifically, the loan receives a cursory review by the Guam Cooperative Extension and involves a complete review upon final certification. Farm plans proposing a multi-crop production are reviewed for adherence to a Guam Planting Calendar[9], marketing plans and financial profiles of each of the proposed crop enterprise. This includes cash inflows and outflows (revenues and expenses). There have been several applications that have little to no farm record accounting for their production and sales activity. These applications require more time to prepare because of increased interview time and time spent in client advisement regarding record keeping and information submission.

For the most part, the bulk of ADF applications and the basic proposed plans reviewed have not adopted any formal farm planning system. This is apparent in the many ADF cases screened by the Guam Cooperative Extension for completeness. Additional time is needed to meet with clients to discuss the importance of his planning activity which will allow for timely review of management, accounting, marketing and farm operations. This certification process also ensures that the client is given the basic review and recommendations to help minimize farm risks and improved chances for operating a sound farm enterprise. The loan approval time frame varies oftentimes dependent on the amount and type of financing requested. The normal time frame can be within a 1- to 2-month time frame inclusive of the downtime to acquire additional information. Normally, the certification process provides a checklist review to ensure that all aspects of the ADF application are screened properly.

A cursory profile of the ADF Fund activity show the range of funding committed in support of this sector as shown in Table 10.6. A total of 26 loans valued at $766,786 were issued as of the second quarter 2001. Since the program's inception, the total funds dedicated to support applicants qualifying under the ADF program shows a healthy subsidy allocation to this industry of about $2.76 million.[10] Acquisition of farm machinery, equipment, production supplies and materials were the typical funded requests.

**Table 10.6.** ADF loan profiles

| Year | Loans issued | Range of loan amount | Total value |
|---|---|---|---|
| 1983 | 43 | N/A | $411,342 |
| 1985 | 8 | N/A | $267,340 |
| 1986 | 5 | N/A | $62,720 |
| 1989 | 1 | N/A | $26,000 |
| 1990 | 5 | $10,000–$70,000 | $131,000 |
| 1991 | 5 | $15,000–$300,000 | $549,182 |
| 1992 | 2 | $10,000–$14,377 | $24,377 |
| 1993 | 3 | $20,000–$402,000 | $522,000 |
| 2001 | 26 | $477–$402,000 | $766,786 |
| Source: GEDA | | | |

The Department of Agriculture requires farmers to secure a bona fide farmer certification. The certificate allows the farmer to obtain a government vendor number, to be exempt from the gross receipts tax, and also to qualify to procure farm materials and equipment from the Government of Guam's General Services Agency.

### Factors for Consideration of Whole-Farm Planning

Deciding what to grow or what alternative crops should be considered to diversify a farmer's operation can best be addressed through the development of a whole-farm plan. In the course of reviewing ADF applications and reviewing proposed farm plans, the most often cited comment about the process is the need to standardize the package of material and the relevant information necessary to complete the packet. The current standard involves the GEDA generated application form, which is tracked through a numbered application.

Understanding the business of production agriculture is foremost in this phase of developing a whole farm plan. The basics of cost analysis are the underlying assumptions for developing estimates of total production costs and total returns for each farm enterprise. As part of the business planning process, identifying potential alternative crops and the associated production problems is best put to paper before implementing any effort to determine their viability. Farmers should have a basic idea of the processes involved in analyzing total costs and the two types of basic costs: fixed costs and variable costs. This chapter, at the least, provides for a basic template of key information needed to properly assess a farm plan. Some of the basic factors for whole farm planning include two critical activities that most farmers oftentimes overlook but which should be a requirement for the ADF review. The first factor involves developing a summary list of all production activities, which include the type and volume of production to be carried out on the entire farm and the resources needed to do it. By scheduling production carefully, farmers can take advantage of market opportunities. For example, Guam's recent hosting of the 1999 South Pacific Games when local fruits and root crops were in high demand, particularly by athletes. **Table 10.7** shows a profile of several key variables that the farm plan should consider.

**Table 10.7.** Production considerations

- Seasonal factors
- Farm safety & pesticide management
- Environmental considerations
- Market linkages
- Infrastructure consideration

The second factor is the development of a financial plan, more specifically, adopting budgeting protocols tailored to the farm's operations. This requires developing enterprise budgets for each farm activity. **Tables 10.5** and **10.6** show the profiled uses and range of funding levels approved by GEDA.

The early adoption of a basic accounting system will generate good accounting information. Accurate costs and price information are essential in developing accurate records that will aid in developing accurate records that will aid in managing the day-to-day and long term decisions for local farms considering an ADF loan.

The budget identifies the level of financing needed to undertake the proposed venture. More specifically, the development of a whole-farm budget is required. This includes the estimates on income, expenses, and profit. The farm plan should also profile the necessary cash inflows and outflows of the entire operation for the first year on a monthly basis and the next five years as summary totals. **Table 10.8** profiles a typical cash flow budget that should be accompanied with each ADF farm loan application. This budget template can easily be tailored to meet the needs of the farmer. For more detailed budget information, refer to the Developing Budgets chapter in this guide.

Other considerations include liquidity, land, capital, and labor needs. A key supporting point required by most lenders is the exit or payback strategy for the proposed farm venture or enterprise. The application requires the client to submit personal financial statements and records of past tax returns as evidence of the client's track record and credit references.

**Table 10.8.** Sample cash flow budget for XYZ Guam farm.

| Name of Client: XYZ | Annual Estimate | 1st year Monthly Expenses | 2nd year Monthly Expenses | 3rd – 5th Years Yearly Expenses |
|---|---|---|---|---|
| **Cash Inflow Items** | | | | |
| Crop A | | | | |
| Crop B | | | | |
| Crop C | | | | |
| **Total Cash Inflow** | | | | |
| Cash outflow items | | | | |
| Fertilizers | | | | |
| Utilities | | | | |
| Farm supplies | | | | |
| Machine hire | | | | |
| **Total Farm Operating Expenses** | | | | |
| Other expenses | | | | |
| Family living expenses | | | | |

**Table 10.9** lists the activities involved in whole farm planning.  It profiles several categories needed to identify cost factors and returns for each part of the proposed farm enterprise.

**Table 10.9.** Whole farm planning schedule list

- Farm goals & objectives
- Inventory of available resources
- dentifying possible enterprises and estimated resource requirements
- Estimate gross income & variable costs
- Select combination of enterprises
- Preparation of whole-farm budget
- Market determination

### Summary

The goals of the Guam's agriculture sector, like the more sizable tourism sector, oftentimes cannot be attained without the support of government programs tailored to meet specific industry needs. The ADF program is a case in point that provides a win-win situation for farmers and government. Many of the specialized services are presented and offered with the best of intentions. They sometimes come up short when the farm enterprise fail to adopt whole farm planning as part of their farm strategies. Through the proper use of the ADF funding protocols, the farming community will be equipped with the right planning tools to properly answer important questions on what to produce by assessing business goals and production capabilities and by adoption of appropriate accounting systems and by development of a marketing plan. Organizing and improving market linkages and market information systems will require both industry and government efforts in order to improve a farmer's overall strategies for success. Through the government's economic incentive programs, farmers and related agricultural enterprises can compete and cater to marketplace needs.

Such programs are important in shaping this sector, and provides for a more coordinated review as well as identifying timely trends that may serve as constraints or opportunities. Assessing risk situations and developing contingency plans to minimize their impact ultimately becomes a driving factor commonplace in our island farming community. The ADF structure ensures that risks at all levels are minimized through careful planning using a variety of tools that for the most part are only slowly being incorporated by both new and well established farmers. Educating farmers about these standards will help ensure the harboring of the right values and stewardship of land and water resources while providing a source of income for the farm family.

## Acknowledgements

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[1] United States Department of Agriculture, Soil Conservation Service, Soil Survey of Territory of Guam, May 1988.

[2] United States Department of Commerce, Bureau of the Census, Comparisons of Population of Guam by Districts 1990 and 2000. Table 1.

[3] Guam Micronesian Chef Association Membership Meeting July 2000, Pacific Islands Club Hotel comments from the membership.

[4] United States Department of Agriculture, National Agricultural Statistical Service, 1998 Census of Agriculture Guam.

[5] United States Department of Agriculture, National Agricultural Statistical Service, 1998 Census of Agriculture Guam.

[6] United States Department of Agriculture, National Agricultural Statistical Service, 1998 Census of Agriculture Guam. Table 6.

[7] Quarterly Guam Economic Review, Economic Research Center, Guam Department of Commerce, Table 27, Agricultural Sector- Production of Fruits and Vegetables, January-March 2000.

[8] Current Labor Force Survey, Bureau of Labor Statistics, Guam Department of Labor, March 2001

[9] University of Guam, College of Agriculture and Life Sciences, Guam Cooperative Extension Service, Guam Planting Calendar, Circular No. 3, 2nd Revision.

[10] Guam Economic Development Authority, Government of Guam.

# Part 3. Plant Problems and IPM Solutions

# Chapter 11 Trouble Shooting Problems

**Robert L. Schlub, Extension Plant Pathologist**

The causes of poor plant health can be placed into four major groups. One is due to infectious agents such as viruses, bacteria, fungi, nematodes, and parasitic plants. These are commonly referred to as plant pathogens. Another cause is larger living organisms such as insects, mites, snails, and mammals; these will be referred to as animal pests. Weeds make up the third group. All other causes of plant health problems are placed in the group "unfavorable factors." Unfavorable factors cause the plant to produce symptoms are often referred to as non-infectious diseases; examples include soil nutrient deficiencies, and genetic mutations.

The easiest plant problem to diagnose are those where the causal agent itself (maggots, beetles, bugs, caterpillars, snails, mold or weeds) can be seen. If the agent is a pest, refer to **Chapter 13: Animals Pests** and **Chapter 14: Insects and Mites**. If weeds are crowding out your crop, refer to **Chapter 15: Weeds**.

When the causal agent is not readily apparent, diagnosis depends on the occurrence of symptoms, injury, or signs. Plants that are being harmed by plant pathogens or non-infectious agents produce symptoms; examples include yellowing, stunting, sporting, and wilting (dropping of leaves). Symptoms are the plant's response to disease causing agents. Symptoms take from a few days to several weeks to develop. Plant injury is immediate. Examples include animal feeding, storm damage, and fertilizer burn. Animal pests generally cause plant injury and leave signs. Signs are indications that something is present or was present. Signs left by insects include presence of frass (droppings), shed skins, or sticky wet excrements. Signs of plant pathogens include ooze from bacteria and structures of fungi or parasitic plants.

Common occurring symptoms produced by eggplants, peppers, and tomatoes and their associated causes can be found in **Table 11.1**. For other symptoms and causes not listed in Table 11.1, refer to the section on Nutrient Deficiencies and Symptoms in **Chapter 3: Production and IPM Pest Prevention** and the Diseases section in **Chapter 12: Plant Diseases**.

**Table 11.1.** The causes of symptoms, injury and signs associated with unhealthy eggplant, pepper, and tomato plants starting with the likeliest.

| FRUITS and FLOWERS | Likely Causes (see key) |
|---|---|
| Irregular areas of discoloration on fruit | C4, C6, D5, D13 |
| Spot on small fruit | A2, A9, A13, A8, A3 |
| Spots on marketable fruit | A2, C4, A9, A8, A1, A13, A6, A3, A8 |
| Cracks or surface blemishes | D15, D12, C9, C10, C8, D8, A3 |
| Rotten fruit | C4, C5, D11, A6, A2, A1, A8 |
| Flower end of fruit rotten | D11, A9 |
| Fruits, small or few | D5, C10, C2, D15, C8 |
| Fruits deformed or off color | C9, C10, D5, D15, C8, A14, A3 |
| Holes in fruit | C5, C3 |
| Large sections of fruit missing | C3, C5, C12, C14, C13, C15 |
| Off flavor | D6, D15, A3 |
| Dropping of flower and/or fruits | D6, D3, C10, D15 |

| SEEDLING | Likely Causes (see key) |
|---|---|
| Yellow coloration | D3, D9, D7 |
| Cotyledons or leaves with spots and/or specks | C3, A2, A5, A1, D16 |
| Tissue bitten away | C5, C14, C12 |
| Rotted at the soil line (damped-off) | A6, D9, D10, A9 |
| Wilted | D6, D9, A4, D10, D14 |
| Poor emergence | A6, D16, D9, D6, C12, C2 |

| PLANT/STEM | Likely Causes (see key) |
|---|---|
| Internal discoloration of stem | A4, A3 |
| Brown spots | A8, A1, A13, A5, A8, A2, A11 |
| Spots where bark is missing | C14, C5 |
| Hole in stem | C5 |
| Gnawed or rotted near soil surface | C2, C5, A6, C14, A12 |
| Stem broken | C5, C12, D14, A3 |
| Slightly stunted | D5, A10, D6, A14, C1, A1, C8, A3 |
| Severely stunted | A14 |
| Weak or shriveled | D6, A4, D4, C10, A3, A14 |
| Thin yellow intertwining vine | A7 |
| Excess adventitious roots | D9, A5, A4, A3 |
| Callus at stem base | D14 |
| Presence of white mold | A11, A6 |

| ROOTS | Likely Causes (see key) |
|---|---|
| Blackened and rotten | A6, D8, D10, A4 |
| Area of swelling | A10 |
| Poor development | A6, A1, A3 |

| SHOOTS/LEAVES | Likely Causes (see key) |
|---|---|
| Leaf yellowing | D3, D2, D7, D5, D1, C7, A14, A10, A12 |
| Irregular yellow areas | C7 |
| Young leaves yellowish with green veins | D1 |
| Older leaves yellowish with green veins | D2 |
| Slow growth with purplish veins first appears on older leaves | D4 |
| Silvery leaves | C10, C11 |
| Younger leaves small and dark or leaf tip burned | D8, D10 |
| Yellow to dark brown spots | A2, A9, A8, A13, A5, A1, A11 |
| Tiny white dots or specks on leaf surface | C7, A3 |
| Brown areas at leaf edge | D10, A3, D5, C7, A9 |
| Silvery trail | C14 |
| Holes surrounded by green tissue | C5, C3 |
| Tunnelling in the leaves | C5 |
| Tissue eaten from leaf edge | C5 |
| Paper thin patch | C5 |
| Sticky surface | C1, C8 |
| Distorted shoots or leaves | C1, C9, A14, C10, C8 |
| Curled | C1, C9, A14, A4 |
| Dropping of leaves | D4, A8, A5, A13, D5, D3,C8 |
| Die-back of shoots | C9, A13, A1, A3 |
| Wilted | A4, D6, D14, D9, A3 |
| Silk webbing | C5, C9, C8 |

| Key | | Color Plate | Figure | Table |
|---|---|---|---|---|
| **PLANT PATHOGENS** | | | | |
| A1 | **A** = anthracnose | 20, 38 | 12.3, 12.4 | 12.1<br>12.2<br>12.3<br>12.4<br>12.5 |
| A2 | **BS** = bacterial spot | 18 | 12.2 | |
| A3 | **BC** = bacterial canker | 28, 29, 30 | | |
| A4 | **BW** = bacterial wilt | 19 | | |
| A5 | **CLS** = Cercospera leaf spot | 21 | 12.5, 12.6 | |
| A6 | **D** = damping-off or **RR** = root rot | 22 | 12.8, 12.9, 12.10, 12.11 | |
| A7 | **Dd** = dodder | 44 | | |
| A8 | **EB** = early blight or **FR** = fruit rot | 20, 23, 25, 42 | 12.12 | |
| A9 | **PB** = Phomopsis blight | 24 | 12.13 | |
| A10 | **RK** = root knot | 40, 41 | 12.18 | |
| A11 | **SLS** = Septoria leaf spot | 25 | 12.14 | |
| A12 | **SB** = southern blight | 26 | 12.15, 12.16 | |
| A13 | **TLS** = target leaf spot | 27 | 12.17 | |
| A14 | **V** = viruses | 31, 32, 33, 34, 35, 36, 37, 39 | | |
| **ANIMAL PESTS** | | | | |
| C1 | Aphids | 2 | 14.1, 14.2, 14.3 | 14.1, 14.2, 14.3 |
| C2 | Ants | | 14.4 | |
| C3 | Beetles | 15, 16 | 14.17, 14.18 | 14.1, 14.2, 14.3 |
| C4 | Fruit piercing moth | | 14.11 | 14.2 |
| C5 | Caterpillars | 5, 6, 7, 8, 9 | 14.9, 14.10 | 14.1, 14.2, 14.3 |
| C6 | Leaf-footed bug | 11 | 14.13 | 14.2 |
| C7 | Leafhoppers or fleahoppers | 13, 14 | 14.16 | 14.1, 14.2, 14.3 |
| C8 | Mealybugs | 12 | 14.14, 14.15 | |
| C9 | Mites | 4 | 14.7, 14.8 | |
| C10 | Thrips | 3 | 14.5, 14.6 | |
| C11 | Whiteflies | 10 | 14.12 | |
| C12 | Chicken/bird | | | |
| C13 | Mice | | | |
| C14 | Snails and slugs | 17 | | |
| C15 | Wild pigs | | | |
| **UNFAVORABLE FACTORS** | | | | |
| D1 | Deficiency Fe—Iron | | | 3.10 |
| D2 | Deficiency Mg—Magnesium | | | |
| D3 | Deficiency N—Nitrogen | | | |
| D4 | Deficiency P—Phosphorous | | | |
| D5 | Deficiency K—Potassium | | | |
| D6 | Deficiency Water | | | 4.1 |
| D7 | Deficiency Light | | | |
| D8 | Excess N—Nitrogen | | | 3.10 |
| D9 | Excess Water | | | |
| D10 | Fertilizer burn | | | 3.10 |
| D11 | Blossom-end rot | 42 | | 12.1 |
| D12 | Growth cracks | 43 | | |
| D13 | Sunscald | | | |
| D14 | Wind | | | |
| D15 | Weather/time of year | | | |

# Chapter 12 Plant Diseases

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**George Wall, Research Plant Pathologist**

As mentioned in the Trouble Shooting Problems chapter, infectious and non-infectious agents are responsible for diseases. When a plant is exposed to one of these agents, it responses by producing symptoms. Symptom identification is an important tool in disease diagnosis and will be discussed in this chapter.

Infectious diseases are caused by plant pathogens. They obtain nutrition from a plant (host) and can spread to other plants. Viruses, bacteria, fungi, nematodes, and parasitic seed plants are plant pathogens. There are hundreds of diseases reported on eggplants, peppers, and tomatoes. Fortunately, only a few have been reported on Guam; and of those, fewer still are responsible for the majority of the losses **[Table 12.1]**.

Environmental factors, poor pollination, and problems arising from genetic causes are examples of non-infectious causes. A non-infectious agent does not spread from plant to plant nor does it obtain nutrition from a host plant.

**Table 12.1.** Occurrence of diseases reported on Guam

| **CAUSE** | **CROP** | | | |
|---|---|---|---|---|
| Disease Name | **Eggplant** | **Sweet Pepper*** | **Hot Pepper**** | **Tomato** |
| **Bacteria** | | | | |
| **BC** = Bacterial canker | N | N | N | C-1 |
| **BS** = Bacterial spot | N | C-1 | O-2 | C-1 |
| **BSR** = Bacterial stem rot | N | N | N | R-2 |
| **BW** = Bacterial wilt | O-1 | O-1 | R-2 | C-1 |
| **Fungi** | | | | |
| **A** = Anthracnose | | | | |
| on leaves | R-3 | O-3 | O-3 | R-3 |
| on fruits | O-3 | O-2 | C-1 | R-3 |
| **CLS** = Cercospora leaf spot | O-3 | O-2 | O-3 | R-3 |
| **D** = Damping-off | O-2 | O-2 | O-2 | O-2 |
| **EB** = Early blight | N | N | N | O-3 |
| **FR** = Fruit rot | O-1 | C-2 | O-1 | R-2 |
| **GLS** = Gray leaf spot | N | N | N | R-3 |
| **PB** = Phomopsis blight | C-1 | N | N | N |
| **RR** = Root rot | O-3 | O-2 | O-3 | O-2 |
| **SLS** = Septoria leaf spot | N | N | N | R-3 |
| **SB** = Southern blight | O-2 | O-2 | O-2 | O-2 |
| **TLS** = Target leaf spot | R-1 | N | N | O-2 |
| **Nematode** | | | | |
| **RK** = Root knot | C-2 | C-2 | C-2 | C-2 |
| **Viruses** | | | | |
| **V** = Viruses | N | O-2 | O-2 | O-1 |
| **Parasitic seed plant** | | | | |
| **Dd** = dodder | O-2 | O-3 | O-3 | O-2 |
| **Non-infectious agent** | | | | |
| Blossom-end rot | R-2 | O-2 | R-1 | O-1 |

**Occurrence of diseases reported on Guam.**
**C** Common
**O** Occassional
**R** Rare
**N** No report

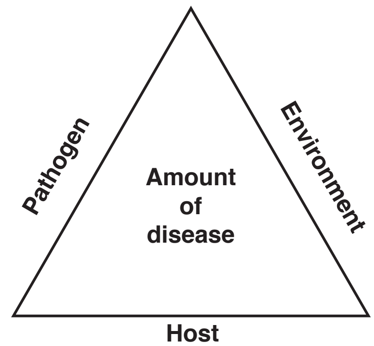
**Relative importance on specific solanaceous crops.**
**1** High
**2** Moderate
**3** Low

* Sweet pepper fruits are medium to large sized, shaped like a bell or banana, colored green, yellow, orange or red, mild or sweet flavored and often eaten raw.

** Hot pepper fruits are small to medium in size, pungent in flavor and used dried or as a chopped condiment.

### Disease Triangle

The Disease Triangle is often used to show the interaction of three components of an infectious disease: pathogen, environment, and host. An infectious disease is the result of a susceptible host coming in contact with a pathogen in a suitable environment. In an Integrated Pest Management (IPM) program, all three factors (host, pathogen, and environment) are considered. By avoiding particular crops (hosts), many diseases can be eliminated [**Table 12.1**, **12.2**]. Chemicals can be used to reduce the impact of pathogens and proper production practices reduces the influence of the environment. Since IPM incorporates all cultural practices, the risk to the environment from chemicals leaching into ground water and washing into streams is reduced.




**The three components which are responsible for the development of an infectious disease.**

**Table 12.2.** Eggplant, pepper, and tomato pathogens and their associated diseases and pathogenicity range for crops commonly grown on Guam. The actual number of hosts infected on Guam will be considerably less than what is reported as possible

| | Disease | Agricultural Host |
|---|---|---|
| **Bacteria** | | |
| *Clavibacter m. michiganensis* | **BC** | tomato, pepper |
| *Erwinia carotovora* | **BSR** | brocolli, cabbage, carrot, cauliflower, Chinese cabbage, crucifers, cucumber, eggplant, melon, onion, potato, summer squash, sweet pepper, taro, tomato, watermelon |
| *Ralstonia solanacearum* | **BW** | eggplant, peanut, pepper, potato, tomato |
| *Xanthomonas campestris* pv. *vesicatoria* | **BS** | beans, broccoli, cabbage, cassava, cauliflower, cucumber, soybean, sweet pepper, tomato |
| **Fungi** | | |
| *Alterneria solani* | **EB** | bok choy, broccoli cabbage, carrot, garlic, honeydew, leek, mustard, onion, pechay, pumpkin, squash, tomato |
| *Cercospora* spp. | **CLS** | most cultivated plants have their own host specific species |
| *Choanephora cucurbitarum* | **FR** | cucumber, eggplant, guava, papaya, pepper, pumpkin, melon, snap bean, soybean, summer squash, swamp cabbage (kang kong), sweet potato, tomato, watermelon |
| *Colletotrichum* spp. | **A, FR** | all cultivated plants should be considered susceptible. Some species are host specific and others have very wide host range |
| *Corynespora cassiicola* | **TLS** | banana, cucumber, guava, papaya, pepper, pumpkin, melon, snap bean, soybean, summer squash, swamp cabbage (kang kong), sweet potato, tomato, watermelon |
| *Diaporthe phaseolorum* | **FR** | bean, onion, peanut, pepper, soybean, swamp cabbage (kang kong), tomato |
| *Erysiphe cichoracearum*<br>*Oidium asteris-punicei Peck (anamorph)* | **PM** | bittermelon, bottle gourd, chayote, cucumber, eggplant, lettuce, sponge gourd, melon, okra, pepper, pumpkin, watermelon, mango, papaya |
| *Fulvia fulva* | **LM** | tomato |
| *Phoma destructiva* | **LB, PR, StB** | eggplant, pepper, tomato |
| *Phomopsis vexans* | **FR, PB** | eggpplant |
| *Phyllosticta* spp. | **LS** | most cultivated plants have their own specific species |

**Table 12.2.** Eggplant, pepper, and tomato pathogens and their associated diseases and pathogenicity range for crops commonly grown on Guam The actual number of hosts infected on Guam will be considerably less than what is reported as possible (continued).

| | Disease | Agricultural Host |
|---|---|---|
| *Phytophthora* spp. | **RR, DD, FR** | all cultivated plants should be considered susceptible |
| *Pythium* spp. | **RR, D** | |
| *Rhizoctonia* solani | **RR, D** | |
| *Sclerotium rolfsii* | **SB** | avocado, bean, bok choy, cashew, cabbage, carrot, chayote, corn, cucumber, eggplant, garlic, grape, grapefruit, leek, lettuce, melon, okra, onion, papaya, peanut, pechay, pepper, pumpkin, summer squash, swamp cabbage (kang kong), summer squash, sweet potato, Honolulu taro, red taro, tangerine, tomato, watermelon |
| *Septoria lycopersici* | **SLS** | tomato |
| *Stemphylium botryosum* | **FR, GLS** | bean, cabbage, carrot, onion, parsley, pechay, pepper, pumpkin, radish, squash, tomato |
| **Nematodes** | | |
| *Meloidogyne javanica* | **RK** | banana, bean, bittermelon, bok choy, cabbage, cantaloupe, carrot, cucumber, eggplant, garlic, lettuce, luffa, melon, okra, onion, pechay, pepper, pineapple, pumpkin, soybean, summer squash, sweet basil, sweet potato, tomato, watermelon |
| *Pratylenchus* spp. | **LN** | bamboo, bananas, corn, most grass spp., potato, sweet potato, tomato, yam |
| *Rotylenchulus reniformis* | **RN** | banana, bittermelon, broccoli, cantaloupe, carrot, califlower, Chinese cabbage, Chinese chives, corn, cowpea, cucumber, edible-podded pea, eggplant, garden bean, ginger, green onion, head lettuce, lima bean, marigold, mountain apple, okra, papaya, passion fruit, pea, pineapple, potato, radish, sweet pepper, tomato, tuberose, watermelon, wild bean, winter squash |
| **Viruses** | | |
| *Ageratum yellow vein virus* | **AYVV** | tomato, possible eggplant, pepper, cucurbits, and beans |
| *Cucumber mosaic virus* | **CMV** | bananas, broad bean, carrot, celery, cucumber, eggplant, gourd, ground cherry, lima bean, muskmelon, onion, pepper, potato, pumpkin, spinach, squash, sweet potato, tomato, watermelon |
| *Tomato bushy stunt virus* | **TBSV** | tomato, eggplant, pepper |
| *Tomato mosaic virus* | **ToMV** | eggplant, ground cherry, hot pepper, sweet pepper, tomato |
| *Tobacco mosaic virus* | **TMV** | cucumber, eggplant, ground cherry, muskmelon, pepper, spinach, squash, tomato |
| **Parasitic Seed Plants** | | |
| *Cuscuta* spp. | **Dd** | asparagus, carrot, eggplant, melons, onion, pepper, sweet potato, tomato |

**A** anthracnose
**BS** bacterial spot
**BSR** bacterial stem rot
**BW** bacterial wilt
**CLS** Cercospora leaf spot
**CMV** *Cucumber mosaic virus*
**D** damping-off
**Dd** dodder
**EB** early blight
**FR** fruit rot
**GLS** gray leaf spot
**LB** leaf blight
**LM** leaf mold
**LN** lesion nematode
**LS** leaf spot
**PB** Phomopsis blight
**PM** powdery mildew
**PR** Phoma rot
**RK** root knot
**RN** reniform nematode
**RR** root rot
**SB** southern blight
**SLS** Septoria leaf spot
**StB** stem blight
**TLS** target leaf spot
**TMV** *Tobacco mosaic virus*
***ToMV*** *Tomato mosaic virus*

**Table 12.3.** Timing and relative effectiveness of management recommendations to control or reduce the most commondiseases of eggplant, pepper, and tomato on Guam (**H** = High, **M** = Medium, **L** = Low)

| | A | BC | BS | BW | CLS | D | Dd | EB | FR | PB | RK | RR | SB | TLS | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Preplant** | | | | | | | | | | | | | | | |
| Crop selection | M | H | M | L | H | L | H | H | H | H | L | L | M | H | M |
| Seed treatment | M | M | M | L | L | M | L | L | L | M | L | M | L | L | L |
| Cultivar selection | L | H | M | M | M | L | L | M | M | M | M | M | L | M | M |
| Chemical control | L | L | L | L | L | M | H | L | L | L | M | M | M | L | L |
| Planting date | M | M | M | L | M | M | L | H | L | M | L | M | L | M | L |
| Site selection | L | H | L | H | L | M | M | L | L | H | M | H | H | L | L |
| Field preparation | L | M | M | M | L | M | H | L | M | L | L | M | M | L | L |
| Irrigation | M | L | M | L | M | M | L | M | M | M | L | M | M | M | L |
| **At Planting** | | | | | | | | | | | | | | | |
| Chemical control | L | M | M | L | L | M | M | L | L | M | L | M | M | L | L |
| Transplanting | L | M | M | M | M | H | L | L | L | M | L | M | L | L | M |
| Grafted seedlings | L | L | M | H | M | H | L | L | L | M | H | H | M | L | M |
| Scouting | L | M | M | M | L | H | H | L | M | L | L | H | L | L | M |
| Weed control | M | M | M | M | M | L | H | M | L | L | L | L | L | M | M |
| Row covers | L | L | L | L | L | L | M | L | L | L | L | L | L | L | H |
| Mulching | M | M | L | L | L | L | M | L | M | M | L | L | M | L | M |
| **During Season** | | | | | | | | | | | | | | | |
| Chemical control | H | M | M | L | H | L | H | H | M | H | L | L | M | H | L |
| Plant removal | L | L | L | M | L | M | H | L | L | L | L | L | M | L | M |
| Sanitation | M | H | M | M | M | M | H | M | M | M | M | M | M | M | M |
| Scouting | M | M | M | M | M | M | H | M | M | M | M | M | M | M | M |
| Trellising | M | M | M | L | M | L | L | M | M | M | L | L | M | M | L |
| **After Harvest** | | | | | | | | | | | | | | | |
| Residue management | L | M | L | M | L | M | M | L | M | M | M | M | M | L | L |
| Crop rotation | M | H | M | M | M | L | M | M | M | H | L | M | L | M | M |
| Cover crop | M | H | M | M | M | M | H | M | M | H | H | H | M | M | M |

**A** anthracnose
**BC** bacterial canker
**BS** bacterial spot
**BW** bacterial wilt
**CLS** Cercospora leaf spot
**D** damping-off
**Dd** dodder
**EB** early blight
**FR** fruit rot
**PB** Phomopsis blight
**RK** root knot
**RR** root rot
**SB** southern blight
**TLS** target leaf spot
**V** viruses

### Disease Control and IPM

An IPM approach to disease control starts before planting (preplant) when decisions regarding crop, cultivar, planting date, site selection, irrigation, and chemical treatment of seed and soil are made. At the time of seedling emergence, preventative chemical sprays can be initiated. The use of cultural practices such as transplanting, grafting, scouting, staking, weed control, row covers, and mulching begins at planting. Once symptoms appear, the objective of IPM is to reduce disease loss through the use of chemicals and/or by plant removal and sanitation. After harvest, practices such as crop rotation and residue management are used to reduce the likelihood of disease in the future. The effectiveness of the various IPM practices depends on the disease to be controlled **[Table 12.3]**. Therefore, it is important to be able to correctly identify the disease. To aid in disease identification, refer to the section on Disease Identification in this chapter and **Chapter 11: Trouble Shooting Problems**.

#### Crop Selection

Many diseases can be avoided and others reduced through selection of various crops [**Table 12.2**, **12.3**].

#### Cultivar Selection

You can reduce disease losses associated with a particular crop such as tomato by carefully selecting the cultivar. Many cultivars have been screened for their susceptibility to diseases by seed companies and research centers. Some cultivars are disease resistant, which prevents the plant from developing a particular disease. Also desirable are cultivars that have disease tolerance, meaning they may become diseased but do not suffer heavy yield losses. Though a cultivar may be given a resistant rating by a seed company, its performance on Guam may be different because of the existence of different strains or races of pathogens and differences between our environment and that of the seed companies' trial plots. Reported resistance to **RK** often fails at soil temperatures above 27° C. Refer to **Chapter 3: Production and IPM Pest Prevention**, **Appendix 2: Guam Variety Evaluation Trials**, **Appendix 3: Guam Farmer Survey**, current seed company catalogs, and university screening trial reports for further information.

#### Seed Treatment

**BC**, **BS**, **PB**, **A**, and **V** are diseases which can be found in or on seeds. Any seeds which are dark or shriveled should be suspect and discarded. Many seed companies treat seeds with fungicides and chlorine or acid based chemicals. Chlorine or acid based chemicals eliminate **BC**, **BS**, **PB**, and **A**, that may be present on the seed surface but does not affect viruses which are internal. Fungicide treatment provides some protection against **A**, **PB**, **D**, and **RR**. Hot water seed treatment can be used to eliminate both internal and external pathogens. If you suspect that your seed may be infected, soak your pepper or tomato seeds in hot water for 25 minutes at 122° F. Eggplant should be soaked for 30 minutes at 122° F prior to planting. Agitating pepper seeds in 1:4 Clorox® bleach solution for 40 minutes and then rinsing in clean water will reduce bacterial leaf spot.

#### Chemical Control

A variety of chemicals are used to reduce diseases. Preplant herbicides are used to control weed hosts and **Dd**. Insecticides are used to control insects which cause damage by eating crops, creating wounds for infection, and/or by spreading diseases (vectors). Nematicides are used to control nematodes, and fungicides are used to control fungal diseases. Chemically treated seed reduces the risk of early infection caused by seed-borne (**A** and **PB**) and soil-borne (**D** and **RR**) diseases. Fungicides are mainly used later in the growing season against foliar diseases (**CLS**, **EB**, **TLS**, **SLS**, and **PB**). Chemicals are less effective against bacterial diseases (**BC**, **BS**) and ineffective against viruses. Fungicides do not cure existing symptoms or eliminate pathogens. However, they do reduce pathogen levels, protect the host, and reduce losses. The first spray should be made before symptoms appear if a particular disease commonly occurs in the field. Otherwise, the first application should be applied immediately after the first symptoms appear.

An alternative to man-made chemicals for disease control are biological control agents. These live organisms can be used to destroy specific pathogens or keep them from causing damage. Biological control agents are slower acting than chemicals but protect longer. For information on chemical and biological control agent recommendations and safety, refer to the Guam Fruit & Vegetable Pesticide Guide supplement and contact your location Cooperative Extension Office.

### Planting Date

The majority of eggplants, peppers and tomatoes are planted near the end of the rainy season. This is to time flowering and fruit set during the drier months. Excess soil moisture increases root rot (**RR**) and fruit rot (**FR**, **PB** and **A**). Since water is necessary for most fungal spores to germinate, excessive rain increases susceptibilities of fruits, leaves, and flowers to infection. Splashing rain and runoff also aid in the spread of bacteria, fungi, nematodes, and **Dd**.

### Site Selection

When choosing a site, it is important to consider the crop to be planted, soil characteristics, and topography (the lay of the land). Eggplants, peppers, and tomatoes grow best under full sun and in well-drained soils which have a pH value in the range of 6 to 7. Poor drainage favors fruit and root rots. The land should have a gentle slope to aid in removal of surface water in areas where drainage is a problem. Areas of high wind or salt spray should be avoided and/or protected with a windbreak. Areas of high infestation of weeds and **Dd** should also be avoided. Weeds serve as a pest and disease source for planted crops. Whenever possible, practice crop rotation. New crops should not be situated next to areas where diseased crop plants are currently standing. These practices reduce the likelihood of soilborne diseases such as **BW**, **D**, **BC**, **RR**, and **SB** from developing. For more information, refer to the section on Site Selection in **Chapter 3: Production and IPM Prevention**.

### Field Preparation

Field preparation involves one or more tillage operations to make the soil suitable for seeding or transplanting. Tillage is a general term that refers to any operation that disrupts and/or moves the soil. The purpose of tilling is to reduce weeds and prepare the soil for planting. If the soil is deep, it should be tilled to 12 inches; if shallow, it should be tilled down into the subsoil. The plow layer provides the greatest soil volume for vigorous root growth. The extent to which a root systems develops is influenced, in many cases, by the soil profile. Under ideal conditions, peppers and eggplants will develop roots as deep as 36-48 inches and tomato roots will grow even deeper. Prior to transplanting, use a rotary tiller, bedding disk, or a double disc tiller in combination with a leveling board to till the soil.

Eggplants, peppers, and tomatoes may be planted or transplanted in furrows or on flat or raised beds. Planting in furrows conserves moisture from rains in the dry season and water from drip irrigation. However, if the soil is slopping, furrows can contribute to soil loss from erosion. Flat beds are easy to prepare and suitable for most situations. Where drainage is poor or when crops are in production during the height of the wet season, raised beds are recommended to reduce saturation of the soil. Bell peppers are grown on Guam on raised beds, they develop less **BW** and **BS**. Excess soil moisture contributes to soilborne diseases such as **A**, **D**, **RR** and **SB**.

### Irrigation

Drip is better than irrigation by sprinkling because it reduces the spread of foliar diseases (leaf diseases) such as **A**, **BC**, **BS**, **CLS**, **EB**, **PB**, **SLS**, and **TLS**. If overhead irrigation is used, water in the morning so the leaves can dry quickly. Excess moisture should be avoided, especially in clay soils and soils with a history of root and fruit rots. For more information, refer to **Chapter 4: Irrigation, Drainage, and Fertigation**.

### Transplanting

The use of transplants is beneficial because the plants are protected from exposure to diseases and the grower can easily inspect the seedling for any possible problems. Transplants should be kept away from actively growing fields to reduce infection by pathogens that may become airborne or insect vectored. Field damping-off can be eliminated using transplants grown from high-quality fungicide-treated seed planted in artificial soil. By using transplants, abnormal seedlings which may be the result of diseased or poor quality seeds can be discarded early. To reduce the spread of diseases (**BC**, **A**, **FR**) during the transplant process, it is recommended to clean hands, tools, and flats or trays when working with seedlings. All trays would be washed and soaked in dilute bleach before using for the next crop. For more information, refer to the section on Transplants in the **Chapter 3: Production and IPM Prevention**.

### Grafting Seedlings
Grafting is the process of making a plant more desirable by combining the roots of one plant with the stem and leaves of another **[Figure 12.1]**. Grafting can be utilized to maximize yield when plants are grown in plastic or glass houses or when land resources are limited. Grafting offers the grower the advantages of using transplants, with the additional advantages of a more vigorous root system which can guard against against **RR** and **BW**. Eggplants can be grafted to resistant root stocks of *Solanum torvum* or *S. integrifolium*.

A.

B.

**Figure 12.1. [A]** The rootstock and scion should be of equal size and thickness not less than $^1/_8$ inches. **[B]** The top of the rootstock is placed into a cut in the scion stem and wrapped. Two week later, the scion's roots should be wended from rootstock by gradually cutting through it over a ten day period. (Source: Kingham, H.G. 1973. The U.K. Tomato Manual, Grower Books, London pp. 114)

### Scouting
Once the seedlings emerge, they need to be inspected for diseases and insects (scouted). Plantings should be scouted regularly (at least weekly) in order to determine if new diseases have developed and to determine the effectiveness of present practices. Chemical sprays are only effective if applied early and for the disease for which they are intended.

### Staking, Trellising, and Caging
Staking, trellising, and caging allows for easy inspection and picking, promotes uniformity of color, improves chemical spray coverage, and reduces fruit lesions (**A**, **BC**, **BS**, **EB**, **PB**, and **SB**). It is also a good way to conserve land resources while increasing yield. Increasing air-movement by trellising decreases periods of leaf wetness resulting in less foliar diseases (**BC**, **BS**, **A**, **CLS**, **TLS**). Keeping leaves from touching the soil surface also reduces foliar diseases. There are extra costs associated with material and labor. Rotating eggplants and tomatoes with another trellising crop can reduce costs by maximizing the use of the trellis. Plant supports usually are only used on eggplants and indeterminate tomato varieties.

### Weed Control
Eliminating secondary hosts for eggplant, pepper, and tomato pathogens reduces the likelihood of disease by reducing the inoculum in the area. Plants that serve as secondary hosts include weeds and eggplant, pepper, and tomato that have been allowed to go to seed and grow wild. All weeds should be considered as possible secondary hosts for at least some of the many pathogens that have a wide host range **[Table 12.2]**. Many weeds, particularly broadleaf species, are hosts to the root knot nematode. Weeds of particular importance and associated diseases are as follows: *Amaranthus* spp. (spiny amaranthus), **SB**; *Carica* spp. (wild papaya) harbor **SB** and **TLS**; *Euphorbia* spp. (Spurge), **SB** and **TLS**; *Ipomoea* spp. (morning glory), **SB**, and **TLS**; *Solanum carolinenense* L. (horsenettle), **EB** and **SLS**; *Solanum nigrum* L. (black nightshade), **EB**; *Stachytarpheta* sp. (false verena), **BW**.

### Row Covers
Although row covers are not currently used in the production of eggplants, peppers, or tomatoes on Guam, they may be used in the future as insecticides are pulled from the market and where viruses are a problem. Row covers are fine mesh materials that are placed over the crop. The mesh is small enough to keep out aphids and whiteflies. These two groups of insects are responsible for the spread of **V**. When the mesh is laid on top of the plants without a support frame, it is referred to as a floating row cover. This works fine for non-trellis crops. While

the cover is in place, other insects such as thrips, beetles, leafminers, and caterpillars are also excluded. Covering also reduces wind damage. Covers can be used to protect seedlings from **V** and insects prior to transporting to the field. For use in pepper production, the row cover should be supported with wire braces that arch over the plant to prevent wind damage. Refer to **Chapter 14: Insects and Mites** for more information.

**The use of black plastic mulch in eggplant production.**

### Mulching

Mulching is the process of applying select materials around a crop. Each type of mulch has its particular function. Some function to conserve soil, fertilizer, and soil moisture. Mulches reduce the spread of **D**, **RR**, and **SB** because they reduce soil splashing and soil movement. **SB** may be increased with the use of plant material as mulch. Mulch can contribute to snail and slug problems by protecting them from the drying effects of the sun. Plastic mulch is an excellent barrier to weeds and many fruit rotting organisms such as **A** and **PB**. Reflective mulch reduces viruses because it reduces its main vector, the aphid. For tomatoes, red mulch has been shown to increase yield over black mulch. Clear polyethylene mulch is used in soil solarization. Solarization is a process by which pathogens and weeds in the top few inches of soil can be reduced through the heating of the soil by the sun. Solar heating is achieved by placing a sheet of clear polyethylene over moist soil during hot sunny weather. The sheet is left in place for 4 to 6 weeks then removed at the time of planting. Refer to the section on Mulching in **Chapter 15: Weeds** for more information.

### Plant Removal

Removing diseased plants from the field as they appear through the growing season is called roguing. Roguing is most effective when the pathogen is slow to spread, when only a few plants are diseased, and when symptoms develop early. It is not effective against latent diseases such as **FR**. Before entering a field to rogue, the crop's foliage should be dry to reduce the spread of bacterial or fungal pathogens. Roguing should be practiced as early in the season as possible to protect bordering plants from infection and to allow time for bordering plants to fill in the space once occupied by the pulled plant. It is recommended that virus infected plants be placed in a garbage bag for transporting outside the field to reduce the spread of virus carrying aphids that may be on the diseased plants. Plants entwined with **Dd** should also be placed in a garbage immediately to reduce the spread of seeds.

### Sanitation

Equipment and boots should be washed to remove all clinging soil and debris when leaving infested fields to avoid contamination of clean fields with **Dd** and soil borne pathogens (**BW**, **D**, **RK**, and **RR**). Clean fields should be worked before infested ones. To reduce spreading a disease, it is best to enter a field when the foliage is dry and where the plants are the healthiest. To reduce fruit rots in storage, mature fruits should be wiped free of any adhering soil at harvest and placed in soil-free picking crates. Rags and wash water should be changed frequently. The wash water should be chorinated at the 150 ppm rate (1 quart of bleach/100 gallons of water or 0.9 L of bleach/378.5 L of water). Care should be taken to avoid soil contamination in sorting and storage areas. Discard damged, off-colored and badly misshapened fruit during packing.

When you enter a field, the physical moment of the leaves and branches create small wounds. The likelihood that these wounds may get infected by pathogens (**A**, **BS**, **BW**, **CLS**, **PB**, and **TLS**) increases when the plants are wet from rain or dew; Avoid entering wet fields if at all possible. Knives used to prune suckers or cut fruit stems should be disinfected with 10% Clorox® solution, Lysol® spray, alcohol, or other similar liquid to reduce the spread of **BW**, **BC** and **V**.

### Residue Management

Old plants should be removed or incorporated into the soil as soon as possible following the last harvest. The spread of foliar pathogens from old fields to new ones is reduced when fields are tilled or plants are pulled up. Tillage also hastens decomposition which reduces the buildup of soilborne pathogens and some destructive insects.

### Crop Rotation

Crop rotation is the process of switching crops grown on a section of land. These crops should be selected for their disease resistant qualities. The seeds of pathogens (propagules) build up in the soil and on leaf surfaces when susceptible crops are continually planted in the same field. Eventually, disease can reach high enough levels to make it unprofitable to grow a particular crop. Crop rotation reduces the level of airborne diseases such as **A**, **CLS**, **EB**, and **TLS** within a single season of rotation. Corn is an excellent crop to grow to reduce **Dd** and **RK**. Soilborne pathogens which causes **BW**, **D**, **PB**, **RK**, **FR**, **RR**, and **SB** are slower to reduce and may require 2 to 4 years. Since rot and crown rot pathogens have a wide range of hosts, it is best to rotate out of eggplants, peppers, and tomatoes. Even cover crops (a crop grown to protect the soil) can be hosts to **RK** and **RR**. For these pathogens, a period of fallow where no plants are allowed to grow will aid in reducing the likelihood of disease. In the areas where soil erosion is a problem, an alternative management to fallow should be practiced.

### Cover Crop

A cover crop is a non-cash crop grown for the purpose of improving production of subsequent cash crops such as eggplant, pepper, and tomato. Soil that is not actively being farmed should be planted with a cover crop; otherwise, the soil will quickly be covered in weeds which harbor pests and disease organisms. It is also recommended to plant a cover crop between crop cycles to reduce soil erosion, to add organic material, and to improve the microbial health of the soil. A popular cover crop with Guam farmers is Sunn hemp (*Crotalaria juncea* L.). It will grow on all of Guam's varied soils. Well-drained deep soils with a pH of 5 to 7.5 are generally preferable. In addition to the aforementioned benefits of cover crops, Sunn hemp adds nitrogen to the soil, can be used as feed for some live stock, and reduces **RK**.

### Summary

1. **Choose carefully** your crop, variety, planting site, and planting date.
2. **Scout your field** for diseases, insect vectors, and weed hosts.
3. **Reduce plant pathogens** through sanitation, chemical sprays, rouging, proper entering and exiting of a field, and crop rotation.
4. **Stay current** on information by listening, reading, and asking questions.
5. **Get help** from a professional whenever in doubt about a causal agent or recommended treatment.

## Disease Identification

Many diseases can be easily identified once you know what to look for. However, some are more difficult to identify and only a plant pathologist will be able to identify them. This section is to designed to aid growers and agents in identification of common eggplant, pepper, and tomato diseases on Guam and to provide information on how they spread (epidemiology). This section is not intended as an authoritative presentation. To keep the complexity of fungal nomenclature simple, identification will be based on the most common occurring spore stage. To aid in disease diagnosis, features as seen with a hand-lens, through a stereomicroscope, and with a compound microscope will be discussed.

Identification is based primarily on symptoms and signs. A symptom is the visible response of a plant when subjected to a disease agent. A sign is the actual organism. Signs of fungi include the presence of spores (seeds of the fungus), fruiting bodies (a fungal structure containing spores), and mycelium (threadlike filaments of a fungus). The presence of fruiting bodies and spores are critical for positive identification. If diseased tissue is collected with no signs, then the tissue should be placed in a moist chamber to induce the formation of fungal structures. A simple moist chamber can be made by placing two sheets of moist paper towel in a clean plastic bag. The diseased plant tissue sample is placed between the two sheets of paper towel, and the bag is sealed and left at room temperature with ambient light for 24 to 72 hours. Signs of an infectious fungus form quickly, closely followed by the growth of non-infectious fungi (saprophytic fungi); therefore, tissue must be examined daily before the saprophytic fungi overgrow the sample.

## Bacterial Diseases

### BS = bacterial spot

Bacterial spot is very common on peppers and tomatoes. The warmer and wetter the climate, the more severe the disease. Crop losses result from defoliation and fruit spotting.

The bacterium causes brown, circular spots on leaves, stems, and fruit spurs. Spots rarely develop to more than 3 mm. Bacterial spots do not have circular zones which is common with **TLS** and **EB**. A blighting of the foliage occurs when there are many spots close together **[Plate 18]**.

Fruit spots begin as minute, slightly raised blisters on young fruits, occasionally accompanied with a halo. Over time, spots lose the halo, increases in size, and becomes brown, scab-like, and slightly raised. Spots may also be sunken in the middle and raised on the margins. Large numbers of spots occurring simultaneously will result in fruit rot. Fruit spots occurring on green tomatoes are not superficial and cannot be easily scraped off the surface with a fingernail; this distinguishes it from bacterial speck (*Pseudomonas syringae* pv. *tomato*), another disease of tomato.

**Microscopic examination:** Bacterial spot is caused by *Xanthomonas campestris* pv. *vesicatoria*. It is a motile, aerobic, gram-negative rod, measuring 0.7–1.0 x 2.0–2.4 µm. Bacteria are very small and not easily seen individually; however, they can be seen *en masse* (ooze). Bacterial ooze can be seen by cutting a leaf spot in half, placing a drop of water on the cut surface, covering with a cover slide and observing through a compound microscope at low power **[Figure 12.2]** or stereomicroscope. The amount of ooze from a single leaf spot is highly variable; therefore, several spots may need to be examined.

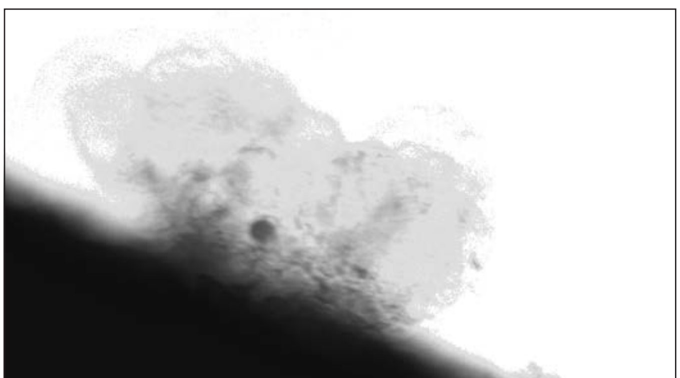


**Figure 12.2.** Bacterial ooze pouring from a lesion into surrounding water creating a clouding effect.

**Disease cycle:** The organism survives in crop residue, seeds, and for a limited period in soil. Disease development is favored by temperatures of 24–30° C and by rainy weather. The bacterium is spread by wind-driven rain and plant cutting tools. It gains entry through wounds created by wind-driven sand, insect punctures, or other means, and through stomates (natural occurring openings for air exchange existing mainly on leaves).

### BW = bacterial wilt

Over 200 plant species, including eggplants, peppers, and tomatoes in 33 plant families have been identified as susceptible to the bacterium, *Ralstonia solanacearum*, which causes bacterial wilt. The disease is also called southern bacterial wilt, solanaceous wilt, southern bacterial blight, and many other names.

Rapid wilting commonly occurs when transplants, are infected **[Plate 19A]**. Wilting of older plants is usually more gradual **[Plate 19D]**. Symptoms on older plants or when conditions are not suitable for disease development include stunting, downcurling of leaflets and petioles; and in tomato, formation of adventitious roots along the stem. The center of the stem (pith) is a light yellow during the early stage of infection and then turns dark brown as the disease progresses **[Plate 19B]**. Pith discoloration helps distinguish **BW** from wilts caused by fungi which discolors the tissue under the bark and not the center of the stem (pith). If an infected stem is cut crosswise, tiny drops of dirty white or yellowish bacterial ooze may appear. Roots of wilted plants may show brown rot.

Wilt caused by **BW** is easy to distinguish from that caused by **A**, **D**, **RR**, and **SB** by placing a section of stem tissue in water. If the plant has **BW**, white, milky streams of bacteria will flow from the cut surface in about 5 minute and cloud the water **[Plate 19C]**.

**Microscopic examination:** *Ralstonia solanacearum* is an aerobic, motile gram-negative rod, 0.5–0.7 x 1.5–2.0 µm. There are a number of different biotypes based determined by laboratory tests. There are also different races which are based on host range studies. Different races and strains have different optimum culture growth ranges 25–28, 27–

32, and 30–35° C. Tomato strains of the pathogen have minimum, optimum, and maximum temperatures of 10, 35–37, and 41° C, respectively.

**Disease cycle:** The disease may strike only a few plants in a field or cause a total loss. The **BW** organism mainly survives protected in tissue of crop plants and weed hosts but can survive outside plant tissue in the soil for months or even years depending on various soil factors. The bacteria enter the plant through wounds made by cultivators, soil insects, nematodes, and broken roots on transplants. They can also enter through weakened tissue such as in the root area where secondary roots emerge. Infection and disease development are favored by high temperatures (30–39°C) and high moisture. Symptoms develop in 2 to 8 days. Upon death and decay of a diseased plant, bacteria enter the soil. The bacteria are disseminated by running water, soil movement, pruning knives, or the movement of infected transplants.

Crop rotation with a nonsusceptible crop such as cucurbits (cucumbers, watermelon, squash, etc.) will help reduce the disease. Use artificial soil for transplant production and plant resistance varieties whenever possible. Tomato varieties, Dynamo and King Kong, showed resistance on Guam.

**BC = BACTERIAL CANKER**

The extent of damaged caused to Guam's tomato production is not known as its symptoms are similar too and hidden by other know pathogens on Guam. Wilt is the most conspicuous symptom of **BC**. Wilt caused by **BC** can be mistaken for **BW** **[Plate 19]**. However, bacterial streaming with BC is far less then with **BW** and the severity of the **BC** is generally less as well. Leaf symptoms caused by **BC** can be distinguished by those caused by other leaf pathogens on Guam because it produces a marginal necrotic lesion [**Plate 28]** where as **EB**, **TLS**, and **A**, commonly produce discrete spots throughout the leaf blade **[Plate 23, 27]** . **BC** may also infect fruits causing what is referred to as bird's-eye spot. The spot begin as whitish spots then turn brown with age mimicking those of BS **[Plate 18]**. **BC** may gain entry through a branch-tip damage by insects through harvesting and spread downward causing internal reddish brown necrotic tissue **[Plate 30]** where as **BW** originates in the roots **[Plate 19]**.

Microscopic examination: Bacterial canker is caused by gram positive, aerobic bacterium that is not motile. Colonies on nutrient agar are characteristically yellow and reach a diameter of 2-3 mm in 5 days at 25° C.

**Disease cycle:** Primary sources of the bacterium include seeds, plant debris, weeds, volunteer tomatoes, and soiled tomato containers. Secondary source of infection occurs by splashing water and contaminated equipment, which results in foliar symptoms, and or fruit spotting. Rainy season is optimal for secondary infections. Plant loss is generally due to primary inoculum sources, whereas loss of marketable fruits is due to secondary sources. Management should focus on purchasing clean seed, cleaning equipment and containers, eliminating solanaceous weeds, crop rotation, and dry season production.

## FUNGAL DISEASES

**A = ANTHRACNOSE**

Hundreds of species of *Colletotrichum* cause anthracnose on hundreds of species of plant. *C. coccodes* is the one most commonly reported on eggplants, peppers, and tomatoes.

Infection may occur on fruits, stems, cotyledons, leaves, and roots. Fruit infection is the more common and it is responsible for the majority of the loss **[Plates 20, 38]**. Fruit spots on tomato begin developing at the color break stage; they are small, scattered, depressed, and with age, gradually expand and appear water soaked. Eventually, these spots deepen, enlarge, and become dark in the middle and give rise to **FR**. On eggplant fruit, spots may be up to 0.5 inches in diameter, sunken, and during moist weather ooze pinkish spores. On hot peppers, fruit spots are small, indefinite, and slightly sunken before the fruits are mature.

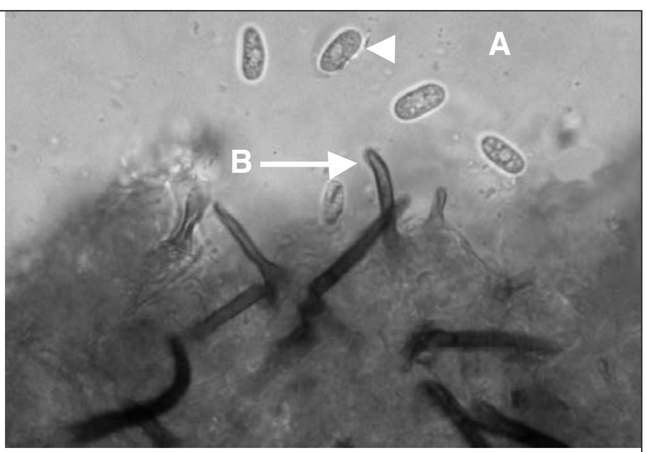
Leaf infection of tomato results in small, circular, brown lesions surrounded by a yellow halo. Initial symptoms on pepper leaves appear as very small, light brown surface spots which become sunken and gradually grow together. Shoot symptoms, most common on hot varieties, usually begin at the growing point of flower bud. The plant dies back as the infection spreads downward. Leaf infection is rarely a problem on eggplant.

Pepper plants may damp-off or develop shoot die-back. Small tan surface spots can develop on cotyledons shortly after emergence. On young green fruit, it causes a small, shiny, pale-brown spot a few millimeters in diameter. As the spot increases in size, the infected tissue becomes dry and brittle; the center of the spot may fall away and leave a hole in the fruit.

In general, pepper plants seem to acquire resistance to infection as they mature, since anthracnose caused by *C. coccodes* does not readily occur in mature pepper plants.

Infected roots of tomatoes and eggplants show browning of their outer layers and reduced and stunted secondary roots; plants can be easily pulled from the soil. Above ground symptoms include yellowing, stunting, and reduced yield.

**Microscopic examination:** The center of fruit spots infected by *C. coccodes* are usually off-colored, and as the lesion matures may become dotted with small 0.5 mm diameter black specks (microsclerotia) which often form in concentric rings **[Plate 38]**. These very small sclerotia generally form just beneath the infected tissue of fruit, stems, and roots. Associated with the microsclerotina are clumps of pink gelatinous masses of conidia (seeds of the fungus). Under the stereomicroscope, the microsclerotia and spore clumps (0.3 mm diameter) may be seen to contain small black bristles (setae), 65–112 µm long. Setae and microsclerotia are not always present in infected tissue. Conidia, as seen under a compound microscope, are cylindrical, one-celled, clear, sometimes slightly curved, with blunt ends, and 16–24 x 2.5–7.5 µm in size. A *Colletotrichum* spp. commonly found on cucumber on Guam is shown in **Figure 12.3**. *C. lindemutheanum* and *C. graminicola* are illustrated in **Figure 12.4**.




R.L. Schlub

**Figure 12.3.** Conidia **[A]** and seta **[B]** of a cucumber *Colletotrichum* spp. which causes anthracnose = **A**.

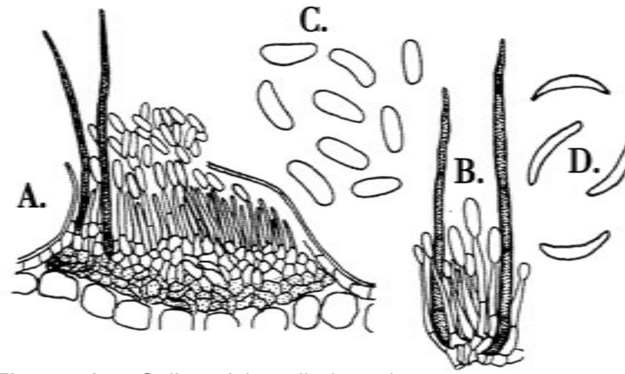



**Figure 12.4.** *Colletotrichum lindemutheanum*: **[A]** section of fruiting body; **[B]** conidiophores, conidia, and setae; **[C]** conida, **[D]** conidia of *C. graminicola*. (Barnett, H.L. and B.B. Hunter. 1998. Illustrated genera of Imperfect Fungi. Courtsey of APS).

**Disease Cycle:** The fungus survives between crop cycles in microsclerotia on seed, in plant debris, and in infected crops and weeds. Many common weeds and crop plants may be infected and contain microsclerotia without any symptoms. Spores and microsclerotia are splashed onto leaves and fruit by splashing water where they germinate and infect. The pathogen may infect green tissue and then remain inactive for a period of time. Splashing water and extended periods of leaf and fruit wetness encourage the spread and development of the disease. Wounds in tissue caused by other plant diseases, sandblasting, and insects may cause points of entry for the fungus.

The likelihood of diseases can be reduced by selecting cultivars resistant to **A**. Seeds should be disease-free and fungicide-treated and the production area should be kept free of weeds. Once disease is found, registered fungicides need to be applied.

### CLS = Cercospora leaf spot

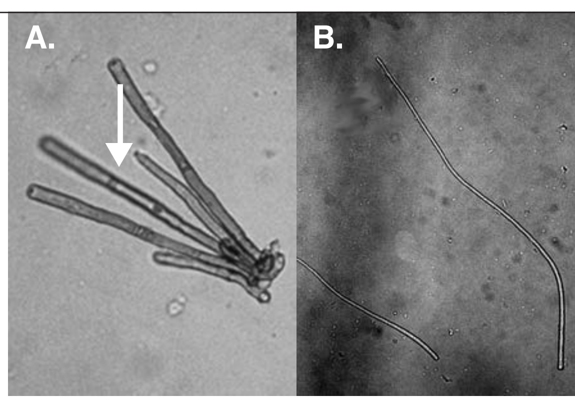
There are a number of different Cercospora species that may infect eggplant, pepper, and tomato leaves. Other common names besides Cercospora leaf spot include Cercospora leaf mold and frog-eye spot.

*C. capsici* , a pathogen of pepper, infects leaves and may infect the stem, fruit stem (peduncle), and leaf stock (petiole). The spots are circular or oblong often with gray centers and dark margins **[Plate 21A]**. When large spots dry, they may crack and portions of dead tissue may fall out.Heavy infection may cause leaf drop. Infection of the fruit stem often results in stunted and irregularly shaped fruit.

*C. melongenae* is the mosly widely distributed species that infect eggplant. The leaf spots are circular to irregular, usually large, and brown to grayish brown.

*Pseudocercospora fuligena* causes leaf spot of tomato. Young leaflets are infected first producing small spots with nondistinctive margins. As the size of the lesion increases, a faint halo develops around a center of brown dead tissue. The spots stops enlarging once the leaflet reaches a certain age.

**Microscopic examination:** On close examination of a leaf spot with a hand-lens, the fungus appears as hairy black clumps with white silvery threads. Under the stereomicroscope, they appear as small bundles of black sticks, many of which have attached silvery threads **[Plate 21B]**. The silvery threads may be nearly the length of a leaf hair. Under the compound scope, the conidiophores are medium brown, develop in clumps, are mostly straight, multicellular with conidia attachment scares often visible **[Figure 12.5A]**. *C. melongenae* produces conidiophore clumps of 3 to 12. *Pseudocercospora fuligena* conidiophores measure 3.5–5 x 25–70 µm and are in clumps of 2 to 7 or more. The conidia are indistinctly multicellular, clear, and long with a narrow pointed tip and a wider base **[Figure 12.5B]**. *P. fuligena* conidia measure 3.5–5 x 15–120 µm. Conidia are borne on the tips of the conidiophores and are pushed aside as the conidiophores continue their indeterminate growth **[Figure 12.6]**. This creates distinct attachment scars on the side of the conidiophores. Growth of long whiplash conidia are common when tissue is incubated in a moist chamber **[Figure 12.5B]**.




R.L. Schlub

**Figure 12.5. [A]** Clump of conidiophores with visible conidia attachment scars characteristic of the Cercospora leaf spot = **CLS** fungus identified on *Benincasa hispida*. **[B]** Conidia are long, whiplash in shape, and are indistinctly multicellular when non-stained.

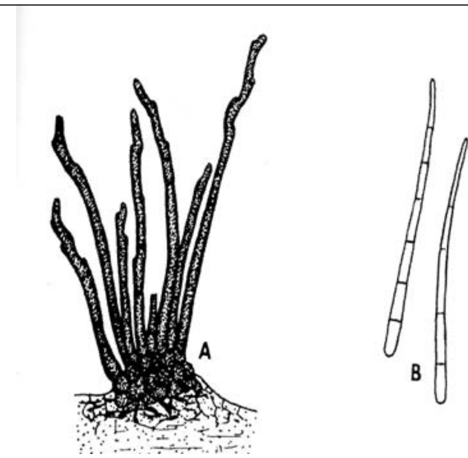



**Figure 12.6.** *Cercospora apii*: **[A]** cluster of conidiophores; **[B]** conidia (Barnett, H.L. B.B. Hunter. 1998. Illustrated genera of Imperfect Fungi. Courtesy of APS).

**Disease Cycle:** It survives mainly on crop debris. Spores are spread by wind, splashing rain, wind-driven rain, and workers. Infection requires free water and is favored by temperatures of 26–32° C. Infection occurs rapidly, but symptoms development is slow, 2 weeks in tomatoes. In peppers, first symptoms appear at about the time of blossom and spores are produced 7 to 10 days after infection.

**D = DAMPING-OFF**
**RR = ROOT ROT**

*Rhizoctonia*, various *Pythium* spp. and to a lesser extent *Phytophthora* spp., *Thielaviopsis basicola*, and *Fusarium* spp. may infect eggplants, peppers, and tomatoes causing seed rot, root rot, soil line stem rot, and damping-off. In addition, *Rhizoctonia* on tomato may cause stem cankers at pruning wounds and fruit rot. *Phytophthora* spp. and *Pythium* spp. are also capable of infecting fruit.

*Pythium* may attack ungerminated seeds and produce a soft mushy rot; however, a crop is at most risk after germination is completed and before the seedling has emerged. Damage at this stage is referred to as preemergence damping-off. At this time, a dark brown or black water-soaked rot quickly engulfs the seedling. After emergence, the young plant is highly suspectible for about 2 weeks. *Pythium* spp. infect through the roots causing a dark water-soaked rot which extends up the stem. Once the rot encircles the stem, the young plant falls over (damps-off). Under moist conditions, white cottony fungal growth may occur on the plant parts and adjacent soil **[Plate 22]**. *Thielaviopsis basicola* is more of a cool weather organism causing a black root rot of young feeder roots.

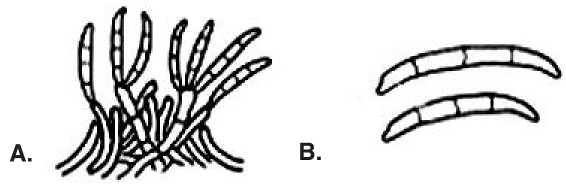



**Figure 12.7. [A]** Spores of Fusarium are produced by short conidiophores which arise from a mass of woven hypha. **[B]** Macroconidia of Fusarium are typically canoe-shaped, contain several cells and have a defined foot. (Streets, R. 1972. The Diagnosis of Plant Diseases: A Field and Laboratory Manual Emphasizing the Most Practical Methods for Rapid Identification. The Arizona Board of Regents. Reprinted by permission of the University of Arizona Press.)

### FR = FRUIT ROT

Fruit rot is a state of rapid decomposition and or putrefaction of a mature fruit in the field or storage. It is associated with fruit ripening, wet conditions, injury, and storage.

It is generally caused by weak or secondary pathogenic fungal or bacterial which only become established after injury or infection by other agents. Primary pathogens responsible for fruit rot include species of *Alternaria*, *Colletotrichum*, *Phoma*, and *Phomopsis*, in which case the pathogen infects immature fruits resulting in small lesions or no symptom production. The initial infection gives rise to fruit rot as the infected fruit matures.

Fruit rot of tomato caused by *Pythium* spp. occurs on mature green or ripe fruit that have come in contact with the soil. The fruit is quickly engulfed in a soft-rot. Cottony fungal growth may develop under high humidity. Soft rot of pepper begins as a small water-soaked spot at the bottom end of the fruit which quickly spreads throughout the fruit.

*Phytophthora* spp. are responsible for fruit rot of eggplants, peppers, and tomatoes. Buckeye rot most commonly occurs on tomato fruit that is in contact with the soil during periods of prolonged wet, warm (18–30° C) weather. Either green or ripe fruit may be infected causing a brownish spot. As the spot enlarges, its surface assumes a pattern of concentric rings of narrow dark brown and wide light brown bands; initially the fruit is firm. Fruit rot of eggplant may affect fruit at any stage of maturity and may start on any portion of the fruit. The fruit spots are dark brown, water soaked, and have a conspicuous light-colored border. A white mold, consisting mainly of fungus sporangia, is commonly present on the spots. The fungus extends deep into the flesh and results in a dark-brown discoloration.

**Microscopic examination:** Pythium, and Phytophthora mycelia generally have no cross walls, are transparent, and when young exhibit cytoplasmic streaming **[Figure 12.9]**. Phytophthora sporangia are usually terminal and single on long hyphae. They are lemon-like, ovoid, or ellipsoid in shape. The apex is differentiated by an internal thickening of the cell **[Figure 12.8]**. Sporangium of Pythium are generally not shaped like Phytophthora; they are generally spherical in shape but may take on a variety of other shapes often appearing as hyphal swellings **[Figure 12.10]**.

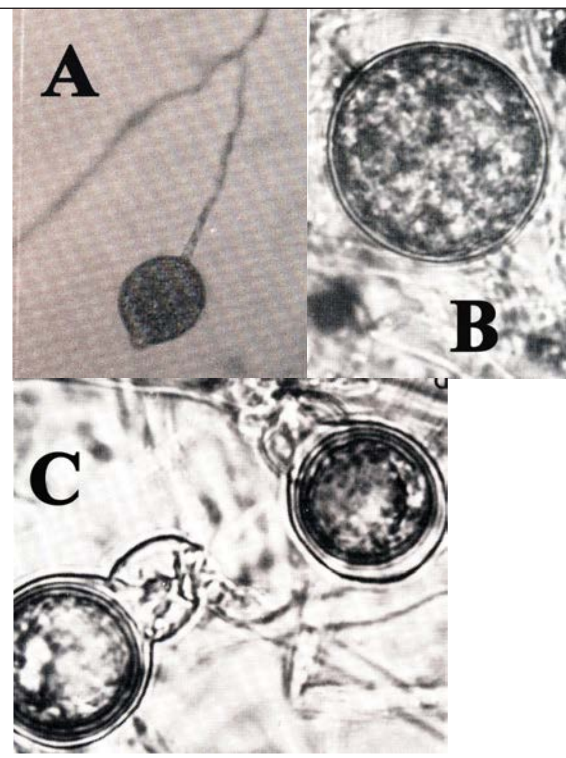
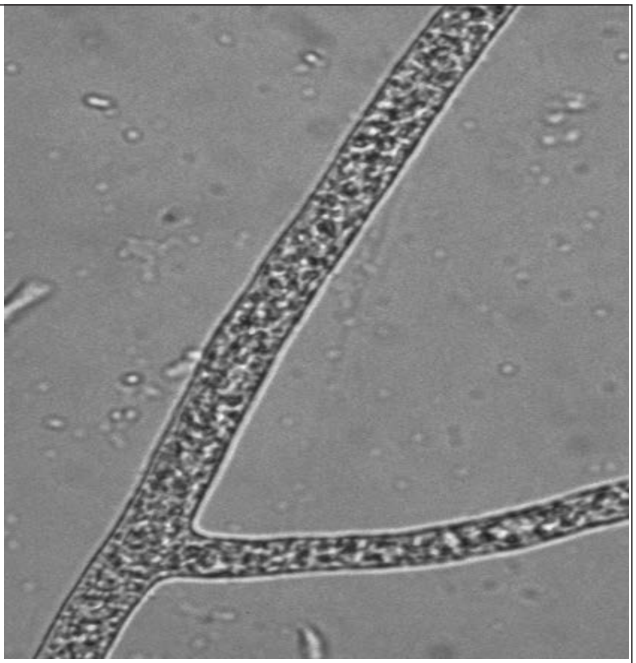



**Figure 12.8.** *Phytophthora nicotianae* var. *parasitica*: (A) sporangia; (B) chlamydospore; (C) oogonia, antheridia, and oospores. (Watanabe, T. 1994. Soil and Seed Fungi. CRC Press LLC)



R.L. Schlub

**Figure 12.9.** Hyphae of *Pythium* and *Phytophthora* are transparent and have no cross walls.

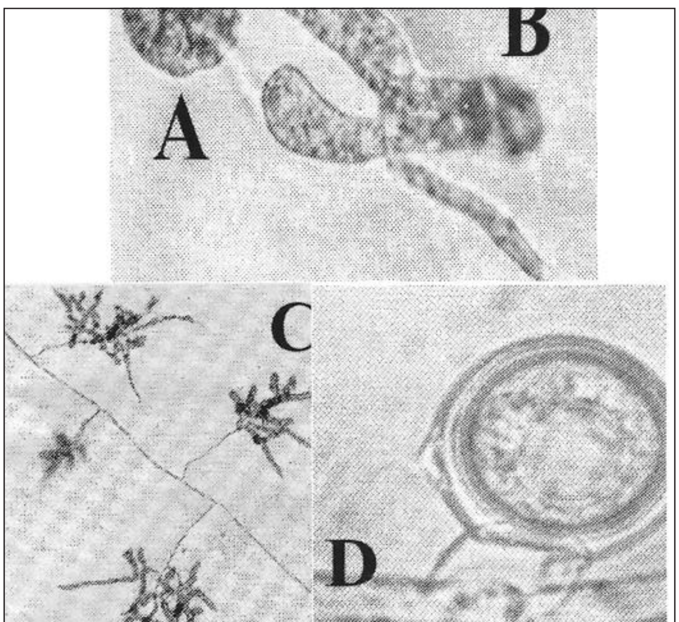



**Figure 12.10.** Sporangia of *Pythium aphanidermatum* may be **[A]** simple, **[B]** lobate, or **[C]** branched. **[D]** The oospores are spherical. (Watanabe, T. 1994. Soil and Seed Fungi. CRC Press LLC)

A quick test for Pythium is to place several pieces of diseased tissue on several cucumber slices in a moist chamber for 48 to 96 hours. If Pythium is present, pieces will yield cottony Pythium mycelium, quickly followed by the production of sporangia. Phytophthora growth on cucumber is much slower at 4–7 days. Phytophthora can be baited using apple. Cut a hole in an apple fruit (yellow apples are best), insert infected tissue, tape over hole, and incubate for 1 week in a moist chamber. Phytophthora causes a firm rot; soft rot is an indication of other fungi.

**Microscopic examination:** Under a hand-lens or stereomicroscope, only threads (mycelia) of *Rhizoctonia solani* are seen. An important characteristic is the darkening to near black of the mycelia with age and occasional appearance of small, superficial sclerotia (tightly packed mycelium). These small sclerotia (0.2–0.5 mm diameter) are white at first, turning brown to dark brown and rough with maturity. Under the compound microscope, mycelial strands are easily stainable, thick, exhibit right angle branching with cross walls forming near their constricted bases and are colorless but darken with age **[Figure 12.11]**. Mature hyphal cells are brown 5–12 µm wide, and up to 250 µm long.

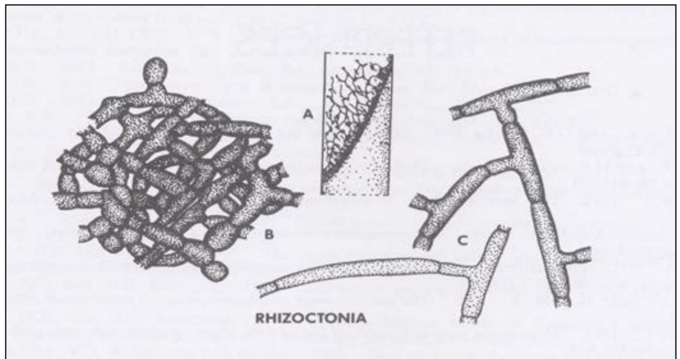



**Figure 12.11.** *Rhizoctonia solani*: original, from culture; **[A]** small sclerotia and mycelium in tube culture; **[B]** section of loose sclerotium; **[C]** cells of mycelium. Barnett, H.L. B.B. Hunter 1998. Illustrated genera of Imperfect Fungi. Courtesy of APS Press.)

**Disease cycle:** Rhizoctonia, Pythium, Phytophthora, Thielaviopsis, and Fusarium are all soilborne pathogens and as such are mainly spread by the movement of soil through runoff-water, tools, equipment, transplants, and workers. These pathogens mainly infect where plant tissue is in direct contact with the soil. Some of these fungi are always present in soil because many can grow indefinitely on old plant debris.

Conditions which favor damping-off development include: overcrowding, overwatering, poor ventilation, poor drainage, and cloudy damp weather. Rhizoctonia is usually most severe at moderate soil moisture. Conditions which favor fruit rot include rainy damp weather and contact with soil.

### EB = Early Blight

There are several species of the fungus Alternaria which may infection one or more solanaceous crops; however, none of them are considered major pathogens on Guam. *Alternaria solani* is the most commonly occurring species and is responsible for early blight. Early blight of tomato occurs on the foliage, stem, and fruit, and during all stages of plant growth; generally causing more damage as a foliar pathogen. When symptoms occur on eggplants and peppers, fruits and foliage are commonly infected. In eggplants, peppers, and tomatoes, the disease usually appears on the older foliage.

On tomato leaves, the first spots are brownish black spots surrounded by yellow tissue. As the spot enlarges concentric rings of dark tissue develop in the spots [**Plate 23A**, **25A**]. Severe infection in tomatoes may cause leaf drop; thereby exposing fruit to possible sun damage (sunscald).

Injury caused by blossom-end rot or sunscald predisposes the fruits to **EB** development. Velvety mass of black spores develop in the diseased areas. Fruits of eggplant are more susceptible as the fruit matures; affected skin is leathery with hard brown underlying tissue to a depth of 0.4 inches. Fruit infection of tomato can occur during the green or ripe stage and generally occurs where it is attached to the stem. Infected tomato fruit frequently drop.

Stem infections are small, dark, and slightly sunken. Concentric rings may form around the point of infection. Young infected seedling often die.

**Microscopic examination:** *Alternaria solani* is mainly a pathogen of tomato. The mycelium is branched with crosswalls. Conidia (12–20 x 120–296 µm) are beaked, multicellular, and form singly or in chains [**Plate 23B**, **23C**] **[Figure 12.12]**. *A. alternata* infects tomatoes and peppers, and *A. melongenae* and *A. tenuis* infect eggplants.

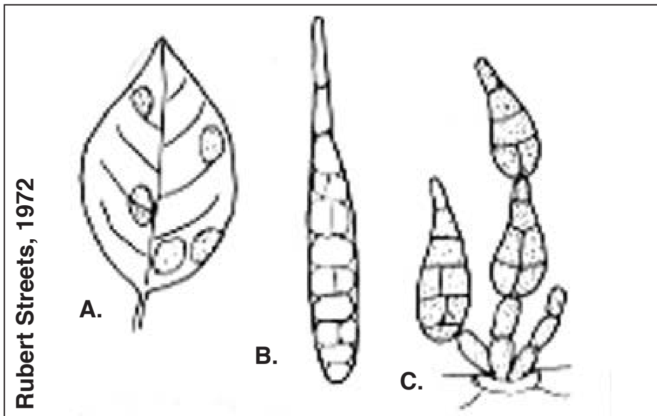



**Figure 12.12.** *Alternaria solani*, **[A]** the causes of early blight of potato and tomato, cause leaf spots. **[B]** Spores (conidia) are thick walled and multicellular. **[C]** Spores are often produced in short chains rising from short conidiophores. (Streets, R. 1972. The Diagnosis of Plant Diseases: A Field and Laboratory Manual Emphasizing the Most Practical methods for Rapid Identification. The Arizona Board of Regents. Reprinted by permission of the University of Arizona Press)

**Disease cycle:** *A. solani* survives between crops on infected plant debris on weeds such as horsenettle (*S. carolinense* L.) and black nightshade (*S. nigrum* L.) and on seed. The spores of the fungus (conidia) are spread by the wind. Spores germinate and infect the plant within 35 to 120 minutes depending on conditions. Heavy dew or frequent rains are necessary for abundant spore production. Plants are more susceptible with increases in age, fruit load, and nutrient stress.

### PB = Phomopsis Blight

Phomopsis blight is caused by the fungus *Phomopsis vexans*. It is a major disease of eggplant on Guam producing leaf, stem, and fruit symptoms. It is also capable of damping-off seedlings. Leaves are attacked at any time, generally starting with the lower ones. The leaf spots are clearly defined, gray to brown with light centers, generally less than 1 cm in diameter and may be numerous **[Plate 24A]**. When leaves are badly affected, they become torn, yellow, and withered. Old spots may contain numerous small black dots which are the pathogen's fruiting bodies. These tiny black pimples are best seen with a magnifying glass **[Plate 24C]**. Fruiting bodies may also be found on infected stems **[Plate 24B]** and fruits. The main stem and branches may develop dry, brown, cracked, brown and often sunken areas called cankers. A canker at the base of the stem may cause a constriction, which weakens the plant and results in increased susceptibility to windbreakage. The fungus usually infects at the calyx and then expands into the fruit. Fruits spots are easily identified as being an area of sunken, discolored, soft and spongy tissue with circular arrangement of fruiting bodies when present **[Plate 24D]**. During dry conditions, infected fruit shrivel and dry down to black mummies. Fruit rot may go undetected at packing and show up as postharvest rot.

Rotating out of eggplant for three years and tilling under the crop after harvest will reduce likelihood of disease. To insure healthy transplants, use disease-free seed of resistant or tolerant varieties and plant in new potting soil. During the season, check the crop often for symptoms and remove any infected fruits or severely infected plants immediately. If the crop is diseased, treat it with a recommended fungicide. Contact your local extension agent for the specifics on fungicide application.

**Microscopic examination:** The fungus is related to Phyllosticta, Phoma, Macrophoma, and Dendrophoma. They all produce pycnidia fruiting bodies, 100–200 x 110-220 µm in size, and pycnidiospores, 5–8 x 1.7–3.6 µm in size; however, Phomopsis also produces stylospores (beta conidia). The pycnidiospores are single-celled, elliptical, colorless and usually contain two or three visible oil droplets. Stylospores which are not always produced are colorless, thin, 1–1.7 µm wide, and generally curved with a length of 13–18 µm **[Figure 12.13]**. The sexual stage of the fungus belongs to the genus Diaporthe.

Rubert Streets, 1972

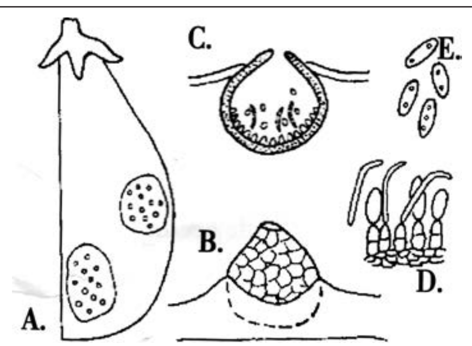



**Figure 12.13. [A]** The Phomopsis blight fungus, *Phomopsis vexans*, causes sunken spots on fruits. **[B]** Inside the spots are fruiting bodies of the fungus which erupt through the surface tissues. **[C]** Section of the fruiting body. **[D]** Two types of spores are produced. The presence of the bent spores is diagnostic for Phomopsis. **[E]** Often only the ovoid shaped spores are produced. Note the presence of oil drops. (Streets, R. 1972. The Diagnosis of Plant Diseases: A Field and Laboratory Manual Emphasizing the Most Practical methods for Rapid Identification. The Arizona Board of Regents. Reprinted by permission of the University of Arizona Press)

**Disease Cycle:** Phomopsis lives from one crop to another in infected plant debris, on seeds, and possibly as spores and mycelium in soil. The fungus remains alive for more than a year in fields where an infected crop had grown, but dies out by the third year. Hundreds of spores ooze from fruiting bodies during moist conditions. These spores are then carried by splashing rain, insects, and by man and farm equipment. If moisture is present, spores can germinate and infect a plant within 12 hours; symptoms occur 7 to 10 days later.

### SLS = Septoria leaf spot

Septoria leaf spot, caused by *Septoria lycopersici*, is one of the most destructive diseases of tomato foliage worldwide. However, on Guam, it is considered a minor pathogen. Leaf spots on tomato first appear as small, dark, water-soaked spots on older leaves. Spots may also appear on stems, petioles, and the calyx, but rarely on fruits. Leaf spots are circular, about 2.6 mm in diameter, with dark brown margins and tan to gray centers dotted with the fungus's fruit body **[Plate 25B]**. Spots on stem and petioles are elongated. The fungus spreads upwards into plants.

*Septoria lycopersici, S. solani*, and *S. melongenae* have been identified as pathogens of peppers and/or eggplants, but are considered minor pathogens.

**Microscopic examination:** The fungal pathogen, Septoria lycopersici, produces numerous black fruiting bodies in the center of mature spots. The fruits bodies contain clear multicelled (6–10 cells) thread-like spotes 67 x 32 µm **[Figure 12.14]**.

Rubert Streets, 1972

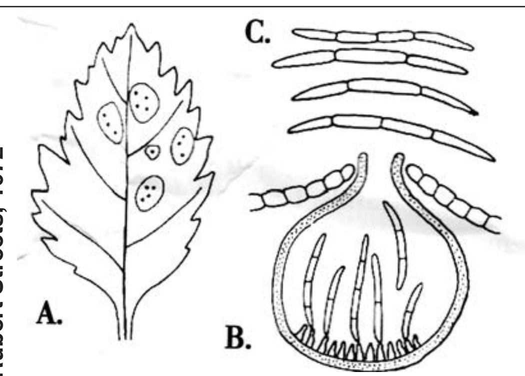



**Figure 12.14. [A]** *Septoria petroselina* var. *apii* causes leaf spot on celery. **[B]** Its fruiting body is flasked shaped. **[C]** Spores are thread like and multicellular. (Streets, R. 1972. The Diagnosis of Plant Diseases: A Field and Laboratory Manual Emphasizing the Most Practical methods for Rapid Identification. The Arizona Board of Regents. Reprinted by permission of the University of Arizona Press)

**Disease Cycle:** S. lycopersici survives between crops in plant debris, in soil on stakes and baskets. Spots are mainly spread by splashing water. Workers and equipment moving through wet foliage can also spread the fungus from plant to plant. S. lycopersici's optimum temperature for infection is between 20–25° C which may explain why we have very little occurrences of **SLS** on Guam. In addition to fungicide sprays, cultural control measures including rotation, rapid incorporation of crop refuse, and reducing contact between foliage and soil will aid in reducing the disease.

## SB = SOUTHERN BLIGHT

Southern blight occurs on hundreds of species of plants and is one of the most destructive diseases on Guam, affecting many ornamental and agricultural plants including eggplants, peppers, and tomatoes.

Symptoms usually appear on plant tissue that comes in contact with soil. Plants of any age may be attacked, but generally does not attack seedlings. The most striking symptoms are the yellowing and wilting of the leaves caused by the fungus attacking the lower stem. The infection causes a browning of the stem tissue which is often accompanied by white fungal growth. The older the plant at the time of infection, the slower the development of the disease. As the disease progresses, the plant may loss its leaves and fall over. The fungus grows up the plant's stem where it invades the underlying tissue and outward into the soil often resembling a fan **[Plate 26A]**. Nearby plants are often infected by adjacent diseased plants. After a week or two, small balls (1-2 mm) of fungus material (sclerotia) may develop at the site of the initial infection **[Plate 26B]**.

**Microscopic examination:** Southern blight is caused by a fungus which appears mainly as white mycelial strands. Under the compound scope, the mycelium appears coarse, has clamp connections (bridge-like swelling at cross walls) [**Figure 12.15A, 12.15B**], and consist of cells 2–9 x 150–250 µm. Sclerotia appear in 5–6 days in culture (27–30° C) **[Figure 12.16]**.

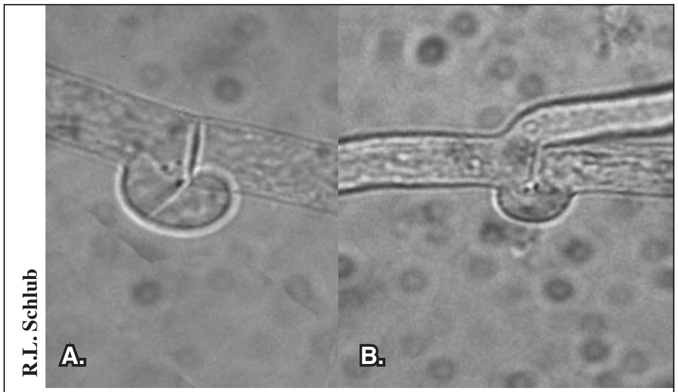



**Figure 12.15. [A]** Bridge-like hypal connection (clamp connection) character of the southern blight - **SB** fungus. **[B]** Hyphal branch arising from an area of a clamp connection.

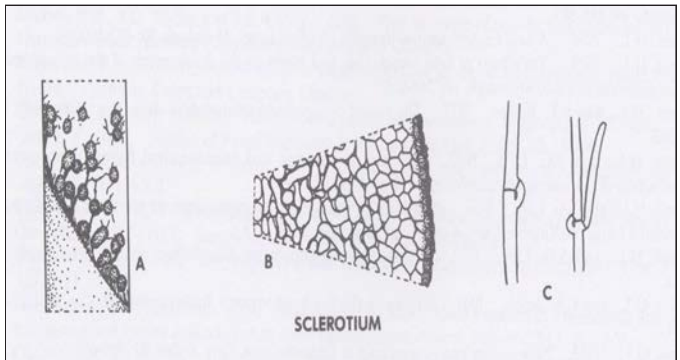



**Figure 12.16.** *Sclerotium rolfsii*: **[A]** sclerotia in tube culture; **[B]** portion of section of sclerotium; **[C]** portions of mycelium showing clamp connections. (Streets, R. 1972. The Diagnosis of Plant Diseases: A Field and Laboratory Manual Emphasizing the Most Practical methods for Rapid Identification. The Arizona Board of Regents. Reprinted by permission of the University of Arizona Press).

**Disease Cycle:** The fungus persists in the soil as resting bodies (sclerotia) which under warm wet conditions, give rise to strands of mold. Once the fungus starts to grow, it will grow on plant tissue, preferring dead or dying material. Epidemics usually follow heavy rain. Sclerotia produced on organic matter and dying plants serve as inocollum for the next crop. Sclerotia lose viability in soil but will persist in infected tissue for months. Cultivators and other farm equipment spread sclerotia and infected plant matter throughout a field. Spreading may also occur from infested transplant soil and runoff water. After each harvest, the crop should be tilled under to hasten its breakdown and a nonsusceptible cover crop planted. Chemical treatment of transplants is recommended if a southern blight disease outbreak is suspected. For the small grower, the use of physical barriers such as aluminum foil or plastic around the base of the plant may be a practical solution. Plastic mulch was found to reduce **SB** in bell peppers on Guam.

### TLS = TARGET LEAF SPOT

Target leaf spot, sometimes referred to as target spot or Corynespora blight, is a leaf, petiole, and stem disease of peppers and tomatoes. It is consider a major disease of tomatoes in some warm climates such as Florida and Caribbean countries. In Guam, outbreaks are generally restricted to the leaves resulting in a shortening of the harvest season.

On tomato leaves, the fungus causes small pinpoint spots that later develop sunken tan to light brown centers. Round spots may develop halos of yellow **[Plate 27A]**. Spots gradually increase in size, becoming circular and brown, and may eventually cause leaflets to collapse. Symptoms in the early stages look like bacterial spot. Petiole and stem lesions resemble those on the leaves. Lesion expansion may encircle the petiole and stem, accelerating the collapse of the leaflets.

Lesions of young tomato fruits are first seen as small, brown, sunken areas. As fruits mature, lesions become larger, darker, and deeply sunken, with fungal growth often evident at the lesion center.

**Microscopic examination:** On close examination of a leaf spot with a hand-lens, the fungus appears as thin, short hairs. It may be very thick under leaf folds and other protected areas. The color of the hair can range from tan to black. Under the stereo microscope, the long multicellular, transparent, thick-walled conidia shimmer on top of their darker conidiophores **[Plate 27B]**. Under the compound microscope, the conidia are large, appear multicellular with a prominent dark basal scar. The conidia vary in length (40–220 µm), in shape (straight to curved), and in shade (transparent to pale brown) **[Figure 12.17]**. Conidia form at the conidiophore's tips and are usually single but may form short chains. The conidiophores also vary, ranging from flexible to straight, pale to mid-brown, 110–850 µm in length with a thickness of 4–11 µm. They are smooth, multicellular, with multiple cylindrical proliferations at their tip.

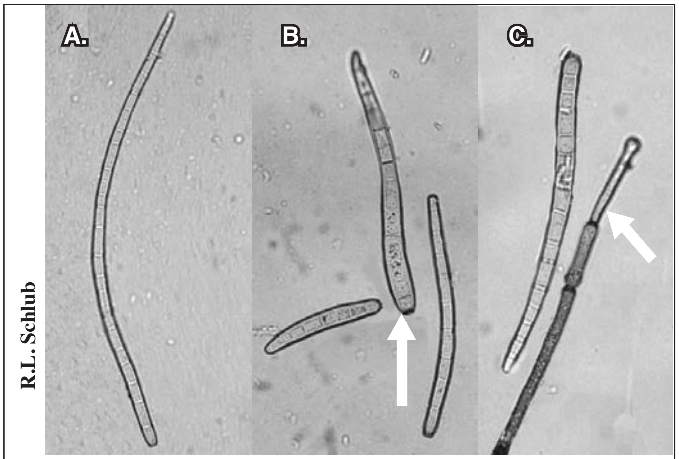



**Figure 12.17. [A] [B]** Conidia vary in length and shape, and are distinctly psueodseptate with dark basal scars. **[C]** Conidiophores of the fungus which cause TLS are multicellular with multiple cylindrical proliferations at their tips.

**Disease Cycle:** The pathogen survives between crop cycles on plant residue and various weed hosts. Spores (conidia) are produced under humid conditions and are airborne. Disease development is favored by temperatures ranging from 20–28° C and high moistures conditions for 16 to 44 hours.

## VIRAL DISEASES

### V = VIRUS

Plant viruses are very small infectious particles which exist inside the cells of diseased plants. Infected plants often have distorted leaves and fruit **[Plate 31, 32, 33, 34, 35, 36, 37]**. Viruses are spread from plant to plant in a number of ways by the use of contaminated tools and propagative materials; by infected seed; and by vectors. More than 100 viruses are transmitted by seeds. On Guam, virus-infected seeds are often a common source of disease outbreaks, especially for farmers who collect their own seeds. Seeds should be collected only from healthy plants or obtained from a reputable seed company. The most important virus vectors are the aphid leafhoppers, whiteflies, and thrips. Plants are usually inoculated with a virus by an insect vector which had recently fed on a diseased plant. The virus spread throughout the infected plant, and in about two weeks, young leaves start to develop symptoms. Worldwide, there are a number of viruses reported to cause diseases of eggplant, peppers, and tomatoes. Fortunately, few are known to occur on Guam. On Guam, virus symptoms in eggplant has not been reported. They are occasionally found in pepper and commonly occur in tomatoes grown in northern Guam and less so than those in the south. Recently, several viruses have been identified in Guam's tomatoes. Which specific one is responsible for yield losses on individuals farms is yet to be determined. Refer to **Chapter 4: Insect and Mites** for more information.

**CMV** (*Cucumber mosaic virus*) is present in tomatoes and likely occurs in peppers, and possibly in eggplant. It is known to occur worldwide in eggplant; however it is not known to cause any striking symptoms or yield loss. It is worldwide in distribution, is commonly seed-borne, and is vectored by the melon aphid, which is common in the region. Cucumber mosaic is a common disease on over 700 plant species worldwide. Aphids usually acquire **CMV** from infected weeds or crop plants. Once acquired, aphids may transmit the virus to healthy crop plants. Symptoms of the disease vary greatly with strain and host **[Plate 39]**. Disease symptoms on tomato usually include stunting of the plant giving it a bushy appearance and leaves with a mild, green mottling or severe shoestring growth **[Plate 31]**. Leaves may twist, fail to unfold, and curl up or down. **CMV** is one of the most destructive viral diseases of peppers worldwide. The age of the pepper plant at the time of infections strongly influences the type of symptom produced and the level of yield reduction suffered. With early infection, symptoms are more prominent and yield effects greater. With early infection, symptoms are more prominent and yield effects greater. Visible symptoms on peppers may include stunted growth, distorted and/or abnormally colored leaves **[Plate 39A]** and fruits **[Plate 39B]**.

**TMV** (*Tobacco mosaic virus*) and **ToMV** (*Tomato mosaic virus*) are discussed together because they are basically indistinguishable. The host range of both are wide including most of the solanaceous species including eggplants, peppers and tomatoes as will as other plant families. The host range of **TMV** is ever wider.They are unusually stable and persists in soil, in plant debris, and on the surface of seeds. **TMV** is very prevalent in many ornamental botanical gardens because of transmission from people who smoke and then handle plant material. Smokers should wash their hands with soap and water before coming into contact with eggplant, pepper, or tomato plants. Seed transmitted viruses are also likely to occur because most seeds are imported to Guam. They are known to be transmitted through tomato seed, occurring in the embryo and on the seed coat.

Infected plants are generally stunted with foliar symptoms ranging from mild mottling to severe leaf distortion **[Plate 32, 34]**. **ToMV** plants that are infected during an early stage of growth are usually stunted and have a yellow cast. Virus symptoms and nitrogen deficiency symptoms may look very similar, but with nitrogen deficiencies, yellowing occurs on the oldest leaves first. Depending on the virus strain, affected fruit may develop mottling, bronzing, yellow mosaic, brown streaks or rings **[Plate 32]**.

**AYVV** (*Ageratum yellow vein virus*) is a member of the *Geminiviruses* family, these are a large family of plant viruses with circular, single-stranded DNA genomes that replicate through double-stranded intermediates. One of the four genera in this family is the *Begomovirus*-group, of which **AYVV** is a member. *Begomovirus* is the largest of these genera and contains whitefly-transmitted *Geminiviruses* that infect dicotyledonous plants. It is likely **AYVV** arisen by recombination among viruses such as Papaya leaf curl.

Little is reported in the literature about **AYVV**; therefore, to understand the pathology of this virus, it is necessary to study a very similar *Begonomvirus*, *Tomato yellow leaf curl virus* (**TYLCV**). **TYLCV** infects mainly tomatoes and occurs worldwide. Infect plants are grow slowly, become stunted with shorted internodes. The earlier the infection, the more severe are the symptoms. Leaves can may show symptoms of interveinal chlorosis (yellowing). Fruit may develop but the yield and fruit quality is reduced. It is vectored by the whitefly Bemisia tabaci. Refer to **Chapter 4: Insects and Mites** for more information on whiteflies and aphids. Refer to **Table 12.4** for more information on viruses on Guam.

**Microscopic examination:** Viruses are too small to be seen with the ordinary microscope. They do not produce any fruiting bodies.

**General treatment to reduce virus diseases:**

1. Avoid planting in soil which once contained **TMV** or **ToMV** diseased eggplant, pepper, or tomato plants.
2. Avoid planting tomatoes and peppers next to cucurbit crops and other crops susceptible to **CMV**.
3. Spraying milk on the foliage can reduce mechanical transmission.
4. Workers should wash their hands with soap and water before handling containers or plants.
5. All pruning tools should be disinfected with 10% trisodium phosphate, 10% Clorox® solution or Lysol® spray.
6. Protect transplants from acquiring virus by growing them away from the field location or grow them under row-cover or very fine netting (0.5 mm).
7. Virus infected fields should be rotated out of tomatoes for at least 90 days with hosts that do not promote the buildup of white fly populations.
8. Kill or removed tomato plants once they are not longer productive and do not establish a new field next to an old infected field.
9. Grow cultivars which are reported to have resistance to **TMV**, **ToMV**, **TBSV**, **TYLCV**, and **CMV**.

## Nematode Diseases

**RK = root knot**

Root knot nematode is a microscopic roundworm which feed on plant roots and belongs to the *Meloidogyne* species. Damage is usually associated with patches of stunted, yellowish plants that are prone to midday wilting. Symptoms of infected plants include yellowing, reduced size and number of leaves, and poor fruit quality and yield. Infected plants often show symptoms of potassium deficiency. Symptoms are first seen on feeder roots where they cause a swelling within the root and not on the surface. Heavy infection may lead to plants with large, severe, malformed roots and few small feeder roots **[Plate 29B]**.

**Microscopic examination:** If a knot is slice in half, the light colored pear shaped females may be seen with a hand-lens. Under the compound microscope, the female appears dark (0.44–1.33 mm long x 0.33–0.7 mm wide) **[Plate 29A]**. Nematodes are best viewed under a stereomicroscope or a compound microscope's low power. The male is shaped like a typical worm (1.0–1.5 mm) **[Plate 29C]**. There are many harmless nematodes that may look like adult males or juvenile root-knot nematodes. To distinguish parasitic nematodes from the harmless ones, one needs to examine the head of the nematode and look for a stylet or spear. The hollow stylet is quite

**Table 12.4.** Summary of what is currently known regarding Guam's tomato virus, those highlighted are the ones most commonly detected.

| Date | Virus | | Test | Confirmed | Mechanical Transmission | Vector |
|---|---|---|---|---|---|---|
| 2006 | **ToMV** | *Tomato mosaic virus* | ELISA | 2016 | yes | none |
| 2006 | **CMV** | *Cucumber mosaic virus* | ELISA marginally positive | 2016 | yes | aphid |
| 2006 | **PVY** | *Potato virus Y* | ELISA | | yes | aphid |
| 2006 | **TMV** | *Tobacco mosaic virus* | ELISA | 2016 | yes | none |
| 2007 | **PLCV** | *Papaya leaf curl virus* | 89% match | | no | whitefly |
| 2007 | **MLCV** | *Malvastrum leaf curl virus* | 90% match | | no | whitefly |
| 2011 | **AYVV** | *Ageratum yellow vein virus* | 89% match | 2016 | no | whitefly |
| 2011 | **SCLV** | *Soybean crinkle leaf virus* | 89% match | | no | whitefly |
| 2016 | **TBSV** | *Tomato bushy stunt virus* | | 2016 | yes | none |
| 2016 | **PVX** | *Potato virus X* | elevated | 2016 | yes | none |

visible and is used by the nematode to puncture and extract the contents of plant cells **[Figure 12.18]**.

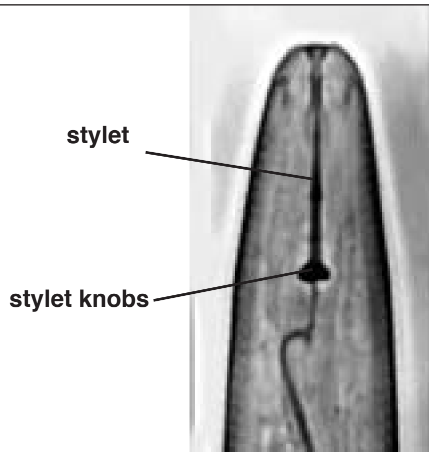



**Figure 12.18.** Close-up of the head of a parasitic nematode. Note the presence of a spear or stylet that distinguishes plant parasites from other nematodes.

**Disease Cycle:** In the absence of a crop or weed hosts, the nematodes survive as eggs and in pieces of infected root tissue. A single female deposits 500–1,000 eggs in a gelatinous matrix. They hatch and go through several juvenile stages. The life cycle is complete in 21–28 days. **RK** nematodes cannot move far on their own but can be spread easily through water runoff and soil clinging to farm equipment. Symptoms are usually most severe in drought-prone, well-drained light soils. Nematode damage may also increase damage caused by **BW** and **RR**. Nematodes are best controlled prior to the beginning of the season through the use of crop rotation, planting of resistant cover crops, and through variety selection **[Table 12.4]**. Weed hosts include nutsedge, morning-glory, pigweed, and Bermuda grass.

### Parasitic Seed Plant

**Dd = dodder**

Dodder is a common parasitic plant related to morning-glory. On Guam, there are two types, *Cassytha filiformis*, which is native to Guam and *Cuscuta campestris*, which was introduced to the island. *C. campestris* is the bigger pest on Guam. It is a thin, yellow, leafless, vine that intertwines with its host plant **[Plate 33]**. The vines have infection pegs (haustoria) that penetrate the leaves and stems of the host plant and feed off the host plant's sap. If left unchecked, the vines will form a dense mat and produce small white flowers which will give rise to thousands of extremely small hard seeds. These may survive in the soil for years. **Dd** is mainly spread when seeds infect hay, crop seed, water, farm machinery, and animals moving from one area to another.

Practicing crop rotation and using immune or resistant crops such as corn and soybean will prevent establishment. The advantage of crop rotation is lost if broadleaf weed hosts are not controlled. Cultivation or hand-pulling is effective, but only on the young seedlings that have not yet attached to a host. If **Dd** is observed soon after attachment, prune the infected portion to at least $^{1}/_{2}$ inch below attachment point. All seed bearing **Dd** should be placed in a plastic bag and removed from the field. For more information on **Dd**, refer to **Chapter 15: Weeds**.

### Non-infectious Diseases

Non-infectious diseases are diseases caused by non-infectious agents such as environmental factors, poor soil, poor pollination, and genetics. Refer to the chapter on Production for information regarding plant symptoms caused by nutrient deficiencies and excesses.

**Blossom-end rot** most often occurs on the blossom end of the fruit of eggplants, peppers, and tomatoes. It generally occurs on the first fruit clusters and generally when the fruit is about a third developed. Blossom-end rot is more likely to develop when there are fluctuations in water supply such as those resulting from long periods of hot, dry weather followed by heavy showers. Initially, light brown patches appear at the blossom end of the fruit. These patches enlarge, darken and extend into the fruit **[Plate 31]**.

Blossom-end rot is caused by a localized area of calcium deficiency within a developing fruit. Lush plant growth can aggravate the disorder because calcium from the soil is diverted to the leaves at the expense of the fruits. Calcium, unlike some other nutrients such as nitrogen, cannot be pulled from old leaves and transported to young fruit tissue.

The best way to prevent blossom-end rot is to provide the plant with adequate water, nutrients, and a healthy root system to insure a steady rate of growth and water uptake. Water conserving mulches may help to prevent blossom-end rot. Care should be taken to avoid excess nitrogen and cultivating too deeply near plants after fruit set and in dry weather. If blossom-end rot is a persistent problem then apply weekly foliar application of calcium nitrate at 10 lb / 100 gallons or calcium chloride at 5 lbs/100 gallons should be applied.

**Sunscald** is caused by direct sunlight or high temperatures (40° C) on young tissue. Symptoms are primarily noticed on fruit. Tender transplants can be sunscalded and may turn a light gray to brown. Overexposed areas on fruits and stems turn whitish.

On pepper fruit, irregular, light-colored, areas may appear anywhere sunlight is in excess. Affected areas become sunken or wrinkled and creamy white as fruit ages. In dry weather, the area may dry up and become paper thin. The smaller-podded varieties with erect fruits are not as susceptible as the large fruit varieties such as the bells. Mature green fruits are more sensitive than mature red fruits. Damage is generally on the top half of the tomato and occurs when fruits suddenly become exposed to full sunlight. The affected area remains white or back if invaded by secondary fungi while the rest of the fruit turns red. Mature green and breaker tomatoes are most susceptible.

To control sunscald, you must maintain adequate foliage by controlling leaf pests and diseases and by providing proper amounts of nutrients and water. If you prune, be careful you do not cut out needed foliage.

**Stem callus** may form as the result of wind whipping. When plants are grown in hard, rocky or crusted soil, callus tissue may form at the soil line as the result of wind whipping the plant back and forth. A callus is more brittle than the rest of the stem, and wind whipping will eventually cause the stem to snap on old plants. Winds screens or staking will reduce the damage. If the wind whipping is severe enough, the surface stem tissue can be worn away faster than callus tissue can form; thereby, resulting in the death of a young plant. Hilling soil around the crown of tomatoes stimulate adventitious roots which reduce wind whipping. Hilling peppers or eggplants is not recommended because it contributes to crown rot and lower yields.

**Water wilt** results when soils are saturated after excessive rain (waterlogged). The effect is more pronounced and more rapid under high temperatures. Tomatoes are sensitive to waterlogging, especially shortly after germination and at the time of fruit maturity. Tomato wilting begins at the growing tip and looks similar to **BW**. However, discoloration of the vascular stem, a symptoms of **BW**, does not occur with water wilt. If the condition persists, yellowing of the leaves and collapse of the stem will occur. Adventitious roots may form at the base of tomatoes. Waterlogged pepper plants tend to lose their leaves. Providing good drainage will prevent the problem. If the condition does occur, cultivate the effected field area as soon as possible.

**Growth cracks** occur on tomatoes, are highly varietal dependent. They increase in severity with maturity **[Plate 32]**. Cracking may start appearing at the mature green stage in susceptible cultivars or not until red ripe in tolerant ones. In resistant varieties, cracking rarely occurs. Fluctuations in rain and temperature and over fertilization induce cracking. Tomatoes grown on soils with good moisture-retaining capacity and relatively high organic material are less prone to cracking.

**Chilling injury** can result when fruits of eggplants, peppers, and tomatoes are exposed to temperatures after harvest. For more information, refer to **Chapter 5: Harvest and Postharvest Handling**.

**Poor color** can be caused by a number of factors. In peppers, if the plants are too crowded, the overly dense canopy will prevent sufficient light penetration for good fruit coloration. In tomatoes, the shoulder or top of the fruit may be yellow or green instead of red like the rest of the fruit. The cause is most likely high temperatures combined with high light intensity during fruit ripening. Cultivars vary considerably in their susceptibility.

Blotchy ripening, and gray wall (also called internal browning) occurs in some tomato cultivars. These fruits develop a normal red color except in the affected areas. A fruit cross section show brown veins with yellow to gray cells. **TMV** infection, low potassium, and a sudden temperature change have be associated with the disease.

**Off-flavor** or a bitter tasting eggplant at the time of harvest is caused by lack of soil moisture. Adequate irrigation during dry weather will eliminate the problem. The green and white fruited varieties are usually less bitter under these conditions than the purple varieties. Water stress will cause the fruits to also be harder. For the best tasting tomato, allow the fruit to shelf ripen. The flesh of the tomato becomes pulpy and flavor fades in the refrigerator. Off-flavor in sweet peppers and flavor can result when hot and sweet peppers are grown side by side.

**Poor pollination** affects the appearance of the fruit. Fruit puffiness in tomatoes is characterized by fruits with an angular appearance. The inside of the fruits have partially filled locules (ovary cavity). Catface of tomato is also caused by poor pollination. Catfacing includes enlargement of the blossom scar or misshapen fruit from non-uniform locule formation.

## Pathogens found in the Western Pacific and Micronesia

**Table 12.5.** Pathogens associated with crops in the Western Pacific and Micronesia.

| Name | Eggplant | Hot Pepper | Sweet Pepper | Tomato | Comments[1] |
|---|---|---|---|---|---|
| **Bacteria** | | | | | |
| *Clavibacter michiganense* | | | | G, H | bacterial canker |
| *Erwinia carotovora* | | | | G, AS | bacterial stem rot, black heart, soft rot |
| *Erwini cartovora* subsp. *cartovora* | | | | H | soft rot |
| *Erwini cartovora* subsp. *atroseptica* | H | | | | black heart, soft rot |
| *Ralstonia fuligena* | | G | G | P | |
| *R. solanacearum*<br>*R. solanacearum* (race 1) | G, H | G | G, P | G, P, AS, H | bacterial wilt |
| *Xanthomonas campestris* pv. *vesicatoria* | | | | G, P, H | bacterial spot; affects all above ground plant parts |
| **Fungi** | | | | | |
| *Alternaria solani* | H | | | G, H | early blight; collar and fruit rot |
| *A. tenuissima* | | | | H | |
| *Botryodiplodia theobromae* | G | G | G | | most important as a cause of postharvest fruit rot |
| *Botryosphaeria dothidea* | | | | AS | reported on eggplant, tomato, and other hosts but not on pepper |
| *Cephalosporium* sp. | | | G | | not reported as a pathogen of solanaceous crops |
| *Cercospora capsici* | | G, P, AS | P | | frog-eye leat spot; spots on fruits and leaves |
| *C. egenula* | AS | | | | Cercospera leaf spot |
| *C. melongenae (Gloeosporium* sp.*)* | AS, H, G | | | | Cercospera leaf spot; circular to irregular spots |
| *Cladosporium* sp. | | | | AS | not reported on eggplant or pepper |
| *Colletotrichum* sp. | G, AS | | | | anthracnose |
| *C. acutatum* | | | G | | not reports as a pathogen of solanaceous crops |
| *C. capsici* | | G | G | | anthracnose of pepper |
| *C. gloeosporioides* | | G | | G, AS, H | anthracnose, fruit rot, leaf and stem spot |
| *Corticium rolfsii* | AS, G, H | AS, G, H[2] | AS, G, H[2] | AS, G, H | sclerotium rot |
| *Coryneospora* sp. | | | | G | target spot, target leaf spot |

**AS** American Samoa **G** Guam **H** Hawaii **MI** Marshall Islands **P** Palau
**?** Likely

**Table 12.5.** Pathogens associated with crops in the Western Pacific and Micronesia (continued).

| Name | Eggplant | Hot Pepper | Sweet Pepper | Tomato | Comments[1] |
|---|---|---|---|---|---|
| *C.* cassiicola | | P | | AS | target spot; target leaf spot; shot-hole leaf spot; leaf blight |
| *Curvularia* sp. | | | | G | saprophyte and at most a weak pathogen |
| *C.* lunata | | | G | | pod rot |
| *Diaporthe* sp. | | | G | | pathogen of pepper, tomato, and many woody ornamentals |
| *Dothiorella* sp. | | | | AS | not reported as a pathogen of solanaceous crops |
| *Drechslera* sp. | | G | G | | not reported as a pathogen of solanaceous crops |
| *Erysiphe cichoracearum* (*Oidium asteris-punicei* Peck) | G | | | | powdery mildew |
| *Fulvia fulva* | | | | AS, H | leaf mold, infects leaves |
| *Fusarium* sp. | H | | G | G, AS, H | root and crown discoloration |
| *F. oxysporum f.* sp. *lycopersici* | | | | G, H | wilt |
| *Gibberella fujikuroi (Fusarium moniliforme)* | G | G | G | G, H | not reported as a pathogen of pepper |
| *Glomerella cingulata* | G | | G | | anthracnose; internal mold of fruit |
| *Macrophoma* sp. | | | G | | not reported as a pathogen of solanaceous crops |
| *Macrophomina phaseolina* | H | | | H | charcoal rot |
| *Myrothecium roridum* | | | | MI | ring rot, occurs on fruits |
| *Pestalotia* sp. | | G | | | not reported as a pathogen of solanaceous crops |
| *Pestalotiopsis* sp. | | | | AS | leaf spot |
| *Phoma* sp. | G, AS, H | | | MI | leaf and fruit spot |
| *P.* destructiva | | | | H | fruit rot; leaf and stem blight |
| *P.* terrestris | | | | H | pink rot |
| *P.* vexans | H | | | | fruit rot |
| *Phomophsis* sp. | | | | H | stem-end fruit rot |
| *P.* vexans | G | | | | blight, fruit rot, leaf spot |
| *Phyllosticta* sp. | | | G | | leaf spot |
| *Phytophthora* capsici | H | | | H | |
| *P.* cinnamomi | | | | H | root rot |
| *P.* dreschsleri | | | | H | damping-off of seedlings; crown and root rot |
| *P.* infestans | | | | G, H | late blight |
| *P.* nicotianae | | | | H | leaf spot; blight and rot; defoliation |
| *P.* palmivora | | | | H | root rot |
| *P. nicotianae* var. *parasitica* | H | | | AS | buckeye rot of fruit, stem rot, defoliation |
| *P. parasitica* | G | | AS | | fruit and root rot |
| *Pythium* sp. | H | P, MI | | | damping-off, root rot |
| *Pythium aphanidermatum* | | | | H | root rot |
| *Rhizoctonia* sp. | H | G[2] | G[2] | G | damping-off, root rot |

**AS** American Samoa **G** Guam **H** Hawaii **MI** Marshall Islands **P** Palau
**?** Likely

**Table 12.5.** Pathogens associated with crops in the Western Pacific and Micronesia (continued).

| Name | Eggplant | Hot Pepper | Sweet Pepper | Tomato | Comments[1] |
|---|---|---|---|---|---|
| *R. solani* | G | | G, AS | G, H | Rhizoctonia damping-off; root and stem rot |
| *R. stolonifer* | AS | | | | fruit rot |
| *Sclerotina sclerotiorum* | H | | | | sclerotina fruit rot; white mold; lesions of leaves and stems; pink rot |
| *Sclerotinum rolfsii* *(Athelia rolfsii)* | G, H | P, G | G | G, H | southern blight |
| *Septoria lcyopersici* | H | | | G, H | Septoria leaf spot; leaf spot |
| *Stemphylium* sp. (*Leptosphaerulina* sp.) | | G | | G | gray leat spot; fruit rot |
| *S. solani* | | | | H | gray leaf spot |
| *Ulocladium* sp. | | | G | | reported on eggplant, tomato, and other hosts but not pepper |
| *Verticillium* sp. | | | | G, H | |
| **Nematodes** | | | | | |
| *Helicotylenchus* sp. | | | | H | spiral nematode |
| *Heterodera trifolii* | | | | H | cyst nematode |
| *Meloidogyne* sp. | H | | G | H | root knot |
| *M. arenaria* | | | | H | root knot |
| *M. incognita* | G | | | H | root knot |
| *M. javanica* | | | | G, H | root knot |
| *Pratylenchus brachyurus* | | | | H | lesion nematode |
| *P. pratensis* | | | | H | lesion nematode |
| *Radopholus similis* | G, P, FSM, H | G, P, FSM, H[2] | G, P, FSM, H[2] | G, P, FSM, H | burrowing nematode |
| *Rotylenchulus reniformis* | G, AS, H | G, AS, H[2] | G, AS, H[2] | G, AS, H | reniform nematode |
| **Virus** | | | | | |
| *Ageratum yellow vein virus* | | | | G | yellow leaf curling and stunting |
| *Cucumber mosaic virus* | H | | | G, ?AS, H | leaf distortion, mottling, shoestringing |
| *Tomato bushy stunt virus* | | | | G | |
| *Tomato mosaic virus* | | | | G, H | |
| *Tomato mottle virus* | | | | H | |
| *Potato Y virus, mosaic* | | G[2] | G[2] | ?G, H | |
| *Spotted wilted virus* | H | G[2] | G[2] | H | |
| *Tobacco mosaic virus* | | G[2] | G[2] | G, H | |

**AS** American Samoa **G** Guam **H** Hawaii **MI** Marshall Islands **P** Palau
**?** Likely

1 "Reported" (statement of occurrence in compendia of plant diseases).
2 Reports do not distinguish between hot and sweet peppers and/or between *Capsicum annuum* L. and *Capsicum frutscens* L.

This list is derived from a number of sources including the Crop Protection Compendium Data Base CAB International, Hawaii Pest Database web site, technical papers of the South Pacific Commission, Guam Agricultural Experiment Station Annual Reports, and personal communication.

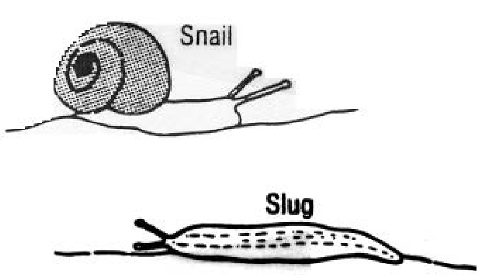
# Chapter 13 Animal Pests

**Manuel Duguies, Extension Veterinarian**

Pests other than insects and mites, can cause serious damage to vegetables. These pests include slugs, snails, rats, mice, chickens, birds, pigs, and deer. The following control measures may reduce the damage caused by these animals. The proper use of baits, traps, barriers, dogs, and guns will be discussed. The cost and effectiveness may vary due to the size of the field, its location, and the pest population in the area.

### Snails and Slugs

Snails and slugs are mollusks and are related to clams, oysters, and other shellfish. Snails have visible external shells. Slugs have internal shells and a fleshy exterior **[Plate 17]**. They must stay moist at all times which is why they hide in damp places and avoid the sun and dry places. They are most active during the night and early morning. They prefer to eat young shoots, fruits, and other succulent plant parts but will eat the bark off of a mature stem if food is limited. They secrete a mucoid substance on their trails which leaves an objectionable mark on plant leaves.




**When snails and slugs aren't eating your plants, they are hiding in dark, damp places.**

Desiccants, poison baits, and cultural practices are useful methods to control snails and slugs. A desiccant such as salt can be sprinkled or poured as a solution on snails and slugs to kill them. Common molluscicides are commercially available in the form of poisonous baits. These baits are broadcast around the area to be protected and in areas where snails and slugs may be hiding. Baits are most effective when applied on a damp night followed by a dry day. Avoid irrigation for at least 12 hours after treatment. Refer to the latest edition of Guam's Fruit and Vegetable Guide for specific product recommendations.

The removal of any coverings near the field that may provide a shelter for these pests is also helpful. Be sure that snails and slugs are not present when using a mulch for weed control as these may serve as a shelters for them. Keep all irrigation drip lines at least 4.6 meters (15 feet) away from any weeds or grass. This will reduce the chance that snails and slugs will enter your field under the cover of the drip line.

### Rats and Mice

Rats and mice can be a serious problem in the field. They nibble on fruits and leaves which can lead to decay and disease. Keeping weeds mowed and the immediate area free of garbage and trash will reduce the likelihood that mice and rats will become a problem. If a problem does arise, a control program must be started before the next cucurbit crop is planted and then maintained until the harvest season is over.

Poison baits, traps, and cultural practices can be used to control rats and mice. Rodenticides come in the form of poison baits, of which there are two kinds. A single treatment of a non-anticoagulant bait can kill rats and mice while anticoagulant baits require several feedings by the rodent. Different carriers are used to attract rats versus mice. Poison baits should be placed directly in or near burrows. To prevent accidental poisoning, signs should be posted as to their presence and location. Pets should be kept on a leash or fenced away from traps and poison. Fields should be plowed or burned, if permitted, after the last harvest so that food will not be available for rats and mice to eat. Plowing also destroys the tunnels and burrows in the field made by these pests.

### Birds and Chickens

The bird population on Guam is so low that hardly any damage is caused by them. Fields near residential areas, however, may encounter problems with chickens. Chickens like to scratch on newly-tilled soil, eat seeds, eat fruits, and damage seedlings. Birds and chickens can also be controlled by providing a barrier or scaring them away. To control damage from your neighbor's chickens, ask that they be caged during the planting/growing season. Installing a net fence and placing guard dogs around the area will also help. Scarecrows with noise and/or guard dogs will help to scare birds away. Placing fruits under a frame with netting will act as a barrier to their feeding.

**Mice, birds and chickens will eat non-germinated seeds.**

### Wild Pigs and Deer

Wild pigs are possibly the most destructive of all large animals on Guam. They damage crops by eating the fruits. Wild pigs cause the greatest damage at harvest. Deer eat only the growing tips of plants which usually causes little yield loss once the plants are growing vigorously. Clearing around the perimeter of the field will reduce the chance of this problem because pigs and deer usually do not come into open areas. The footprints of pigs and deer are hard to distinguish because they are both split-hoofed. However, pigs are shorter and they drag their feet forward while walking or stepping, thereby making a longer, less distinct print.

Barriers, hunting, and repelling are the most common control practices. A strong fence around a field is very effective. A hog wire (chain-linked fence) around the perimeter will prevent animals from entering the field. Be sure the bottom wire is close to the ground to prevent animals from crawling underneath. Fence height should be between 2.1–2.4 meters (7–8 feet) for deer and at least 1.2–1.5 meters (4–5 feet) for pigs. Shorter fences can have strands of barbed wire not more than 4 inches apart to extend the height of the fence. Fences may be expensive, but provide the most effective control against vertebrate pests. Electric fences are also recommended; they cost less to set up and are easier to install than a regular fence. They have some disadvantages, such as human safety, shorting of wires, high long-term cost, and dependence on a power source. Electric fences should always have a posted warning sign. Dogs can be strategically posted in corners or points where pigs and deer are likely to enter the field. Dogs can be put on a long leash or connected to a long line to allow them to run from one end of the field to the other. Barking will frighten pigs away or at least signal the farmer of something unusual in the field. However, there are reports that posting dogs becomes ineffective as over time pigs learn ways to outmaneuver the dogs. It is unlawful to use dogs to hunt, catch, or kill wild pigs and deer. Use of scarecrows with accompanying sound or noise barrage can also be used.

Farmers may not hunt or trap wild pigs and deer on their land without a permit from the Guam Department of Agriculture. Permits are issued only after inspection. Report any damage to your cucurbit crop to the Department of Agriculture as soon as possible.

### Theft and Vandalism

There have been police reports of thefts and vandalism among cucurbit fields. Pickup trucks or possibly all terrain vehicles are driven into the fields with the intention to destroy the crop or to steal a truck load.

Loss from theft and vandalism can be reduced by reducing accessibility and improving visibility. Inform neighbors and be on the look-out for suspicious activity. Make fields inaccessible by constructing fences and piling up dirt and boulders around the field. Avoid too many entries or exits and provide strong gates for each entry/exit. Clear away brush and install night lights so that the area can be easily monitored. Guard dogs also serve to deter intruders and their barking also serve to alert the owner. Posting signs such as **Do Not Enter**, **No Trespassing**, and **Private Property** can also be a deterrent to potential vandals.

# Chapter 14 Insects and Mites

**Lee Yudin, Extension Entomologist**
**Robert L. Schlub, Extension Plant Pathologist**
**Ross Miller, Research Entomologist**

"Integrated pest management", IPM for short, makes use of good farming practices to reduce the size of the bite that pests and pesticides take out of farm profits. This means that sometimes it is better not to spray insecticides since insect pests are kept at low numbers by beneficial insects which feed on them. These "good bugs" only feed on the pests, and will not eat the crop if the pests are absent. Unfortunately, these beneficial insects are often easily killed by insecticides, more so than the pests you are trying to control. Killing all insects leaves your field open to re-invasion by the pests. A field that contains no insects is not a healthy field. For this reason, so called "preventive sprays" may actually pave the way for pest invasions.

Quite a few pest problems have been caused by the overuse of insecticides. For example, in Hawaii and the Marianas, a small fly called the serpentine leafminer is a major pest of vegetable crops that are sprayed heavily. This fly has become resistant to insecticides and usually survives daily pesticide applications. In fields where pesticides are not often used, the fly is killed by tiny wasps barely visible to the naked eye. Heavy pesticide use kills the wasps, but only some of the flies. Without the wasps in the field, fly populations quickly build up to levels that will destroy the crop. Similar situations can occur with thrips, whiteflies, and other insect pests. IPM can help maintain a "balance of nature" by preserving these natural enemies in the fields, and may actually provide better insect control with fewer pesticide treatments.

### IPM in the Pacific Islands

Many farmers currently spray their crops on a weekly basis whether pests are present or not. This practice is not desirable from a health or environmental standpoint, and costs more than spraying only when needed. To spray as needed, one needs to know what the important pests are and when they should be controlled with chemicals.

Some chemical insecticides not only kill pests and beneficial insects but are also toxic to other organisms, including fresh water and marine life. Insecticides, if improperly applied, may end up in groundwater or pass into sensitive coral reef ecosystems.

### Designing Your Field to be Pest Resistant

There are things you can do even before planting to lower the risk of crop loss due to pests and to reduce chemical sprays.

- In buying seeds, select varieties which are resistant to insects and plant diseases common on Guam.
- Before planting, destroy weeds on the farm. These wild plants may harbor pests and diseases that can move into your crop. They also provide refuge for some natural enemies.
- Use transplants rather than direct seeding. Seedlings grown in Speedling® trays can be protected from aphids which transmit viruses, as well as from other pests, by covering them with fine mesh screening (row covers).
- If you are using plastic mulch, try to use white or silver mulches instead of black. Studies have found that mulches which reflect sunlight are very effective in keeping aphids and thrips off young plants. Several experiments have shown that highly reflective mulch protect plants from getting mosaic virus vectored by aphids.

### Surveying for Pests

#### Yellow Sticky Traps

Yellow sticky traps can be used to detect flying insects (such as winged aphids, trips, whiteflies, and beetles) and give you an early warning of their presence. Unfortunately, a great many insects that are not crop pests are also caught. Thrips are very small and difficult to see. Sometimes heavier insects such as beetles, grasshoppers, and plant bugs slip off the traps, so check the ground underneath each trap. The use of sticky traps eliminates the need to wait for the appearance of damaged fruits, stems, or leaves to determine whether or not to spray. You should put out at least five traps: one near each corner of your field and one near the center.

Yellow sticky traps can be used to detect flying insects.

Traps should be fixed to the top of two-foot bamboo or wooden stakes driven into the ground between rows. The sticky material used to coat the traps may have to be replaced several times during the growing season. A material call Tack-Trap®, specifically designed for traps, will last most of a growing season if a thick coat is applied.

Sticky traps are available commercially or you can make your own. To make your own, get some large bright yellow plastic 8 oz drinking cups and coat them with Tack-trap®. If Tack-trap® is not available, you might experiment with breadfruit or jackfruit sap. Tanglefoot® is another good coating for sticky traps.

#### Plant Inspection

Inspecting your crop for pests is the most common way of conducting a pest survey. For each pest, there is a different method of sampling. In order to get a representative sample of these pests, it is necessary to sample about 20 different locations in your field. You should survey your field at least once a week or more often if you think damage is occurring.

### Pest Descriptions and General Treatments

#### Aphid

**Melon aphid** (*Aphis gossypi*) **[Figure 14.1]** is one of the most common aphid genera occurring on Guam and the Pacific region. Aphids are small, soft bodies insects **[Plate 2A]** that sucks plant sap. They are usually found on the underside of leaves. These insects have a very unusual life cycle. In the tropics, all aphids are female and do not mate. Unlike most insects, which lay eggs, adult female aphids give birth to babies which look like miniature adults **[Figure 14.2]**. Most aphids spend their whole lives on a single plant in a colony of relatives. However, when colonies get very large or their home plant is under some sort of stress, adults with wings are produced. These adults will fly off and establish colonies on new host plants. Melon aphids are common throughout the tropical Pacific region, and throughout the world. This insect feeds on a wide variety of plants and is particularly troublesome on cucurbits (cucumbers, melons, watermelon, and related crops), okra, and citrus. It transmit a number of major plant diseases. It feeds on eggplants, peppers, tomatoes, beans, and spinach to name a few other hosts. It can also be found on various weeds and ornamental plants. Another common aphid in the region is the banana aphid **[Figure 14.3]** which has been reported on tomatoes, bananas, ginger, and heliconia **[Table 14.2]**.

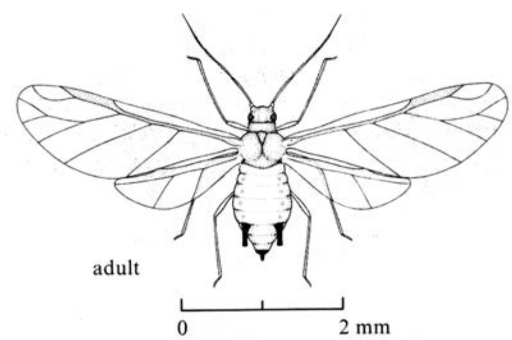



**Figure 14.1.** Adult cotton aphid (melon aphid), *Aphis gossypi*. (from Hill, 1975).

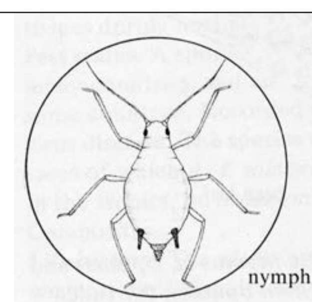



**Figure 14.2.** Nymph stage of an aphid, *Aphis gossypi*: (from Hill, 1975).

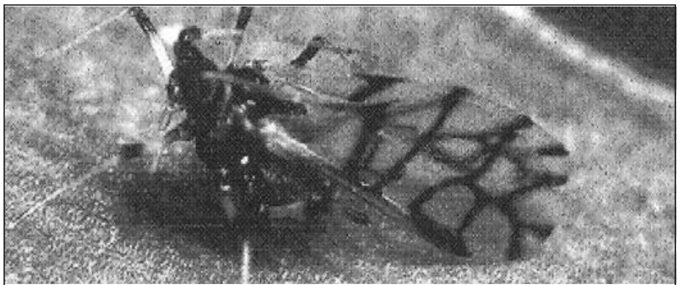


**Figure 14.3.** Adult banana aphid, *Pentalonia nigronervosa.* (from Hawaii Plant Database).

Very high numbers of aphids may suck enough sap out of a plant to affect its growth. Plants that are home to large colonies may be stunted, wilt easily, and have crinkled leaves. If stunting occurs, loss of yield can be expected. Other indications of an infestation are the presence of white cast skins of the aphid **[Plate 2B]** and unusual amounts of ants and flying insects. Ladybugs and hoverflies are very effective at feeding on aphids, and will sometimes clean up infestations. However, this often happens too late, after significant aphid damage has already occurred on the crop.

**General treatment:** Attack on a crop by aphids commonly begins in small scattered spots over the field. Such spots should be sprayed to keep aphids from becoming established. Treatment of an entire field is rarely warranted. Since winged aphids have the ability to fly into newly planted fields, it is advisable that a grower spends the time inspecting newly planted fields every couple of days, for winged aphids and early colony establishment. It is very important that aphid colonies not be allowed to get established early in the planting cycle. Aphid control is best if colony establishment is kept to a minimum. Insecticidal soap usually is not very effective against aphids in the field situation, and may kill ladybeetle larvae which are predators of aphids.

**Aphids vector viruses**. Besides causing damage to plants by feeding, aphids also are a major pest problem because they vector numerous viruses, moving them from plant to plant. One problem with spraying for aphids is that the insecticides cause those that are not killed instantly to move around more than usual. Each time they move and feed, they can transmit viral diseases to another plant. Treating aphids with insecticide may actually increase problems with virus diseases if sublethal dosages are used.

**General treatment:** Unfortunately, there is no cure for virus-infected plants. Once diseased plants are identified, they need to be spot-treated immediately with an insecticide to kill all the insects on them, and then clipped off at the base of the stem the following day. If you simply pull diseased plants and leave them in the field, the virus-infected aphids living on them will simply move onto healthy plants and continue to spread the disease. The best strategy for dealing with virus problems is prevention and delaying initial infection in the field. Here are some tips that can help prevent aphids from carrying viruses into your field from adjacent areas. These tips will also help to prevent other pest problems.

1. Use transplants. Seedlings can be protected from aphids carrying virus by growing them under fine mesh netting.
2. Plow old fields under soon after harvest.
3. Remove weeds particularly wild pumpkin, bittermelon, and papaya from your farm. These plants can be a source of viruses and melon aphids.
4. All pruning tools should be disinfected with 10% trisodium phosphate, 10% Clorox® solution, or Lysol® spray.
5. Use reflective mulch (white or shiny silver). Experiments at the University of Guam and Hawaii have shown that reflective mulch greatly reduces the number of aphids and other pests landing on young plants, reduces virus infection, and increases yield. Refer to the mulching section in **Chapter 15: Weeds** for more information.
6. Use row covers. In watermelons, cantaloupes, and possibly cucumbers grown on the ground, floating row covers will prevent aphid infestations until the covers are removed at flowering time. Row covers can be purchased in various length and widths making it suitable to cover unstaked eggplant, pepper, and tomato plants. Row covers also help prevent infestation by other insects.

### Ants

There are many different kinds of ant with various colony or nesting preferences: buildings, rotten wood, soil, pavement, lawns, and gardens. Ants are social insects that have three castes (queens, males, and workers) and live in colonies or nests. The workers are the most commonly encountered in the garden as they forage for food and water. When desirable items are found, many species will recruit ants from the colony to help gather the food and return it to the colony.

Some ants share an interesting relationship with aphids. Ants alone can be a problem in a grower's field independently of aphids, feeding on roots and stems of young seedlings. But there are many times a grower will see both aphids and ants living side by side. A substance called "honeydew" is secreted by the aphid and the ant feeds upon this substance. Ants utilize aphids as a food source and will protect aphids from other insects which may feed directly on the aphid. Eliminating the aphid population will also reduce ant activity in the field.

For the Guam farmer, **fire ants** (*Solenopsis geminata* (F.)) can be a nuisance because they can sting and cause damage to plants. They frequently build their nests under drip irrigation lines. Ants may feed on germinating seeds, stems of young plants and blossoms. Damage to seedlings is usually greatest during hot dry days. Besides aphids, ants also contribute to damage caused by mealy bugs and scales insects because they are often involved with the distribution, establishment, and protection of these insects.

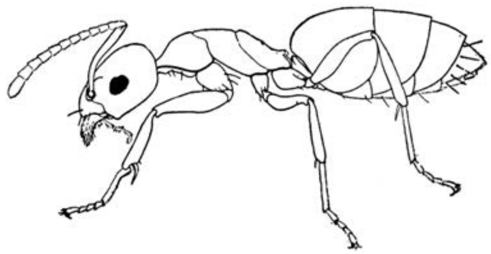


**Figure 14.4.** Side view of a typical ant body. (from Metcalf, et al., 1967).

**General treatment:** To thoroughly control ants, you must treat the colony with a registered insecticide to kill the queen or use a bait that the workers will carry back to the queen and developing young for consumption. The most effective method for finding the mound is to follow a line of foraging workers back to the colony.

### Thrips

**Melon thrips**, (*Thrips palmi*), major pest of cucurbit crops, and **onion thrips** (*Thrips tabaci*) **[Figure 14.5]**, a major pest of onions, are also pests of eggplants, peppers, and tomatoes. Onion thrips is considered the more serious of the two pests. Onion thrips are found in most countries, outdoors in warm climates, and in greenhouses in colder areas.

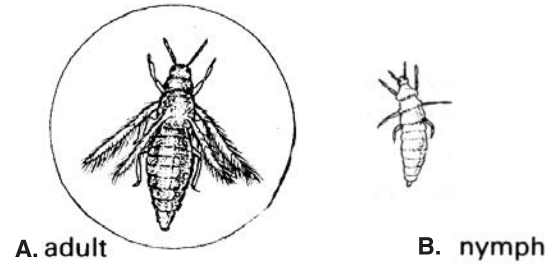



**Figure 14.5. [A]** Adult and; **[B]** nymph stages of onion thrips, *Thrips tabaci*. (from Woodworth, California Agricultural Experiment Station, Bulletin 207).

Thrips have two pairs of wings that resemble small feathers **[Figure 14.6]**. The body of the female onion thrip is about 0.9–1.0 mm long and the male, which is rarely present, is smaller. The adult life span is about 2–3 weeks, during which time the female lays 20–100 eggs. Each egg is oval, white, and inserted single in the leaf tissue. Nymphs, [**Figure 14.5B**, **Plate 3A**] once fully grown, leave the plant and enter the soil where they change to adults in a week. Plant damage results from both adults and nymphs. They have rasping and sucking mouth parts which they use to scrape off the top layer of cells and then suck the juice. This causes the destruction of cells and results in the appearance of whitish-silvery blotches on the leaf surface [**Plate 3C**, **3D**]. Feeding on young eggplant fruits results in scarring (**Plate 3B**) and/or deformity. Hot and dry weather conditions seem to favor extreme thrip populations. Associated with feeding damage are drops of black secretions from the thrips. These feces remain long after the thrips themselves have left. Thrips, when numerous, may cause premature wilting, retardation of leaf development, and distortion of fruits and of young shoots. Onion thrips also damage eggplants, peppers, and tomatoes because it is a vector for *Tobacco streak virus* and tomato spotted wilt. These are also vectored by the melon thrips.

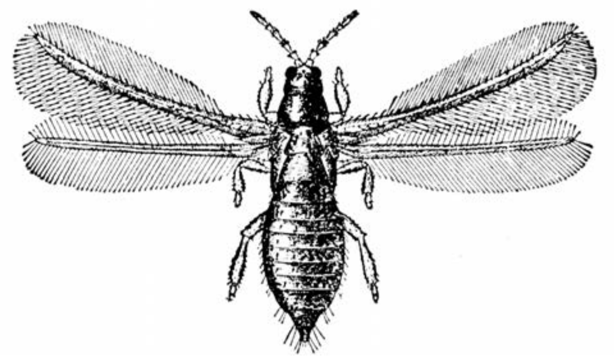


**Figure 14.6.** Adult thrip with wings extended. (from Moulton, U.S.D.A., Dept. Bul. 173).

Due to their very small size, most growers do not realize they have a thrips problem until it is too late. Most growers will need extra help determining the presence of thrips in their fields. If you suspect that a leaf or tip of a branch has thrips, shake it vigorously inside a white plastic cup. If thrips are present, you will see tiny, shinny, yellowish or brown insects running around in the cup. Growers should contact their local Cooperative Extension Service for assistance in determining early thrips invasion.

**General treatment:** Vigorous plants normally outgrow thrip damage; so keep plants well fertilized and watered. If present, thrips are not easy to control with insecticides. Experiments at the University of Guam and Hawaii have shown that using insecticides may sometimes result in increased numbers of thrips compared to untreated controls. Predatory mites and minute pirate bugs, which normally eat thrips, are killed by these insecticides. Because predators of thrips are common in many fields, it is important only to treat fields when thrip numbers exceed threshold damage. Preventative treatments may actually cause a thrips outbreak by killing natural enemies. For current updates on treatment for thrips, contact your local cooperative extension agent.

### Mites

The **broad mite** (*Polyphagotarsonemus latus)*, **spider mite** *(Tetranychus truncatus)*, and **flat mite** (*Brevipalpus* spp.) can be major pests during some seasons where weather is very hot and dry. Although related to insects, mites along with spiders and ticks are members of the arachnid class and have 8 legs **[Figure 14.7]**. These mites are very small and require a microscope to observe their presence. Mites penetrate plant tissues by using their chelicerae (mouth parts) to withdraw fluids from leaf cells. General plant decline and leaf distortion are symptoms of mite damage **[Plate 4]**. A severe infestation may cause bud and flower drop. The fruits that survive these infestations will often have a cork-like, scarred surface **[Plate 3B]**. Cupping or curling upward of the leaf margin is symptomatic of a broad mite infestation. The curling is the result of corky tissue development on the underside of the leaf, which is often bounded by two distinct brown lines parallel to the main vein. The edges of the leaf themselves remain undamaged.

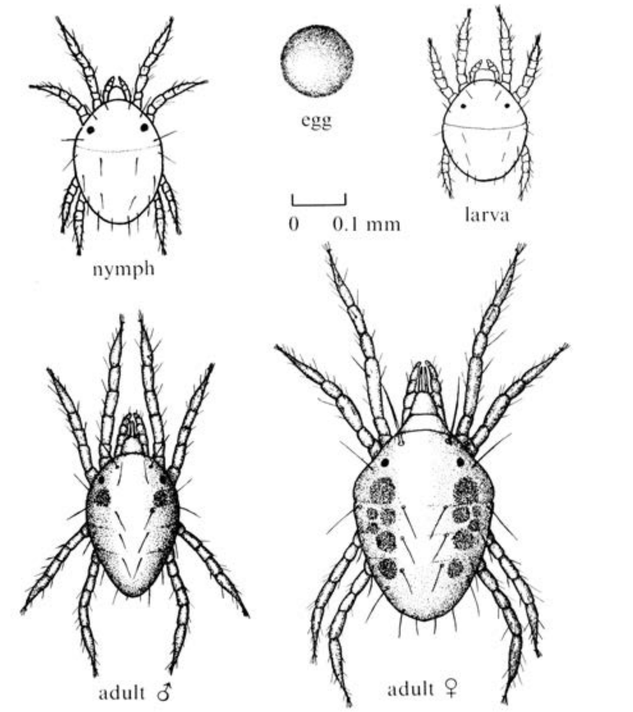



**Figure 14.7.** Growth stages of tropical red spider mite. (from Hill, 1975).

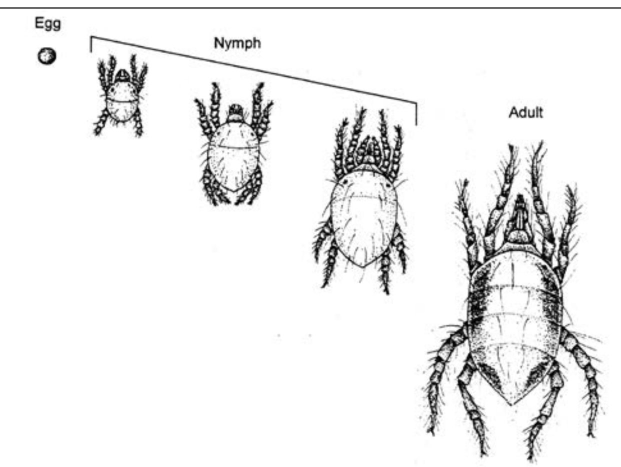



**Figure 14.8.** Gradual metamorphosis of a mite (from Crop Protection for Pacific Islands; ADAP Project, 1995).

**General treatment:** The use of approved miticides can result in effective control measures. On Guam, an introduced predatory mite, *Metaseillus* sp., has proved to be effective against the broad mite. There are also some indigenous predatory mites that can be effective in reducing plant feeding mite populations. Because predators of mites are common in many fields, it is important only to treat fields when mite numbers exceed threshold damage. Preventative treatments may actually cause an outbreak by killing natural enemies. Refer to Guam's Fruit and Vegetable Guide for specific cucurbit and registered pesticide recommendations.

### Caterpillars

A caterpillar is the worm-like growth stage of butterfly, moth, or other insects. Caterpillars are among the most damaging pests. With their strong biting and chewing mouth parts, they may completely destroy seedlings, feed on leaves, bore in the stem, or penetrate into the fruits making them unmarketable. They do not look like adults, which often cause no feeding damage themselves. The caterpillar stage is always separated from the adult stage by a pupal stage during which the insect takes no food and is usually immobile. Common names for caterpillar include canker worm, armyworm, cutworm, looper, earworm, fruitworm, hornworm, maggots, and bollworm.

**Green semi-looper** (*Chrysodeixis eriosoma*), a common pest of cucurbits, is found on tomatoes in Micronesia and Samoa. The caterpillar is green with white stripes **[Plate 5]** and moves with a looping movement.

The **rice cutworm** or **cluster caterpillar** moth, *Spodoptera litura* (F.) **[Figure 14.9]**, occurs on eggplants, peppers, and tomatoes. It is black with small blue and yellow spots along the sides **[Plate 6]**. The adult moth lays 200–300 eggs underneath leaves. They are covered with brown scales taken from the body of the mother. They hatch in three to four days. When young, the larvae feed in a group on the underside of leaves, leaving the upper leaf tissue and veins intact. When older, they spread through the plant and consume entire leaves. When they are mature, they leave the plants and pupate in a small circular cell in the soil. The life cycle takes about 25 days. Adult moths are nocturnal and are not often seen. The larvae are primarily leaf feeders, but may occasionally cut young plants at the soil line. They may also feed on the green fruit of tomatoes. Unlike tomato fruitworms, they generally do not bore into the fruit.

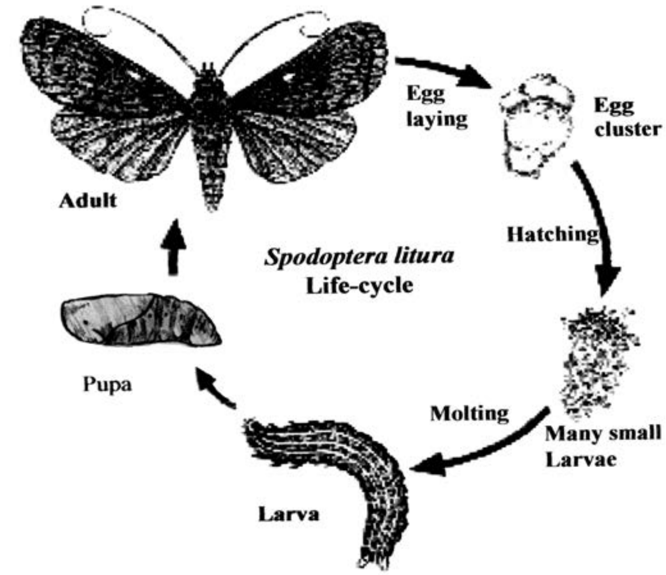



**Figure 14.9.** Life cycle of *Spodoptera litura*. (modified illustration from Crop Protection for Pacific Islands; ADAP Project, 1995).

This moth is widespread throughout Asia and is present in the Marianas, most of the Carolines, and the South Pacific region including American Samoa. Many vegetables and other crops are damaged by cluster caterpillars. Crops likely to be seriously damaged in this region are various taros, cabbage and its relatives, and tomatoes.

**General treatment**: The most important step in caterpillar control is the early detection of the eggs and young caterpillar. A chemical or biopesticide control program must begin immediately after discovery. One of the best known biopesticide bacterium is *Bacillus thuringiensis*, which is effective against caterpillars without harming its natural enemies.

**Fruitworms** damage a number of crops including beans, corn, cotton, eggplant, lettuce, okra, soybean, sugarcane, pepper, and tomato. In beans, larvae feed on leaves, buds, flowers, and within pods. In corn, larvae feed on developing tassels and kernels. In lettuce, they feed on seedlings and bores into heads. On eggplants, larvae bore into buds and destroy shoots. In tomatoes, they mainly cause damage to flower buds and fruits but occasionally have been seen to bore into stems **[Plate 7]**.

**Corn earworm** or **tomato fruitworm** (*Heliothis zea*) lays its eggs on terminal leaflets. Young invaded tomatoes generally fall while older fruits stay on the plant and rot. Fruit rotting is caused by fungi and bacteria that become established at the wound site. The worm (1-$^{1}/_{2}$ inches when mature) causes deep watery cavities in tomato fruits which contain feces and cast skins. The worm pupates and eventually gives rise to a 1-$^{1}/_{2}$ inch light buff moth with irregular darker lines and spots near the outer margins of the wings. Development from egg to adult requires about 30 days.

**Asiatic corn borner** (*Ostrinia furnacalis*) is mainly a pest of corn and sorghum. Peppers are one of its many secondary hosts. The **old world bollworm** (*Heliothis armigera*) **[Plate 8]** can cause serious losses in cotton, tomatoes, and corn. On Guam, it has been reported on eggplants and peppers besides tomatoes.

**General treatment**: Pick and destroy wormy fruits before the caterpillars mature. If you need to spray, use *Bacillus thuringiensis*. It is effective enough to control population on tomatoes. Crop rotation should be practiced; that is, avoid planting susceptible crops (corn, beans, peppers, and tomatoes) one after the other.

**Leafminers** are yellow maggots of tiny flies (*Liriomyza sativae* and *L. trifolii*) **[Figure 14.10A]**. They tunnel or mine between the top and bottom surfaces of leaves [**Figure 14.10C**, **Plate 9**]. The adult flies are about the size of a pin head and are black and yellow in color **[Figure 14.10B]**.


**Figure 14.10.** Leafminers, *Liriomyza sativae* and *L. trifolli*: **[A]** Exposed mine revealing vegetable leafminer larva; **[B]** Adult leafminer; **[C]** Mines caused by leafminer larva. (courtesy of Flint, Pests of the Garden and Small Farm, 1998).

**General treatment**: We do not recommend treating for leafminers unless damage is severe. They are resistant to almost every insecticide known and can become resistant to new insecticides within a single crop cycle. Plants can also tolerate numerous mines in leaves without yield being affected. The most effective control method is to not interfere with the several species of tiny wasps which kill leafminer larvae and pupae. If unharmed by insecticides, these wasps can maintain excellent control of leafminer populations, and will keep populations low. In the Marianas and Hawaiian islands, problems with leafminers often indicate that too much pesticide is being used in the crop. The most effective parasitic wasps have been introduced to Hawaii, Guam, Pohnpei, and American Samoa. Elsewhere, effective control agents are lacking and government entomologists should be consulted about biological control possibilities in these areas.

### Fruit-piercing moth

Eggs of this moth, *Othreis fullonia* (*Lepidoptera: Noctuidae*), are laid on coral trees (Erythrina trees). The caterpillars feed on the coral tree leaves. This insect is principally a pest in the adult stage **[Figure 14.11]**. It feeds primarily at night on a wide variety of ripening fruit by piercing the fruit and sucking out the juice. Moth populations are generally higher during the rainy season. Large populations of moths occur periodically following droughts.

**Figure 14.11.** Fruit-piercing moth, *Othreis fullonia*. (illustration from CSIRO Entomology website).

A round, pinhole-sized puncture is made in fruits when an adult moth feeds. The hole serves as an entry point for disease organisms and can result in early fruit drop. A small cavity is left in the fruit in the feeding site. The area of the fruit around the cavity will be dry and spongy.

The moth feeds on a wide variety of fruits including citrus, guava, mango, papaya, pomegranate, eggplant, and tomato.

**General Treatment**: Fruit-piercing moths are difficult to control with insecticides because the moths spend only a short time on the fruit, do not breed on the affected crops, and are strong fliers. Fruit-piercing moths are repelled by strong lights. Kerosene pressure lamps may be used if electricity is not available. Lights should be placed at a height of five feet at 40–70 feet intervals downward of plants to be protected.

### Whiteflies

Whiteflies are small insects that look like moths; however, they are neither moths nor flies. Whiteflies are small hemipterans that typically feed on the undersides of plant leaves. They are in the same group of insects as aphids, planthoppers, leafhoppers, and shield bugs. Though two species, *Bemisia tabaci* and *Bemisia argentifolii*, have been identified in the Pacific region and on the island of Guam, it is not universally accepted that they are different species but instead are both *Bemisia tabaci* B. biotype. Both are vectors of *Begomoviruses* such as **AYVV**.

**Tobacco** or **sweet potato whitefly** (*Bemisia tabaci*) and more importantly **silverleaf whitefly** (*Bemisia argentifolii*) are two of the species of whitefly occuring on Guam. The silverleaf whitefly was first recorded on Guam in 1993. On Guam, it has been frequently found on eggplants, tomatoes, cucumbers, and watermelons. The heaviest infestations are seen on eggplant.s *Synedrella nodiflora*, *Ipomoea obscura*, *Commelina benghalensis*, *Malachra capitata*, *Passiflora foetida*, *Euphorbia hirta*, *Physalis angulata,* and *Stachytarpheta jamaicensis* are its host plants among farmland weeds. The development time from egg to adult ranged between 16 to 20 days on tomato seedling grown in a screenhouse. The adults **[Plate 10A]** appear like tiny white moths. Heavily infested leaves appears to be covered with a snowy-like subtance **[Plate 10B]**. The immature stages appears as tiny snowy-like scabs on the underside of the leaf. They cling tightly to leaves and are very difficult to see without a hand lens **[Figure 14.12]**. Whiteflies feed by sucking sap from the leaf.

**General treatment:** In Guam, two parasites of the nymphs are known, and parasites have been introduced to Saipan. When farmers quit spraying on Guam, whiteflies often become less abundant, suggesting some control by natural enemies. Natural enemies often maintain control as long as they are not killed by pesticidal sprays. Whiteflies show resistance to most of the insecticides. For current updates on treatment for whiteflies, contact your local cooperative extension agent.

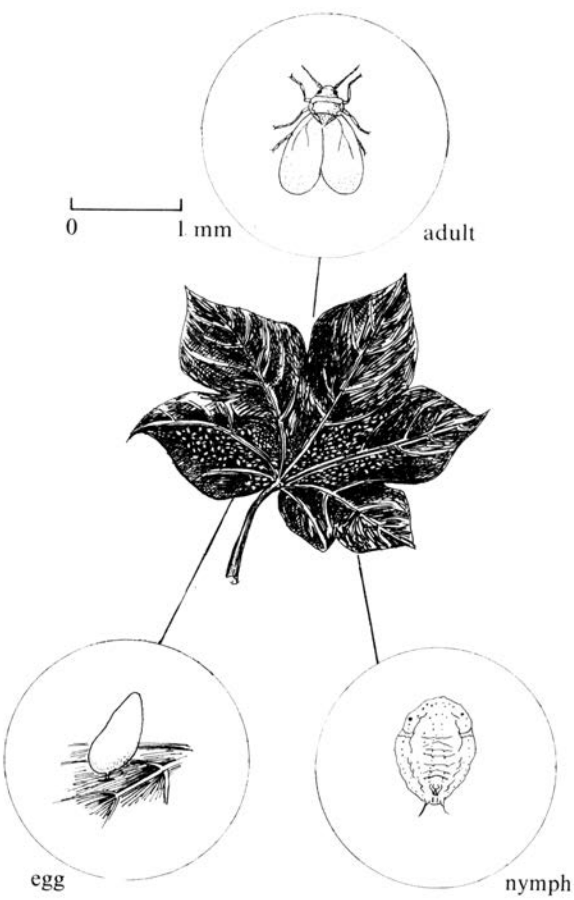



**Figure 14.12.** Stages of tobacco whitefly (cotton whitefly), *Bemisia tabaci*, on cotton leaf. (from Hill, 1975).

### Leaf-Footed Bug

The leaf-footed bug (*Leptoglossus gonagra*) [**Figure 14.13**, **Plate 9**] is a fairly large insect which is black with red spots on its underside. They are often referred to as stink bugs. The immature stages are similar but lack wings. Eggs are laid in rows on the stems of plants. These insects have piercing sucking mouth parts and suck juices out of various parts of the plant which may cause deformation of the affected parts. If present in high numbers, leaf-footed bugs can kill terminal buds. Tomato fruits damaged near maturity are normal in shape, but exhibit irregular yellow spots (cloudy spots) when the fruits turns red. An enzyme secreted during the feeding process prevents normal color development. The insect's puncture wound can generally be found in the affected areas.

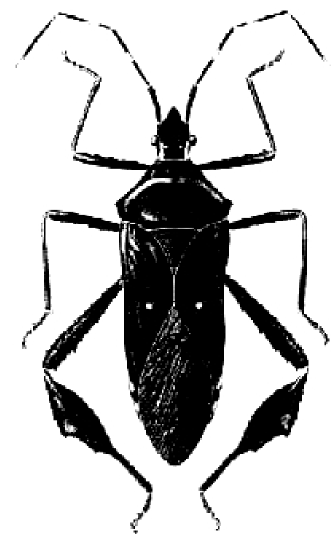


**Figure 14.13.** Leaf-footed bug, *Leptoglossus gonagra*. (illustration from CSIRO Entomology web site).

**General treatment:** Leaf-footed bugs are generally kept at very low levels in the Marianas by a tiny wasp which attacks the eggs, but large numbers do ocassionally occur in sweet potatoes grown on Guam. The egg parasite has greatly reduced the pest problem on Pohnpei where the leaf-footed bugs are extremely common. Sprays are probably not necessary if there is less than one bug per 10 plants. Refer to Guam's Fruit and Vegetable Guide for specific registered pesticide recommendations.

### Mealybugs

Mealybugs are small elliptical waxy-covered insects **[Plate 12]**. There are several mealybug species on Guam, which attack a wide variety of hosts. In 2002, a new species for Guam was identified, the papaya mealybug *Paracoccus marginatus* Williams. Fifty hosts have so far been identified in various Caribbean countries. On Guam, hibiscus, plumeria, and papaya are highly susceptible. Symptoms include: malformation of flowers, young shoots, and stems; size reduction of leaves and fruits; dropping of leaves, flowers, and fruits; and whitish covering on infested host tissues. The whitish, lumpy covering is due to an accumulation of female egg sacs.

The striped mealybug, *Ferrisia virgata* (Cockerell), is common on tomatoes and eggplants, particularly on water stressed plants. It feeds on the leaves, shoots, and fruits and will move onto the roots in dry weather. It sometimes gets under the calyx and cause scarring on the fruit. This can be a serious problem on eggplants. The insect occurs throughout most of the Pacific region.

The adult female striped mealybug is covered with powdery white wax and has a pair of purplish dorsal stripes along the back **[Figure 14.14]**. Long, glossy white wax threads extend from the body and there are two long wax tails. The combination of tails and stripes on the back serves to distinguish this insect from other species of mealybugs.

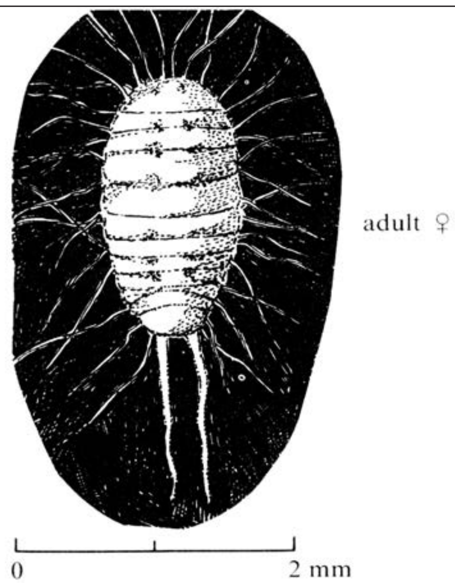



**Figure 14.14.** Adult female striped mealybug, *Ferrista virgata*. (from Hill, 1975).

Eggs are laid alongside the adults and the young nymphs usually develop close by. The female nymphs looks like the female adult but smaller. The male, when nearly grown, encloses itself in a white case then emerges transformed into a tiny, active, two-winged, fly-like insects **[Figure 14.15]**. Male mealybugs are almost never seen in the field because they are so small and fragile. Although the mealybugs can walk, they do not generally move very far and large clusters of mealybugs may appear on plants. The mealybug life cycle takes about 40 days. Mealybugs are often tended by ants. The ants keep other insects, including mealybug parasites and ladybeetles, away from the mealybugs.

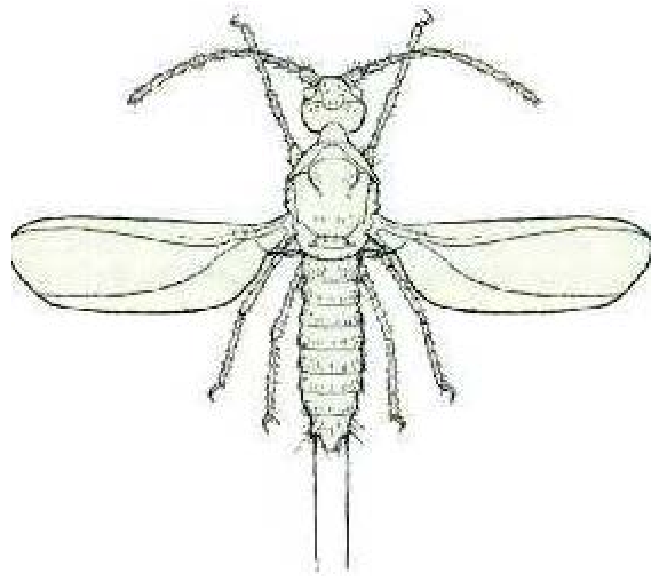


**Figure 14.15.** Adult striped male mealybug, *Ferrista virgata*. (Illustration from CSIRO website).

**General Treatment**: Plants should be maintained in a healthy condition, avoiding water stress. Plants should not be kept in the field long past their peak yielding period. On tree crops, parasites will usually eventually control the infestation. But on field crops, insecticidal control may be necessary. The use of spreader-stickers is very important when using insecticides because of the need to penetrate the wax which covers the body. Use twice the normal dose of spreader-stickers when treating for mealybugs or scales. Refer to Guam's Fruit and Vegetable guide for specific pesticide recommendations.

### Leafhoppers

Leafhoppers are common on most plants and transmit some plant diseases. The adult leafhoppers are basically wedge-shaped, less that $^{1}/_{4}$ inch long and fly or hop when disturbed **[Plate 13C]**. Nymphs resemble adults but have no wings **[Plate 13A]**. Leafhoppers are typically found on the underside of leaves and populations are often higher on new growth.

Although some host plants do not exhibit feeding damage, most develop leaf symptoms which include yellowing between the veins, areas of whitish mottling, and browning or yellowing of leaf margins (Plate 13B). Eggplants are more susceptible to damage than peppers and tomatoes. On Guam, it was found that the local green variety of eggplant appeared to be more resistant to leafhopper than the purple Northrup-King Oriental variety. Most of the observed damage is probably a reaction to saliva injected during the feeding process by the leafhopper. Evidence of an infestation include the presence of the insect, its cast skins, and tiny varnish-like spots of excrement.

**General treatment:** Low to moderate levels of leafhopper generally do not warrant any control measures. Because of their mobility and abundance, leafhoppers are not easy to control once levels are high. It is best to keep populations low by removing alternate hosts (crops and weeds) before one plants a crop sensitive to leafhopper damage. Chemical control is most effective when hoppers are small and less mobile. Care should be exercised when using chemicals because the  leafhopper's natural enemies, which are many, may be reduced.

### Fleahoppers

The garden fleahopper, *Halticus tibialis* Reuter, is distributed throughout Micronesia. It is a small, shiny, black bag about 2 mm long with charateristic orange lines on the forewings **[Plate 14]**. The fleahopper uses its long powerful legs to hope like a flea, hence its name fleahopper **[Figure 14.16]**. It is usually a minor pest but, in some seasons, it can cause serious damage particularly to young seedlings (less than 6 leaves). Older peppers and tomatoes are generally not damaged as the fleahopper only feeds on the older, lower leaves. However, eggplants can be damaged through to the fruiting stage.

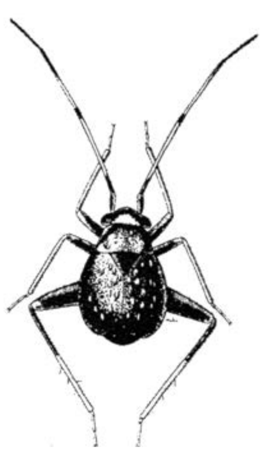


**Figure 14.16.** Garden fleahopper, *Halticus bractatus* (redrawn from the Illinois Natural History Survey).

Both nymphs and adults feed on the upper surfaces of leaves during the day. Nymphs resemble the adults except for the absence of wings and a reduced luster. Both nymphs and adults pierce the leaf tissue and suck the sap. The punctured areas on leaves appear as whitish spots **[Plate 14]**. The occurrence of black dots or excreta on the leaf surface is also an indication of the presence of fleahoppers. The female fleahopper lays eggs by inserting them into the leaf tissue of the host plant. Newly emerged nymphs mostly remain on the undersurface of leaves. The life cycle is completed in about six weeks.

**General Treatment:** Because fleahoppers feed on many different weeds, including morning-glory and *Bidens* sp., crop fields and areas adjacent to the fields should be kept free of weed hosts of this pest. They prefer plants grown near the ground. This pest will constantly multiply in the weed hosts and migrate to the crop. Infested plants should be sprayed if fleahopper numbers become a problem. The pest is most damaging to transplants due to the lack of foliage. Refer to Guam's Fruit and Vegetable Guide for specific pesticide recommendations.

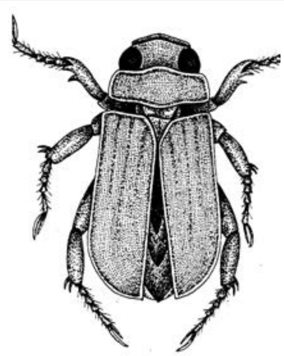
### Beetles

**Philippine ladybeetle** (*Epilachna viginsexpunctata philippensis* (Deck) and **cucumber ladybeetle** (*E. cucurbitae* Richards) attacks plants in the Solanaceae, including tomatoes, eggplants, potatoes, husk tomatoes, but rarely peppers. The Philippine ladybeetle is 1 cm (0.39 inches) in length and is present in all of the southern Mariana Islands **[Plate 15]**. The cucumber ladybeetle is 0.75 cm (0.30 inches) in length and is present in American Samoa as well as in other islands in the South Pacific region. The cucumber ladybeetle attacks various species of cucurbits such as cucumbers, pumpkins, and melons. The biology of the two beetles is otherwise very similar. Bright yellow eggs are laid in clusters on the underside of leaves of the host plant. These hatch after 4–5 days into larvae which feed on the undersides of the leaves. The larvae feed for 17–18 days, then pupate where they have been feeding. The pupal stage takes 6 days. The larvae and pupae are bright yellow and spiky all over **[Plate 15B]**. The beetle larvae are easily distinguished from beneficial aphid-eating species of ladybeetles, since the aphid feed ones have dark larvae which move very quickly. The adult aphid-eating ladybeetles in the are bright red and black or pink and black, with few spots; instead of being dull-orange with many spots, which is the color of both the *Epilachna* species. Both adult and larvae feed on the leaves of their host plant leaving distinctive parallel brown scrape marks on the leaves. Breeding is continuous, so all stages of the beetle may be found on the plant at any given time. On Guam, they have been seen to develop on the weeds *Solanum nigrum* and *S. guamense*.

**General Treatment**: A parasitic wasp, *Pediobius foveolatus*, has been introduced to Guam and the Northern Marianas. It attacks the pupal stages of the beetle and keeps the numbers down, so that it is rarely a pest in these areas. However, as it does not always keep the beetles under control, it is necessary to monitor beetle numbers, and spray if they become too numerous. If it becomes necessary to spray, the beetles are readily controlled with insecticides. Refer to Guam's fruit and Vegetable Guide for pesticide recommendations.

**Chinese Rose Beetle**, *Adoretus sinicus* (Burmeister) is a night feeder. During the day, they remain under leaves, loose bark, or are shallowly buried in the soil. Emerging at dusk, adults feed on leaves between the leaf veins creating leaves with a lace-like or shot hole appearance **[Figure 14.18]**.

A.



B.

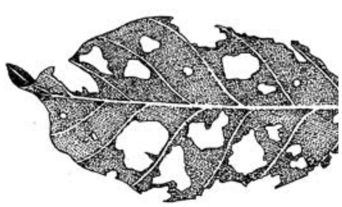


**Figure 14.18. [A]** Chinese rose beetle, Adoretus sinicus. **[B]** rose beetle damage (from Crop Protection for Pacific Islands; ADAP Project, 1995).

The life cycle (egg-adult) is completed in 6–7 weeks. The adult is pale reddish brown beetle, 0.5 inches (1.3 cm) in length. Its body is covered with fine white hairs that give it a grayish appearance. The larval form is a C-shaped, white grub that lives in loose soil and feeds on non-living plant material.

**Oriental flower beetle**, *Protaetia orientalis*, a pest of coconut on Guam, is a black beetle with white spots and is 1.9 cm (0.75 inches) in length. It occasionally causes damage to corn, papaya, mango, and tomato fruits **[Plate 16]**.

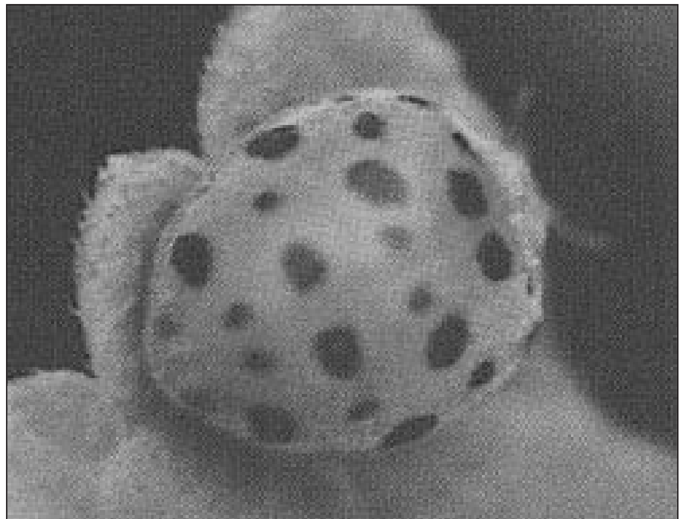


**Figure 14.17.** Philippine ladybeetle, *Epilachna viginsexpunctata* and *E. cucurbitae*. (source unknown).

## Insects and Mites Found in the Western Pacific and Micronesia

**Table 14.1.** List of insects and mites attacking **pepper** crops in the Caroline Islands, Mariana Islands, and Hawaii.

| Scientific Name | Palau | Yap | Truk | Pohnpei | Kosrae | Mariana Islands | Hawaii | Comments |
|---|---|---|---|---|---|---|---|---|
| *Anthonomus eugenii*<br>pepper weevil | | | | | | | X | |
| *Antianthe expansa*<br>solanaceous treehopper | | | | | | | X | |
| *Aphis fabae*<br>leafspot | | | | | | X | X | |
| *Aphis gossypii*<br>cotton or melon aphid | X | X | X | X | X | X | X | on leaves |
| *Bacterocera dorsalis*<br>oriental fruit fly | | | | | | | X | |
| *Bacterocera latifrons*<br>solanaceous fruit fly | | | | | | | X | |
| *Bemisia argentifolii*<br>silverleaf whitefly | | | | | | | X | |
| *Ceratitis capitata*<br>Mediterranean fruit fly | | | | | | | X | |
| *Chloriona formosella*<br>planthopper | | X | | | | X | | sucks sap |
| *Contarinia maculipennis*<br>blossom midget | | | | | | | X | |
| *Epilachna vigntisexpunctata philippensis*<br>Philippine lady beetle | | ? | | | X | | | adult & larva eat leaves |
| *Helicoverpa zea*<br>corn earworm | | | | | | | X | |
| *Heliothis armigera*<br>old world bollworm | | | | | | X | | in fruit |
| *Heliothis zea*<br>corn earworm | X? | | | | | X? | | in fruit |
| *Liriomyza sativae*<br>vegetable leafminer | | | | | | G | | larvae mine lives |
| *Liriomyza trifolii*<br>serpentine leafminer | | N | | N | | G, S? | X | larvae mine leaves |
| *Myzus persicae*<br>green peach aphid | | | | | | S | X | sucks sap from leave |
| *Nezara viridula*<br>southern green stink bug | X | X | X | X | | X | X | leaves, stems, fruit |
| *Ostrinia furnacalis*<br>Asian corner borer | X | | | | | | X | bore in fruit |
| *Paracoccus marginatus* Williams<br>papaya mealybug | | | | | | G | | |
| *Phenacoccus gossypii*<br>Mexican mealybug | | | | | | | X | |
| *Phytorus lineolatus*<br>phytorus leaf beetle | | | | | | X | | eats leaves |

**Table 14.1.** List of insects and mites attacking **pepper** crops in the Caroline Islands, Mariana Islands, and Hawaii (continued).

| Scientific Name | Palau | Yap | Truk | Pohnpei | Kosrae | Mariana Islands | Hawaii | Comments |
|---|---|---|---|---|---|---|---|---|
| *Pinnaspis strachani* hibiscus snow scale | | | | | | | X | |
| *Polyphagotarsonemus latus* broad mite | | | | | | X | X | scars leaves and fruits |
| *Pseudaulacaspis penttagona* white peach scale | X | | X | | | X | | on stems |
| *Sophonia rufofascia* two-spotted leafhopper | | | | | | | X | |
| *Spodoptera exigua* beet armyworm | | | | | | | X | |
| *Spodoptera litura* rice cutworm | X | ? | X | X | ? | X | | larvae eats leaves |
| *Steneotarsonemus pallidus* cyclamen mite | | | | | | | X | |
| *Strymon echion* larger lantana butterfly | | | | | | | X | |
| *Thrips hawaiiensis* Hawaiian flower thrips | | | | | | | X | |
| *Thrips palmi* melon thrips | | N | | | | G | X | scars leaves |

**N** New island record.

**Y** Confirmation of a species previously reported as maybe present or needs verification.

**?** Species may be there but its presence has not been verified with absolute certainty.

**X** Present

**G** Guam

**S** Saipan

**R** Rota

**C** Commonwealth of the Northern Marianas

This list is derived from a number of sources including Insect Pests of Micronesia web site; the Major Invertebrate Pests and Weeds of Agriculture and Plantation Forestry in the Southern and Western Pacific website and Hawaii Pest Database website.

**Table 14.2.** List of insects and mites attacking **tomato** crops in the Caroline Islands, Mariana Islands, and Hawaii.

| Scientific Name | Palau | Yap | Truk | Pohnpei | Kosrae | Mariana Islands | Hawaii | Comments |
|---|---|---|---|---|---|---|---|---|
| *Aculops lycopersici*<br>tomato russet mite | | | | | | | X | |
| *Agrotis ipsilon*<br>black cutworm | | | | | | | X | |
| Amorbia emigratella<br>Mexican leafroller | | | | | | | X | |
| *Anomis flava*<br>hibiscus caterpillar | X | X | | | | X | | eats leaves |
| *Antianthe expansa*<br>solanaceous treehopper | | | | | | | X | |
| *Aphis gossypii*<br>cotton or melon aphid | X | X | X | X | X | X | X | sucks sap |
| *Aphis middletonii*<br>erigeron root aphid | | | | | | | X | |
| *Aspidiotus destructor*<br>coconut scale | X | X | X | X | | X | X | on leaves sucks saps |
| *Atractomorpha sinensis*<br>pink-winged grasshopper | | | | | | | X | |
| *Bacterocera cucurbitae*<br>melon fly | | | | | | | X | |
| *Bacterocera latifrons*<br>solanaceous fruit fly | | | | | | | X | |
| *Bemisia argentifolii*<br>silverleaf whitefly | | | | | | G | X | on leaves, vectors virus |
| *Bemisia tabaci*<br>sweet potato whitefly | X | | | ? | | X | X | on leaves, vectors virus |
| *Chrysodeixis chalcites*<br>green garden looper | N | | | | | X | | eats leaes |
| *Chrysodeixis eriosoma*<br>green garden looper | | | | | | | X | eats leaves |
| *Contarinia maculipennis*<br>blossom midge | | | | | | | X | |
| *Crytopeltis tenuis*<br>tomato bug | X | | X | X | | X | X | distort leaves |
| *Dacus cucurbitae*<br>melon fly | | | | | | X | | bores into fruit |
| *Empoasca pitiensis*<br>green leafhopper | | | | | | ? | | sucks sap from leaves |
| *Epilachan vigintisexpunctata philippensis*<br>Philippine lady beetle | | ? | | | X | | | adult & larva eat leaves |
| *Epitrix hirtipennis*<br>tobacco flea beetle | | | | | | G | | chews pit-like holes in leaves |
| *Eudocima (Othreis) fullonia*<br>fruit piercing moth | N | | | N | N | X | | pierces fruit |
| *Epitrix hiripennis*<br>tobacco flea beetle | | | | | | | X | |

**Table 14.2.** List of insects and mites attacking **tomato** crops in the Caroline Islands, Mariana Islands, and Hawaii (continued).

| Scientific Name | Palau | Yap | Truk | Pohnpei | Kosrae | Mariana Islands | Hawaii | Comments |
|---|---|---|---|---|---|---|---|---|
| *Ferrisia virgata* striped mealybug | X | X | X | X | | X | X | on leaves, stems |
| *Frankliniella occidentalis* western flower thrips | | | | | | | X | |
| *Frankliniella schultzei* yellow flower thrips | | | | | | | X | |
| *Helicoverpa zea* corn earworm | | | | | | | X | |
| *Heliothis armigera* old bollworm | | | | | | X | | eats fruits, leaves |
| *Heliothis zea* tomato fruitworm, corn earworm | X? | | | | | X? | X | eats fruits |
| *Hercinothrips femoralis* banded greenhouse thrips | | | | | | | X | |
| *Hyperomyza lactucae* aphid | | | | | | | X | |
| *Icerya aegypttiaca* Egyptian fluted scale | X | X | X | X | | X | | on leaves |
| *Icerya seychellarum* seychelles scale | ? | X | | | | | | on leaves, fruits |
| *Leptoglossus australis* leaf-foot plant bag | X | | | X | | X | | sucks sap, fruit |
| *Lipaphis erysimi* turnip aphid | | | | | | X | X | sucks sap from leaves |
| *Liriomyza sativae* vegetable leafminer | | | | | | G | X | larvae mine leaves |
| *Liriomyza trifolii* serpentine leafminer chrysanthemum leafminer | | N | | N | | G, S? | X | larvae mine leaves |
| *Macrosiphum euphorbiae* potato aphid | | | | | | | X | |
| *Melanaphis sacchari* sugarcane aphid | | | | | | | X | |
| *Myzus persicae* green peach aphid | | | | | | | X | |
| *Nesophrosyne argentatus* common brown Australian leafhopper | X | X | | | | X | | sucks sap |
| *Nezara viridula* southern green stink bug | X | X | X | X | | X | X | leaves, stems, fruit |
| *Othreis fullonia* Pacific fruit-piercing moth | | | | | | | X | pierces fruit |
| *Parcoccus marginatus* Williams papaya mealybug | | | | | | G | | |

**Table 14.2.** List of insects and mites attacking **tomato** crops in the Caroline Islands, Mariana Islands, and Hawaii (continued).

| Scientific Name | Palau | Yap | Truk | Pohnpei | Kosrae | Mariana Islands | Hawaii | Comments |
|---|---|---|---|---|---|---|---|---|
| *Pentalonia nigronervosa*<br>banana aphid | X | X | X | X | N | X | X | on leaves |
| *Periodroma saucia*<br>variegated cutworm | | | | | | | X | |
| *Phenacoccus madeirensis*<br>mealybug | | | N | N | | G | | on leaves |
| *Phenacoccus gossypii*<br>Mexican mealybug | | | | | | | X | |
| *Phthorimaea operculella*<br>potato tubeworm | | | | | | | X | |
| *Planococcus citri*<br>citrus mealybug | X | X | X | X | X | X | X | on leaves, roots |
| *Polyphagotarsonemus latus*<br>broadmite | | | | | | X | X | scars leaves, fruits |
| *Protaetia orientalis*<br>oriental flower beetle | | | | | | G | | common pest on a number of plants on Guam |
| *Spodoptera exempta*<br>nutgrass armyworm | | | | | | | X | |
| *Spodoptera exigua*<br>beet armyworm | | | | | | | X | |
| *Spodoptera litura*<br>rice cutworm | X | ? | X | X | ? | X | | larvae eats leaves |
| *Tetranychus turnidus*<br>carmine spider mite | | | | | | X | X | under leaves |
| *Thrips tabaci*<br>onion thrips | X | X | | | | X | X | scars leaves |
| *Trialeurodes vaporariorum*<br>greenhouse whitely | | | | | | | X | |
| *Vesiculaphis caricis*<br>aphid | | | | | | | X | |

**N** New island record.

**Y** Confirmation of a species previously reported as maybe present or needs verification.

**?** Species may be there but its presence has not been verified with absolute certainty.

**X** Present

**G** Guam

**S** Saipan

**R** Rota

**C** Commonwealth of the Northern Marianas

This list is derived from a number of sources including Insect Pests of Micronesia web site; the Major Invertebrate Pests and Weeds of Agriculture and Plantation Forestry in the Southern and Western Pacific website and Hawaii Pest Database website.

**Table 14.3.** List of insects and mites attacking **eggplant** crops in the Caroline Islands, Mariana Islands, and Hawaii.

| Scientific Name | Palau | Yap | Truk | Pohnpei | Kosrae | Mariana Islands | Hawaii | Comments |
|---|---|---|---|---|---|---|---|---|
| Adoretus sinicus<br>Chinese rose beetle | X | | | | | X | X | eats leaves |
| Agrotis ipsilon<br>black cutworm | | | | | | | X | |
| Aleurothrixus floccosus<br>wooly whitefly | | | | | | | X | |
| Amorbia emigratella<br>Mexican leafroller | | | | | | | X | |
| Andaspis punicae<br>scale | X | | | | | G | | on stems |
| Antianthe expansa<br>solanaceous treehopper | | | | | | | X | |
| Anthonomus eugenii<br>pepper weevil | | | | | | | X | |
| Aonidiella orientalis<br>oriental scale | | X | | | | X | | on leaves |
| Aphis gossypii<br>cotton or melon aphid | X | X | X | X | X | X | X | on leaves |
| Aspidiotus destructor<br>coconut scale | X | X | X | X | | X | X | on leaves |
| Bactrocera latifrons<br>solanaceous fruit fly | | | | | | | X | |
| Bemisia argentifolii<br>silverleaf whitefly | | | | | | | X | |
| Bemisia tabaci<br>sweet potato whitefly | X | | | ? | | X | X | on leaves |
| Chrysodeixis chalcites<br>green garden looper | N | | | | | X | | eats leaves |
| Chrysodeixis eriosoma<br>green garden looper | | | | | | | X | |
| Chrysomphalus dictyospermi<br>Dictyospermum scale | X | | X | | | X | X | on leaves, fruit |
| Empoasca solana<br>southern garden leafhopper | | | | | | | | |
| Empoasca stevensi<br>Stevens leafhopper | | | | | | | X | |
| Epilachna vigintisexpunctata<br>Philippine lady beetle | | ? | | | X | | | adult & larva eats leaves |
| Epitrix hirtipennis<br>tobacco flea beetle | | | | | | G | X | chews pit-like holes in leaves |
| Ferrisia virgata<br>striped mealybug | X | X | X | X | | X | X | on leaf, stem, fruit |
| Franklinella schultzei<br>yellow flower thrips | | | | | | | X | |
| Helicoverpa zea<br>corn earworm | | | | | | | X | |

**Table 14.3.** List of insects and mites attacking **eggplant** crops in the Caroline Islands, Mariana Islands, and Hawaii (continued).

| Scientific Name | Palau | Yap | Truk | Pohnpei | Kosrae | Mariana Islands | Hawaii | Comments |
|---|---|---|---|---|---|---|---|---|
| Heliothis armigera<br>old world bollworm | | | | | | X | | |
| Heliothis zea<br>corn earworm | X? | | | | | X? | X | on leaves |
| Hercinothrips femoralis<br>banded greenhouse thrips | | | | | | | X | on leaves |
| Icerya purchasi<br>cottony cushion scale | | | | | | | X | |
| Icerya seychellarum<br>seychelles scale | ? | X | | | | | | on leaves, fruits |
| Keiferia lycopersicella<br>tomato pinworm | | | | | | | X | |
| Lema trilinea<br>Three-lined potato beetle | | | | | | | X | |
| Leptocentrus taurus<br>eggplant horned planthopper | | | | | | X | | on stems, leaves |
| Leptoglossus australis<br>leaf-footed plant bug | X | | | X | | X | | sucks sap |
| Leucothrips pierci<br>thrips | | | | | | | X | |
| Liriomyza sativae<br>vegetable leafminer | | | | | | | X | |
| Liriomyza trifolii<br>serpentine leafminer<br>chrysnathemum leafminer | | N | | N | | G,<br>S? | X | larvae mine leaves |
| Lygus kusaiensis<br>Kosrae lygus bug | | | | | X | | | on leaves |
| Macrosiphum euphorbiae<br>potato aphid | | | | | | | X | |
| Myzus persicae<br>green peach aphid | | | | | | S | X | sucks sap from leaves |
| Nezara viridula<br>southern green stink bug | X | X | X | X | | X | X | leaves, stems, fruit |
| Parasaissetia nigra<br>nigra scale | X | X | X | | X | X | X | on leaves |
| Paracoccus marginatus<br>Williams<br>papaya mealybug | | | | | | G | | |
| Phenacoccus gossypii<br>Mexican mealybug | | | | | | | X | |
| Phthorimaea operculella<br>potato tuberworm | | | | | | | X | |
| Physomerus grossipes<br>large spined-footed bug | N | | | | | X | | sucks sap |
| Pinnaspis strachani<br>lesser snow scale | X | X | X | X | | X | X | on stem |

**Table 14.3.** List of insects and mites attacking **eggplant** crops in the Caroline Islands, Mariana Islands, and Hawaii (continued).

| Scientific Name | Palau | Yap | Truk | Pohnpei | Kosrae | Mariana Islands | Hawaii | Comments |
|---|---|---|---|---|---|---|---|---|
| Planococcus citri<br>citrus mealybug | X | X | X | X | X | X | X | on leaves, roots |
| Polyphagotarsonemus latus<br>broad mite | | | | | | X | X | scars leaves, fruits |
| Protoparce sp.<br>hornworm | | | | | | C | | larvae eats leaves |
| Psuedococcus virburni<br>obscure mealybug | | | | | | | X | |
| Saissetia coffeae<br>hemispherical scale | X | X | X | X | | X | X | on leaves, twigs |
| Spodoptera litura<br>rice cutworm | X | ? | X | X | ? | X | | larvae eats leaves |
| Spodoptera mauritia<br>lawn armyworm | | | | | | X | | eats leaves |
| Strymon echion<br>larger lantana butterfly | | | | | | | X | |
| Sundapteryx biguttula<br>Indian cotton jassid | ? | | | | | G, S | | burns leaves |
| Tetranychus cinnabarinus<br>carmine spider mite | | | | | | X | X | under leaves |
| Tetranychus tumidus<br>spider mite | | | | | | X | X | under leaves |
| Trialeurodes vaporariorum<br>greenhouse whitefly | | | | | | | X | |
| Thrips nigropilosus<br>chrysnathemum thrips | | | | | | | X | |
| Thrips palmi<br>melon thrip | | N | | | | G | X | |

**N** New island record.

**Y** Confirmation of a species previously reported as maybe present or needs verification.

**?** Species may be there but its presence has not been verified with absolute certainty.

**X** Present

**G** Guam

**S** Saipan

**R** Rota

**C** Commonwealth of the Northern Marianas

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# Chapter 14 Weeds

**Roland Quitugua, Extension Plant Pathologist**
**Mari Marutani, Horticulturist**
**James McConnell, Ornamental Horticulturist**
**Robert L. Schlub, Extension Plant Pathologist**

All plants are in some way useful, but are referred to as weeds when they become undesirable. There are many reasons weeds are undesirable; a few are list below.

1. They compete with crops for nutrients, light, air (carbon dioxide) and water.
2. They serve as hosts for insect pests and diseases of crop plants.
3. They interfere with farm operations and increase production costs.
4. They reduce human efficiency through allergies and poisoning.

Weeds are more competitive and persistent than cultivated crops. They have effective mechanisms for persisting in the environment and reproducing. Seed production of weeds is usually prolific. Weed seeds are disseminated by rain, irrigation water, wind, man, and animals. Planting crops using seeds contaminated by weed seeds is also another means of dissemination. Weeds also reproduce by forming vegetative organs such as rhizomes, tubers, corms, and runners. The seeds and vegetative organs can remain dormant if environmental conditions are not favorable for plant development and growth. Weeds out-compete most crops by being faster at germination and growth.

How prolific weeds are at a particular farm site depends on the soil, weather, and biological factors. Important soil factors include moisture content, soil pH, soil temperature, and availability of soil nutrients. Daily temperatures, rainfall, and wind conditions are weather factors. Biological influences are those from animals, plants, insects, and soil organisms.

## Classification of Weeds

On Guam, most weeds are perennials, meaning they are able to live almost indefinitely. Because of Guam's warm climate, many plants continue to survive after a cycle of seed production. Common weeds found in Guam's cultivated fields can be classified into three major groups according to their appearance. The first group is broadleaf weeds **[Table 15.1]** of which nearly all are dicots [**Figures 15.1**, **15.3**, **15.5**, **15.6**]. A few plants in this group have narrow leaves, however, their control is similar to other broadleaf weeds. Broadleaf weeds are further divided into vines and non-vines. Vines on Guam such as morning-glory **[Figure 15.3]**, cause economic loss by over-growing crops such as eggplants, peppers, or tomatoes. Once this has occurred, hand-pulling becomes the only means of control, thereby greatly reducing production costs.

The second group of weeds is grasslike weeds [**Table 15.1**]. Most of these weeds or monocots [**Figures 15.2**, **15.4**, **15.7**, **15.8**]. This group includes the grasses **[Figure 15.2]** and sedges. Grass and sedges have well-developed fibrous root systems which are efficient in absorbing nutrients even in harsh soil conditions. Grasses produce numerous seeds and often reproduce vegetatively by stolons and runners. Purple nutsedge (*Cyperus rotundus* L.), a member of the sedge group, is considered the worst weed in many tropical regions. Purple nutsedge reproduces by tubers and tuberlets, and the persistence of these root structures make them permanent residents in most fields. It is nearly impossible to eradicate purple nutsedge from an infested field.

The third group of weeds is parasitic plants. They attach themselves to the stems and leaves of vegetable crops. One important plant species in this category on Guam is dodder (*Cuscuta campestris* Yuncker). This vine has structures that penetrate into the leaves and stems of a host plant through which it absorbs nutrients and water. More information can be found in the section on dodder in **Chapter 12: Plant Diseases**.

The federal government classifies weeds as common or noxious. A federal law known as the Noxious Weed Act was passed in 1974 to help prevent the spread of plants that are difficult to control.

**Figure 15.1.** The Guam daisy, *Bidens alba*, is an example of a dicot weed; note its broad leaves.

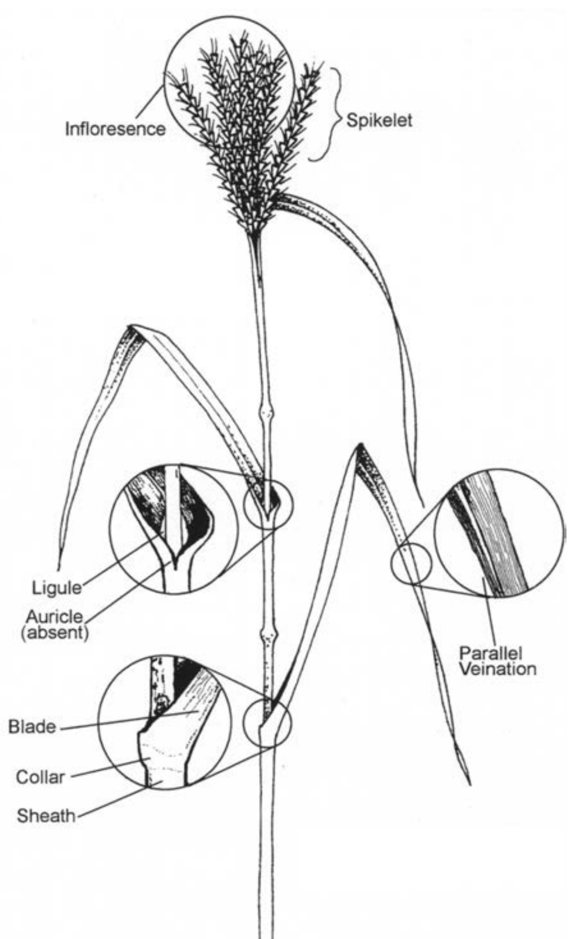



**Figure 15.2.** Grass is an example of a monocot weed; note its narrow leaves.

Refer to **[Table 16.1]** in **Chapter 16: Regulations Regarding the Importation of Propagative Plant Material** for more information.

## Principles of Weed Control

A successful weed control program for a farm on Guam aims to prevent and suppress weed populations. Rarely is total eradication of weeds possible or economically feasible in field situations. However, eradication can be successful in greenhouses and small farming operations. A good weed control plan:

1. Reduces weed populations to levels that allow optimum crop yield.
2. Begins before planting. Various control methods timed properly before planting can eliminate flushes of weeds before they have a chance to cause crop damage.
3. Controls weeds while young before they reproduce by seed or by vegetative means.

## Methods of Weed Control

### Biological Control

Biological control involves the use of biological agents such as animals, insects, and plant pathogens. Using a farm area as pasture for cattle, horses, or goats during fallow periods can reduce weeds. The grazing of these animals along the perimeter of fields creates a buffer zone during the cropping season reducing the amount of pests and plant diseases along the field edge. Swine are known to feed on the tubers of nutsedge. Geese and chickens feed on a wide range of weed species. Specific insects and plant pathogens can also be used to control weeds.

### Cultural Control

Cultural control involves the use of weed reducing management practices such as sanitation, tillage, control burning, mowing, mulching, and solarization.

**Sanitation** involves making sure planting materials and farm equipment are clean and weed-free before moving from one field to another.

**Tillage** is used to cut or bury weeds and is accomplished by hand or mechanical means. **Deep till** is done during field preparation to control persistent weeds and loosen compacted soil. Deep tillage also brings viable weed seeds to the surface where they germinate when air, light, and moisture levels are adequate. To reduce the amount of weed seeds brought to the surface, **shallow till** should be considered. A third form of tillage is the **low-to-no-till** method. Low-to-no-till weed control reduces disruption of the soil surface thereby minimizing weed seed germination and soil structure fracturing. For more information, refer to the section on **Site Preparation** in **Chapter 3: Production**.

**Figure 15.3.** Blue morning-glory *Ipommoea congesta* R. Br. is a viny broadleaf weed with a woody base and deep large root system. Flowers are bell-shaped, 2 to 3 inches long. Leaves are heart-shaped 3 to 4-1/2 inches (Haselwood, E.L., G.G. Motter 1983. Handbook of Hawaiian Weeds).

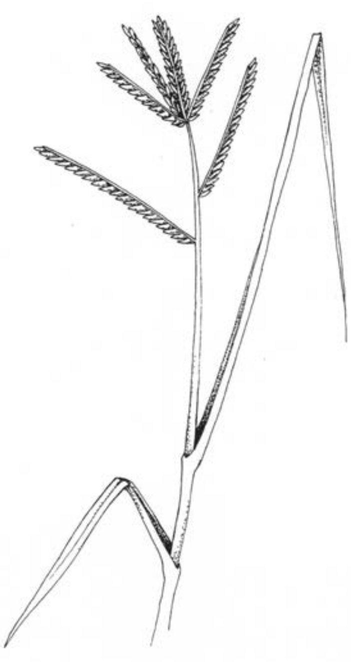


**Figure 15.4.** Goose grass, *Eleusine indica*

**Burning** can control woody weed species, shallow rooted weeds, and weed seeds on the soil surface. Prior to any field burning, a fire permit must be obtained from the Guam Department of Agriculture Forestry section. They can assist in monitoring the burning and recommend any needed fire-breaks. Spot burning can be accomplished with a portable propane weed burner.

**Mowing** keeps weeds from competing with crops and can eliminate taller growing weed species. Mowing also increases soil organic matter, reduces the spread of soilborne pathogens, and reduces erosion by stabilizing the soil especially on sloped areas or between row plants.

**Mulching** is the use of barriers made of synthetic or organic materials to control weed seed germination and/or plant growth. Plastic mulches are available in different colors for various reasons. Black is the most effective for weed control because the color prevents light penetration. Reflective mulches (silver and white) are used to control weeds, aphids, and whiteflies. These mulches act like a mirror and reflect UV light as well as other parts of the light spectrum into the atmosphere. Aphids and whiteflies are ultra sensitive to UV rays and tend to avoid the area. By controlling aphids and whiteflies, viruses spread by these insects are also controlled. Tomatoes have been shown to have increased yields when red mulch is used rather than black. Organic mulches are made of plant materials such as hay, straw, leaves, and mowed cover crops. The thicker the mulch, the greater the weed control. Synthetic weed barriers, also known as geotextile mulches, are used by retail garden centers. They control weeds in a manner like plastic mulches, but allow rain penetration like organic mulches. With a usable life of 10 years, they are considerably more durable than plastic mulches that last 1 to 2 years.

**Solarization** is more suited for small farm operations for economic reasons. The process involves covering the soil with a clear polyethylene sheeting which raises the soil temperature. Increased soil temperature controls some species of weeds, insects, and soil-borne pathogens. Most weeds are controlled by solarization. Those that are not controlled may have heat-tolerant seeds or a deep lying root system or produce bulbs. For best results, solarization should beginning with tilling and moistening the soil. The soil is then covered with clear polyethylene sheeting which is secured loosely to allow room for the growth of any weeds. After a minimum of 21 days, the sheeting is removed. Solarization followed by a herbicide treatment has

**Table 15.1.** Some common weeds occurring in farms on Guam.

| Scientific Name | Common Name | Family Name |
|---|---|---|
| **BROADLEAVES** | | |
| **Viny weeds** | | |
| *Ipomoea indica* (Burm.) Merr. (Figure 15.3) | Blue morning glory | Convolvulaceae |
| *Passiflora foetida* L. | Wild passion fruit | Passifloraceae |
| *Momordica charantia* L. | Wild bittermelon | Cucurbitaceae |
| **Non-viny weeds** | | |
| *Acalypha indica* L. var. *indica* | Acalypha | Euphorbiaceae |
| *Amaranthus spinosus* L. (Plate 39) | Kulites; Klutes; Spiny amaranthus | Amaranthaceae |
| *Bidens alba* (L.) DC (Figure 15.1) | Beggar's tick; Guam daisy; biden | Asteraceae |
| *Boerhavia erecta* L. | Dafao | Nyctaginaceae |
| *Cleome viscosa* L. | Monggos-paluma | Capparidaceae |
| *Commelina benghalensis* L. | | Commelinaceae |
| *Conyza canadensis* (L.) Cronq. | | Asteraceae |
| *Corchorus aestuans* L. | Bilimbines chaka; Tuban chaka | Tiliaceae |
| *Chamaesyce heterophylla* L. (Plate 36, Figure 15.6) | Dwarf poinsettia | Euphorbiaceae |
| *Chamaesyce hirta* (L.) Millspaugh (Plate 37) | Golondrina, euphorbia | Euphorbiaceae |
| *Chamaeyce cyathophora* Murr. | Dwarf poinsettia | Euphorbiaceae |
| *Mimosa pudica* L. | Sleeping plant | Fabaceae |
| *Portulaca oleracea* L. (Plate 38) | Pigweed; purslane | Portulacaceae |
| *Physalis angulata* L. (Plate 34) | Tomato chaka | Solanaceae |
| *Stachytarpheta jamaicensis* (L.) Vahl (Plate 35) | Rat tail | Verbenaceae |
| **GRASSLIKE WEEDS** | | |
| **Grasses (Figure 15.2)** | | |
| *Cenchrus echinatus* L. (Plate 41) | Sandbur | Poaceae |
| *Dactyloctenium aegyptium* (L.) Willd | Crowfoot grass | Poaceae |
| *Digitaria sanguinalis* (L.) Scop. | Large crabgrass; hairy crabgrass | Poaceae |
| *Digitaria violascens* Link | Small crabgrass; smooth crabgrass | Poaceae |
| *Eleusine indica* (L.) Gaertn. (Figure 15.4) | Goose grass | Poaceae |
| *Paspalum conjugatum* Berg. (Figure 15.8) | Sour grass; T-grass | Poaceae |
| *Pennisetum polystachyon* (L). Schult (Plate 40) | Foxtail, boksu | Poaceae |
| **Sedges** | | |
| *Cyperus rotundus* L. (Figure 15.7) | Purple nutsedge | Cyperaceae |
| *Cypertus kyllingia* Endl. (Plate 42) | Sedge, cyperus | Cyperaceae |
| **PARASITIC WEEDS** | | |
| *Cuscuta campestris* Yuncker (Plate 33) | Dodder | Convolvulaceae |

**Figure 15.5.** Wild bittermelon *Momordica charantia* L. is a broadleaf viny weed with yellow flowers and orange fruit with red seeds at maturity (Illustration courtesy of the Southeast Asia Weed Information Center).

**Figure 15.6.** Dwarf poinsettia *Chamaeyce heterophylla* L. is a non-viny broadleaf weed with milky sap and uppermost leaves with red blotches (Illustration courtesy of the Southeast Asia Weed Information Center).

been shown to significantly reduce the number of nutsedge weeds by 90%.

### Chemical Weed Control

Chemical weed control, when used properly, can increase crop profit margins by reducing labor costs associated with weeding. Since herbicides have a residual soil life that varies from months to years, label guidelines should be followed to reduce damage to future crops. Some herbicides are classified as Restricted Use Pesticides (RUP's) and can only be purchased and applied by licensed certified applicators. Before using any herbicides (weed killer), one must first identify the kinds of weeds to be controlled and then choose the proper herbicide for the job. If used improperly, herbicides can harm crops, people, and/or the environment. Always read the pesticide label before use and use the recommended Personal Protective Equipment (PPE). See **Chapter 17: Pesticide Safety** for more details.

The major types of herbicide formulations are emulsions, wettable powders, and granules. An emulsion is one liquid dispersed in another liquid, each maintaining its original identity. Without agitation, the liquids may separate. Once thoroughly mixed, little agitation is required. Oil-soluble herbicides are often made for mixing with water as an emulsion. Emulsions often appear milky and are easy to spray.

A wettable powder is made to be applied as a suspension. A suspension consists of finely divided solid particles dispersed in a liquid. Some herbicides are nearly insoluble in both water and oil-like substances. These are usually finely ground to allow them to disperse in a liquid for a period of time. The smaller the particles, the slower the rate of separation. Most wettable powders still require agitation to prevent the settling of the solid particles. Higher density liquids, such as oils, also slow down the rate of separation.

Granules are applied in a dry form. They are generally mixed with carriers such as sand, clay, or finely ground plant parts. The advantage to granules is that water and spray equipment are not needed. Granules are bulky and are difficult to uniformly apply.

Several types of herbicides are available depending on specific usage and mode of action.

**Selective herbicides** are pesticides that kill some plants while not harming others.

**Figure 15.7.** Purple nutsedge *Cyperus rotundus* L. is a grasslike weed with triangular solid stems and rhizomes and tubers (Illustration courtesy of the Southeast Asia Weed Information Center).

**Figure 15.8.** Sour grass or T- grass *Paspalum conjugatum* Berg. is a rapid creeping grass weed with T-shaped inflorescence (Illustration courtesy of the Southeast Asia Weed Information Center).

**Systemic herbicides** are absorbed by the weeds via the leaves or roots and translocated throughout the weed. Complete coverage is not necessary for control of the weed.

**Contact herbicides** kill plant parts which it come in contact. These herbicides are rarely selective, meaning they will kill all plants. Parts of the plant not exposed to the chemical are not damaged and can initiate new growth; therefore, good coverage on the weed is important.

**Growth regulators** are chemicals that affect growth or metabolic processes in the plant. These herbicides are systemic and move through the plant making them effective in killing the whole plant. Uptake is primarily through the foliage but root uptake may also occur. The plant's response to the chemicals may be delayed, with the full effect not occurring for a week or more after treatment. Some of these chemicals, once mixed, have a short effective life with no residual properties. Growth regulator herbicides which were developed for foliar application may become inactive as soon as they come into contact with the soil.

The rate of application greatly affects the effectiveness of growth regulators. Certain plants may be tolerant of low levels of these chemicals (grasses, for example). Because of this, growth regulator herbicides can often be applied to selectively kill some plants and not others by adjusting the rate of application. However, there are other considerations when selecting an application rate. If the rate of application is too high, the chemical may kill the tissue quickly before it is translocated, making the application less effective. Repeated low application rates may be the most effective. These chemicals are also affected by timing of application. Generally, they are not as effective during midday.

**Preemergence herbicides** are usually applied to the soil surface. Water is used to leach the chemical into the upper soil layer where it is absorbed by soil colloids. These herbicides are designed to remain near the soil surface where they are effective against germinating seedlings while not damaging the root systems of established plants. The amount of rain, the solubility of the herbicide in the water, and the absorption capacity of the soil colloids affect the extent of pesticide leaching. It is important to avoid disturbing the soil to eliminate the possibility of a break in the herbicide barrier, which would allow weeds to germinate.

**Soil sterilants** are chemicals applied to the soil which non-selectively kill living organisms. They are generally applied during field preparation and are not used after the field is planted.

# Chapter 16 Regulations Regarding the Importation of Propagative Plant Material

**Mitchell Nelson, USDA, APHIS PPQ Federal Director**

The responsibility of the United States Department of Agriculture (USDA) Animal Plant Health Inspection Service (APHIS) and Plant Protection Quarantine (PPQ) are to keep exotic plant pests out of the US, including Guam, and the CNMI. APHIS regulatory authority extends to all foreign importations including plant material from Hawaii, Guam, and the CNMI. APHIS does this by passing regulations based on scientifically derived pest risk assessments for import commodities and by inspection of regulated plant products allowed entry into the US. APHIS regulatory authority only extends to pests not known to occur in the US, e.g., *Trogoderma granarium* (Khapra Beetle), or of limited distribution, e.g., *Xanthomonas campestris* pv. citri (Citrus Canker). APHIS does not have regulatory authority on pests already known to occur in the US, e.g., *Cucumber mosaic virus*. States and territories have regulatory authority over these common pests if they have a published quarantine list and maintain internal quarantines for those pests. Updated regulatory information on plant importation can be found at the USDA, APHIS, PPQ web site, www.aphis.usda.gov. Regulations covering plant imports are 7 CFR 319.37 and fruit imports are 7 CFR 319.56.

APHIS divides propagative material into four regulatory categories; prohibited, post entry, restrictive, unrestrictive. The first three categories regulate the importation of nursery stock, ornamental trees and shrubs, fruit trees, endangered species such as orchids and cacti, and certain woody seeds of fagus and palm. Any material under the first three categories are required to enter through one of the APHIS's fifteen controlled Plant Inspection Stations (PIS) which are staffed with inspectors specialty trained in high risk plant inspection. The PIS also have an entomologist, plant pathologist, and a botanist on staff to assist in the inspection and identification of pests. The closest PIS to Guam is in Honolulu; therefore, all shipments of these types of propagative material must be routed through Honolulu even though a cheaper or more direct route may exist.

### Prohibited

Prohibited from import into Guam or exported from Guam to the US mainland are many unusual flower, vegetable, and plant seeds. These are considered Federal Noxious Weeds and are prohibited from import into Guam or exported from Guam to the U.S. mainland **[Table 16.1]**. *Ipomea aquatica*, Cancun or water spinach, is an example of a prohibited plant which is considered a Federal Noxious Weed. In addition, states may prohibit certain seeds that they consider as weeds; contact the state department of agriculture before sending unusual seeds to the US mainland.

Plants from the prohibited category includes citrus, many temperate fruit trees like pome fruit from Asia, whole parts of grasses, and bamboo. Prohibited plants require a special entry Departmental Permit, obtained from APHIS headquarters. These permits are only given to research institutions, mainly for developing new varieties or working on a disease, and only with concurrence of local government. These permits are not available for commercial importation.

### Post Entry

Post entry quarantine is required of all fruit and nut nursery stock, e.g., mango, lychee, macadamia nut, and high value ornamental, e.g., rose, chrysanthemum. Plants are required to be isolated at the importer's premises for 1 to 2 years (depending upon the plant). This procedure was set up in order to allow new varieties of high value ornamental plants and fruit trees to enter the US. The primary concern is that these fruit or high value ornamental plants might have a plant pathogen that can go undetected during the entry inspection. Before importers can import these plants, the local government must have entered into a Memorandum of Understanding with APHIS that they will provide inspection services for the plants, and incorporate the APHIS inspection criteria and penalties into local law. This requires the local government to provide regular inspection of the trees for plant diseases by a qualified plant pathologist. The importer agrees to maintain these plants on their property for the required time period and destroy any diseased trees. The importer is not allowed to sell, take cuttings, or grow trees outside the quarantine zone on their property. Contact local APHIS, PPQ Director to determine if the local government has entered into a Post Entry agreement.

#### Restrictive

Restrictive category is normally of most interest to commercial nurseries. This category includes plants that are endangered, e.g., cacti and orchids, seeds, woody shrubs and seeds, and low value ornamentals. Visit the APHIS, PPQ web site, or contact the local PPQ office for a current list of restrictive plants. They still represent a moderate level of pest risk, therefore are required to be imported through an APHIS-PPQ PIS. Importers should have an APHIS import permit, country of origin Phytosanitary Certificate, and local import permit prior to importation. Restricted plants also have age and size limitations; the permit will state import conditions. All orchids and cacti, except those arriving in tissue culture, are considered endangered species, and have very specific documentation requirements. Contact the local APHIS office for specific import requirements for endangered species.

#### Unrestrictive

Unrestrictive is the largest category of plant material. It includes bulbs, most flower, fruit and vegetable seeds, and plants like ferns and dracena. Unrestrictive material does not have to enter through a PIS. Plants in this category are felt to have the lowest pest risk. The primary pests of concern are insects, which can be discovered through routine inspection. Most plant diseases, especially the seedborne ones in vegetable seeds, are already considered to be in the US. Therefore, importers must be aware that the inspection and certification of imported flower and vegetable seeds does not mean they are not infected with a non-exotic disease such as *Cucumber mosaic virus* or *Tomato spotted wilt*. To reduce the likelihood of importing contaminated seeds, purchase seeds from companies that test seed lots for seedborne diseases. Another means of insuring high quality seed is to purchase certified seed. Most states have certification programs administered by the state's crop improvement associations or Cooperative Extension Service. The Association of Official Seed Certifying Agencies (AOSCA) is an organization of certification agencies in the United States and Canada. Therefore, most vegetable seeds including eggplant, pepper, and tomato may enter directly into Guam and CNMI without USDA permits and certification provide the seed company or supplier is in compliance with  local regulations. For instance, companies shipping seeds to Guam are requires to have a commercial import permit which is issued by Guam Department of Agriculture Plant Protection Office, and a Phytosanitary Certificate from the country of origin. A Phytosanitary Certificate is an international certificate of plant health; only attesting to a product's origin and that an inspector of that country quarantine staff has examined the plant for pests. It is not a guarantee that the plant is pest free, only inspected.

### Soil and Plants in Soil

There may need to be a need to have soil analyzed. Soil represents one of the highest pest risk import commodities. Soil can carry plant, animal, and human diseases, insects, and other invertebrate pests. Plants in soil makes inspection very difficult. That is why the US bans most plant importation of plants in soil. To receive soil from a foreign country, the importer must be a laboratory certified to receive soil. The importer must have a quarantine system in place that tracks the soil, must not allow spillage or cross contamination, and must sterilize samples after analysis is completed. There are laboratories certified to receive foreign soil and analyze soil (including the University of Guam); check with the local PPQ office for updated list. Hawaii, Guam, and the CNMI are also under USDA soil quarantines. Therefore, soil sent to the US mainland from these locations must go to an approved soil laboratory.

### Insects for Biological Control or Identification

APHIS is responsible for controlling the movement of live insects, pests, and biological control agents both domestically and foreign. Permits are required for even the most tested biological control agents; to insure that local government does not have any concerns with their effects on local environment. Contact the local APHIS office or the APHIS web site for permit requirements.

Pest identification services are available from a number of local sources; including your nursery, Cooperative Extension, local PPQ, and books on the market. In addition, APHIS may be able to provide identification of new or exotic pests.

### Export Plants and Plant Samples

Federal Regulations require that plants exported to the US mainland and Hawaii from Guam and CNMI meet the same requirements as for those coming from Asia. This is based upon pest risk and not political status. However, these plants do not have to go through a Plant Inspection Station or require federal permits and health certificates; nor do the size and age limitations apply. Citrus, bamboo, betel nut, cancun (Ipomea), and hibiscus are the major plants prohibited. Water bamboo (not a true bamboo) and dracena are two common plants allowed for export. Most vegetable and flower seeds are permitted. However, be aware of various noxious weed regulations. Contact the local PPQ office for a current list of approved plants.

Plant samples, and turf grass, can be sent off island for analysis. If the plant samples are not capable of propagation, no certification is needed if the material is pest free. Turf samples need to be soil free; unless being sent to a certified USDA laboratory.

**Table 16.1.** Federal Noxious Weed List as of November 1, 2001.

| Aquatic/Wetland Habitat Weeds |
|---|
| *Azolla pinatta* (Azollaceae) (mosquito fern, water velvet) |
| *Caulerpa taxifolia* (Caulerpaceae)(Mediterranean clone of caulerpa) |
| *Eichhornia azurea* (Ponterderiaceae) (anchored water hyacinth) |
| *Hydrilla verticillata* (Hydrocharitaceae) (hydrilla) |
| *Hygrophila polysperma* (Acanthaceae) (Miramar weed) |
| *Ipomoea aquatica* (Convolvulaceae) (Chinese water spinach) |
| *Lagarosiphon major* (Hydrocharitaceae) (Oxygen weed) |
| *Limnophila sessiliflora* (Scrophulariaceae) (ambulia) |
| *Melaleuca quinquenervia* (Myrtaceae) (melaleuca) |
| *Monochoria hastata* (Pontederiaceae) (monochoria) |
| *Monochoria vaginalis* (Pontederiaceae) (pickerel weed) |
| *Ottelia alismoides* (Hydrocharitaceae) (duck-lettuce) |
| *Sagittaria sagittifolia* (Alismataceae) (arrowhead) |
| *Salvinia auriculata* (Salviniaceae) (giant salvinia) |
| *Salvinia biloba* (Salviniaceae) (giant salvinia) |
| *Salvinia herzogii* (Salviniaceae) (giant salvinia) |
| *Salvinia molesta* (Salviniaceae) (giant salvinia) |
| *Solanum tampicense* (Solanaceae) (wetland nightshade) |
| *Sparganium erectum* (Sparganiaceae) (exotic bur-reed) |

| Parasitic Habitat |
|---|
| *Aeginetia* spp. (Orobanchaceae) |
| *Alectra* spp. (Scrophulariaceae) |
| *Cuscuta* spp. other than native or widely distributed species (Cuscutaceae) (dodders) |
| *Orobanche* spp. other than native or widely distributed species (Orobanchaceae) (broomrapes) |
| *Striga* spp. (Scrophulariaceae) (witchweeds) |

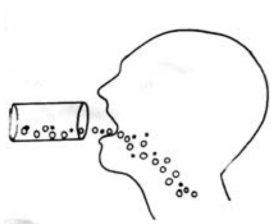
**Table 16.1.** Federal Noxious Weed List as of November 1, 2001 (continued).

| Terrestrial Habitat | |
|---|---|
| Ageratina adenophora (Asteraceae) (crofton weed) | *Pennisetum polystachion* (Poaceae) (missiongrass) |
| *Alternanthera sessilis* (Amaranthaceae) (sessile joyweed) | *Prosopis alapataco* (Fabaceae) (Prosopis spp. are mesquites) |
| *Asphodelus fistulosus* (Liliaceae) (onionweed) | *Prosopis argentina* |
| *Avena sterilis* L. (Poaceae) (animated or wild oat) | *Prosopis articulata* |
| *Spermacoce alata* (Rubiaceae) (borreria) | *Prosopis burkartii* |
| *Carthamus oxyacanthus* (Asteraceae) (wild safflower) | *Prosopis caldenia* |
| *Chrysopogon aciculatus* (Poaceae) (pilipiliula) | *Prosopis calingastana* |
| *Commelina benghalensis* (Commelinaceae) (Benghal dayflower) | *Prosopis campestris* |
| *Crupina vulgaris* (Asteraceae) (common crupina) | *Prospis castellanosii* |
| *Digitaria abyssinica* (=D. scalarum) (Poaceae) (African couch grass) | *Prosopis denudans* |
| *Digitaria velutina* (Poaceae) (velvet fingergrass) | *Prosopis elata* |
| *Drymaria arenarioides* (Caryophyllaceae) (lightening weed, alfombrilla) | *Prosopis farcta* |
| Emex australis (Polygonaceae) (three-cornered jack) | *Prosopis ferox* |
| *Emex spinosa* (Polygonaceae) (devil's thorn) | *Prosopis fiebrigii* |
| *Galega officinalis* (Fabaceae) (goatsrue) | *Prosopis hassleri* |
| *Heracleum mantegazzianum* (Apiaceae) (giant hogweed) | *Prosopis humilis* |
| *Homeria* spp. (Iridaceae) (Cape tulip) | *Prosopis kuntzei* |
| *Imperata brasiliensis* (Poaceae) (Brazilian satintail) | *Prosopis pallida* |
| *Imperata cylindrica* (Poaceae) (cogongrass) | *Prosopis palmeri* |
| *Ischaemum rugosum* (Poaceae) (murain-grass) | *Prosopis reptans* |
| *Leptochloa chinensis* (Poaceae) (Asian sprangletop) | *Prosopis rojasiana* |
| *Lycium ferocissimum* (Solanaceae) (African boxthorn) | *Prosopis ruizlealii* |
| *Melastoma malabathricum* (Melastomataceae) | *Prosopis ruscifolia* |
| *Mikania cordata* (Asteraceae) (mile-a-minute) | *Prosopis sericantha* |
| *Mikania micrantha* (Asteraceae) (mile-a-minute) | *Prosopis strombulifera* |
| *Mimosa invisa* (Fabaceae) (giant sensitive plant) | *Prosopis torquata* |
| *Mimosa pigra* (Fabaceae) (catclaw mimosa) | *Rottboellia cochinchinensis* (Poaceae) (itchgrass) |
| *Nassella trichotoma* (Poaceae) (serrated tussock) | *Rubus fruticosus* (Rosaceae) (wild blackberry complex) |
| *Opuntia aurantiaca* (Cactaceae) (jointed prickly pear) | *Rubus moluccanus* (Rosaceae) (wild blackberry) |
| *Oryza longistaminata* (Poaceae) (red rice) | *Saccharum spontaneum* (Poaceae) (wild sugarcane) |
| *Oryza punctata* (Poaceae) (red rice) | *Salsola vermiculata* (Chenopodiaceae) (wormleaf salsola) |
| *Oryza rufipogon* (Poaceae) (red rice) | *Setaria pallide-fusca* (Poaceae) (cattail grass) |
| *Paspalum scrobiculatum* (Poaceae) (Kodo-millet) | *Solanum torvum* (Solanaceae) (turkeyberry) |
| *Pennisetum clandestinum* (Poaceae) (kikuyugrass) | *Solanum viarum* (Solanaceae) (tropical soda apple) |
| *Pennisetum macrourum* (Poaceae) (African feathergrass) | *Tridax procumbens* (Asteraceae) (coat buttons) |
| *Pennisetum pedicellatum* (Poaceae) (kyasuma-grass) | *Urochloa panicoides* (Poaceae) (liverseed grass) |

All listed seeds and plant parts are prohibited from entry into all parts of the US; and trade within the US. A Plant Pest Permit or Departmental Permit is needed for their import or movement of these seeds.

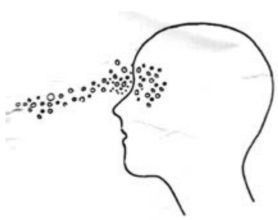
# Chapter 17 Pesticide Safety

**Lee Yudin, Extension Entomologist**
**Victor Artero, Extension Agricultural Economist**

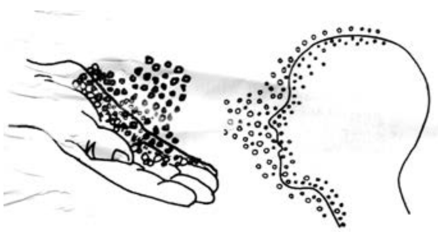


Oral exposure

Inhalation exposure



Ocular exposure



Dermal exposure


Always read the label first!

## Before using any pesticide "Read the Label First."

Pesticides are chemical substances used to kill or reduce pests. When using pesticides, always select the proper pesticide for the pest you are trying to control:

| Pesticide | Pest killed or controlled |
|---|---|
| Insecticide | Insects |
| Fungicide | Fungal pathogens |
| Rodenticide | Rats and mice |
| Herbicide | Weeds |
| Molluscicide | Snails and slugs |
| Algaecide | Algae |

### Pesticide Poisoning

Pesticides can enter the body in four major ways: **oral** exposure (when you swallow a pesticide); **inhalation** exposure (when you inhale a pesticide); **ocular** exposure (when you get a pesticide in your eyes); and **dermal** exposure (when you get a pesticide on your skin). The most common route of exposure is dermal because of handling pesticides without gloves. Pesticide poisoning most commonly occurs in children under five years of age. A simple rule that will help reduce the risk of the number of pesticide poisonings is to **Keep All Pesticides Locked Up and Out of Reach of Children**.

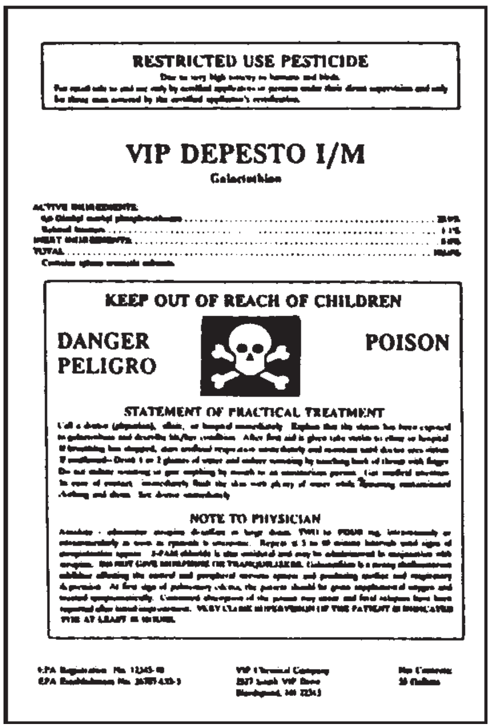
### Pesticide Safety Tips

- **Identify the pest problem.** Most pest control failures are due to improper pest identification. Seek professional assistance for proper identification and control measures. Use the proper pesticide and correct amount to do the job.
- **Follow label instructions carefully.** Always read the label before using the chemical. The label is the law and meant for your safety. It provides information on protective clothing and equipment, first aid treatment, environmental hazards, general and specific use directions, and other vital information.
- **Restricted-Use** pesticides can only be applied by **certified applicators** or those individuals under their direct

Don’t wear soft contact lenses when spraying; they may absorb the pesticide and cause eye irritation.

supervision. The pesticide label states whether or not a pesticide is for restricted use.

- **Wear proper personal protective equipment** when mixing, handling, or applying pesticides. Remember, it is more important to wear personal protective equipment when mixing pesticides because that is when the pesticide is in its most concentrated form.
- **Never mix, handle, or apply any pesticide by yourself.** Make sure you have a partner around in case an accident occurs.
- **Never use kitchen utensils** for pesticide measurements or stirring. Properly label all pesticide measuring spoons, cups, and buckets. Keep them clean and secure properly. **Never reuse pesticide utensils for food**.
- **Mix only the amount needed** to complete the job. Storing mixed pesticides over a period of 24 hours is not recommended. Do not exceed the recommended rate. Check your local pesticide dealer or extension agent for help calibrating your pesticide needs.
- **Never smoke** while mixing, handling, or applying pesticides.
- **Never spray on windy days**. If winds pick up while spraying, stop immediately and resume only when the winds subside.
- **Keep children and pets away** from pesticides and areas that have been treated until it is safe to enter. See the label for specific reentry interval (REI).
- **Remove contaminated clothing and cleanse skin and hair with soap and water**, when a pesticide comes in contact with your skin, hair, or clothing.
- **Never mix clothing** that you have worn when either mixing, handling, or applying pesticides with family laundry. Always wash these clothing separately. Any clothing heavily contaminated should be discarded immediately.
- **Immediately but gently wash out eye** with cold water for 15 minutes or more, when a pesticide comes in contact with your eye. **Never wear contact lenses when applying pesticides**. See a doctor if necessary.
- **Wash your hands and face after any pesticide use.** It is important that this is done before eating, drinking, or smoking.




**Pesticides which carry the least amount of risk are those labeled CAUTION.**

- **Keep pesticide equipment** in **proper working order** by cleaning equipment after each use. **Store equipment in a locked shed or building** separate from pesticides.
- **Never store pesticides** near food, feed, seed, fertilizers, or animals.
- **Never transfer a pesticide to a container**, such as a soft drink bottle, that would attract children.
- **Store pesticides properly** by placing in a cool, dry, well ventilated building, under lock and key, and in the original container with proper labels. The storage area should be supplied with detergent, hand cleaner, water, absorbent material (charcoal, sawdust, paper) to soak up any spills, and a fire extinguisher rated for chemical fires.
- **Dispose of empty pesticide containers safely**. Always rinse out empty containers (metal, plastic, or glass) three times. Pesticide labels give proper disposal directions. “Home Use” pesticide containers may be safely disposed of by wrapping them individually with newspaper, tying them securely, and placing them in a covered trash can. For pesticide spills or further questions about pesticide disposal, you can contact the Guam Environmental Protection Agency (475-1658), or your local Department of Agriculture (735-2082).
- **In case of pesticide poisoning**, refer to the pesticide label immediately for first aid treatment. Then call or go to the doctor or hospital for immediate care. Take the label with you to show to your doctor. Emergency numbers (doctor, hospital, poison center, or 911) should always be clearly posted so anyone can readily call for help.

### Categories of Pesticide Toxicity

Here are three key words to watch for on pesticide labels:

**DANGER** —Highly Toxic. When accompanied with a Skull and Crossbones symbol the toxicity hazard is greatly increased.

**WARNING**—Moderately Toxic.

**CAUTION**—Slightly Toxic.

These signal words reflect the immediate hazard of pesticide exposure only. They do not reflect the hazards of long term exposure to small amounts of pesticides that can accumulate in the body over time.

Home gardeners who wish to apply “least toxic” pesticides should look for those products that contain the signal word **CAUTION**. However, the misuse of any pesticide can cause serious health hazards. Read the label for the proper clothing and protective equipment (chemical resistant gloves, boots, eye wear, and respirator) when using any over the counter pesticide.

## Pesticide Education Safety Program (PESP)

The Guam Cooperative Extension provides educational material and training for those individuals who are required by law to obtain either Private or Commercial certification when mixing, handling, or applying Restricted-Use pesticides. These workshops are offered throughout the year. For further information, please contact your local Cooperative Extension Service.

## Emergencies

In case of an emergency, call the following:

Pesticide Accident Hotline (CHEMTREC): 1-800-4262-8200.
e-mail chemtrec@chemtrec.com

American Association of Poison Control Centers: 1-800-222-1222
e-mail info@aapcc.org

# Part 4. Appendices

# Appendix 1

# Eggplant, Pepper, and Tomato Production Summary

**Robert L. Schlub, Extension Plant Pathologist**
**Frank Cruz, Extension Horticulturist**

| Description | Eggplant | Pepper | Tomato |
|---|---|---|---|
| **Plant Characteristics** | | | |
| Soil pH preference | 5.5 – 7.5 | 6.5 – 7.0 | 5.5 – 7.5 |
| Growth habit | Indeterminate | Indeterminate | Indeterminate<br>semi-indeterminate<br>determinate |
| Maximum root depth | 36 – 48 inches | 36 – 48 inches | greater than 48 inches |
| Pollination | self, insect | self, insect** | self, insect** |
| Seeds per gram | 225 | 150 – 160 | 300 – 350 |
| Transplantability | moderate | moderate | easy |
| Storage life (37–40° F)* | 4 years | 2 years | 4 years |
| **Expected Performance on Guam** | | | |
| Emergence | 3 – 5 days | 7 – 11 days | 3 – 5 days |
| Seed to transplant | 4 – 5 weeks | 4 – 5 weeks | 2 – 4 weeks |
| Transplant to harvest | 60 – 75 days | 50 – 60 days | 60 – 80 days |
| Frequency of harvest | 2 times/week | weekly | 3 – 4 times/week |
| Length of harvest | 4 – 12 months | 2 – 8 months (bell)<br>4 – 12 months (hot) | 1 – 4 months |
| Crop yield per 100 feet | 100 – 200 lbs | 60 – 120 lbs | 100 – 200 lbs |
| Estimated production on Guam (1996–1999) | 40.8 acres | 0.95 acres (bell)<br>3.1 acres (small hot) | 4.7 acres<br>8.7 acres (cherry) |
| Average price growers received for their produce on Guam (1996–2000) | $1.06/lb | $1.54/lb (bell)<br>$3.06/lb (small hot) | $1.50/lb<br>$1.40/lb (cherry) |
| **Guam Recommendations** | | | |
| Planting date | year round | December – March (bell)<br>Not June – September (bell)<br>year round (hot) | December – March<br>Not May – September |
| Seed depth | 1/4 – 1/2 inches | 1/4 – 1/2 inches | 1/4 – 1/2 inches |
| Distance between plants | 3 – 4 feet | 1.5 – 3 feet | 1.5 – 4 feet |
| Distance between rows*** | 6 – 12 feet | 4 – 8 feet | 4 – 8 feet |
| Seed for transplants (100 foot rows) | 1 seed pack | 1 seed pack | 1 seed pack |
| Seeds for transplants (acre) | 1 – 2 oz | 1 – 3.2 oz | 0.5 – 1.5 oz |
| Supplemental water per 100 foot row**** (wet season – dry season) | 20 – 150 gal/week | 10 – 100 gal/week | 20 – 150 gal/week |

* Approximate life of seeds when stored in the refrigerator.
** These crops are mainly self-pollinated but some crossing does occur by insects.
*** The widest spacing is recommended when tilling equipment is used between rows.
**** Estimated water demand per week for plants approaching flowering stage and beyond. An inch of rain is approximately equal to 187 gallons of water per 100 foot row (100 feet x 3 feet).

# Appendix 2 Guam Variety Evaluation Trials

**Mari Marutani, Horticulturist**
**Robert L. Schlub, Extension Plant Pathologist**
**Ruddy Estoy, Jr., Agriculture Extension Assistant**

Cultivar trials provide growers with an opportunity to compare various selections under Guam's soil and environmental conditions. Old reliable varieties as well as new untested ones are chosen for such trials. Characteristics that are commonly evaluated include yield, climactic tolerances, and resistance to pests and disease.

### 2001 Tomato Variety Trial

This section contains information regarding a trial of mid-season tomato varieties conducted from January 19 to May 21 of 2001 at the College of Agriculture and Life Science's Yigo Experiment Station.

**Transplants** were produced in one 3-inch (7.62 cm) deep Todd Planting flat containing potting soil (Sunshine Mix #4). The flat contained 200 one-inch square cells. Thirty seeds of each variety were placed into individual cells on January 19, 2001. After emergence, the seedlings were watered with a starter solution once a week for three weeks. The starter solution consisted of 1 tbsp. (14.9 ml) of water-soluble fertilizer (15-30-15, Miracle-Gro) in 1 gallon of water. Seedlings were grown under shade cloth and "hardened" one week before transplanting on February 15, 2001. To "harden" the seedlings, the flat was exposed to increased hours of direct sunlight.

**Field plot** was located in a $^1/_{20}$ acre field in shallow limestone uplands soil (Guam cobbly clay, pH 7.5). Each variety treatment was planted in mounded rows 5 inches (12.7 cm) in height. Plants were spaced 3 feet (0.9 m) apart and rows 5 feet apart. A preplant of 1.5 kg (3 lbs) of 10-30-10) was banded in a 4-inch (10.1 cm) deep furrow within each row (150 grams/plant). The band was then covered with 3 inches (7.6 cm) of soil resulting in a furrow 1 inch (2.54 cm) deep. The transplants were then planted in each furrow and covered with an additional two to three inches of soil. One week after transplanting, 1 inch (2.54 cm) of soil was mounded around the seedlings.

**Pesticides** were applied only twice. Diazinon was applied four days after transplanting to control ants, which had damaged several seedlings. Seven was applied two weeks before the first harvest to control caterpillars. Weeds were controlled by hand weeding.

**Fertilizer** was applied two weeks after transplanting. A sidedress of 130 g (4.59 oz) of triple sixteen (16-16-16) was applied once a week to each plant.

**Water** was provided by drip irrigation (one line per row) and natural rainfall. Irrigation was done daily for an average of three hours. Plants were not watered during days with moderate rainfall.

**Fruits** were harvested at the onset of color breaking occurring at the bottom of the fruit.

**Data recorded** included marketable and unmarketable fruit yield, average fruit size, and average fruit weight. Values are based only on fruits with firm tissue. Soft fruits due to disease or insect feeding were discarded. Also noted were average plant height and number of fruit per plant.

**Results and Conclusion:** Based on the 2001 trials, all varieties were successfully grown on Guam [**Table A2.1**, **A2.2**]. No one particular variety was superior. Sun Leaper was the poorest performer having the lowest fruit weight, fruit number, and percentage of marketable fruit. Solar Set, a favorite of local farmers, performed well. For descriptions of the 5 hybrid tomato varieties, refer to the section on **Crop Selection** in **Chapter 3: Production**.

**Table A2.1.** Average tomato plant yield obtained from a twenty seedling, 5-variety tomato trial conducted in 2001 during the dry season in Northern Guam.

| Variety | Yield | Number of Fruit | Marketable Fruit | Unmarketable due to: Pest | Cracked | Disease |
|---|---|---|---|---|---|---|
| Sun Chaser | 3.02 kg<br>6.60 lb | 16.33 | 68% | 24% | 6% | 2% |
| Solar Set | 2.96 kg<br>6.53 lb | 15.33 | 70% | 19% | 7% | 4% |
| Heatwave | 3.01 kg<br>6.64 lb | 17.45 | 68% | 16% | 14% | 2% |
| Sunmaster | 2.91 kg<br>6.42 lb | 17.67 | 67% | 19% | 10% | 4% |
| Sun Leaper | 2.42 kg<br>5.34 lb | 15.17 | 59% | 25% | 11% | 5% |

- Fruits were harvested from April 25, 2001 to May 21, 2001.

- Surviving plants were used to determine average (Table 18.2).

**Table A2.2.** Plant and fruit data from a twenty seedling, 5-variety tomato trial conducted in 2001 during the dry season in Northern Guam.

| Variety | % Survived | Average: Plant Height | Fruit Width | Fruit Height | Fruit Weight |
|---|---|---|---|---|---|
| Sun Chaser | 90% | 77.62 cm<br>30.56 in | 7.68 cm<br>3.02 in | 7.41 cm<br>2.92 in | 184.58 gm<br>6.51 oz |
| Solar Set | 90% | 76.87 cm<br>30.26 in | 7.74 cm<br>3.05 in | 6.88 cm<br>2.71 in | 192.88 gm<br>6.80 oz |
| Heatwave | 100% | 70.74 cm<br>27.85 in | 7.76 cm<br>3.06 in | 7.03 cm<br>2.77 in | 172.31 gm<br>6.08 oz |
| Sunmaster | 90% | 74.74 cm<br>29.43 in | 7.63 cm<br>3.00 in | 6.95 cm<br>2.74 in | 164.79 gm<br>5.81 oz |
| Sun Leaper | 90% | 76.63 cm<br>30.17 in | 7.62 cm<br>2.99 in | 6.73 cm<br>2.65 in | 159.6 gm<br>5.63 oz |

- Plant height and survival count taken after the last harvest (May 21, 2001).
- Fruit size (width/height) based on the average of 50 fruits per variety during the peak of harvest (May 2, 2001 to May 8, 2001)

### 1992 Tomato Variety Trial

**Field Plot** was located at the Yigo Experiment Station during the dry season. The soil is a Guam cobbly clay (clayey, gibbsitic, nonacid, isohypothermic, Lithic Ustorthents, pH = 7.5). Eighteen seedlings were transplanted in 2 row/plots (3.6 x 16.4 feet (1.1 x 5 m). Plots were replicated 4 times. During the course of the trial, it rained 17.4 cm (6.85 inches) between February 21, 1992 and May 14, 1992.

**Transplants** were started as seeds on January 14, 1992 and transplanted to the field on February 11, 1992.

**Harvesting** was conducted on March 31; April 1, 3, 6, 9, 13, 14, 15, 16, 17, 20, 22, 24, 27, 29; and May 1, 4, 7, 12, and 14.

**Results and Conclusion:** Philippine Lady beetle (*Epilachna vigintisexpunctata*) and the garden looper (*Chrysodeixis chalcites*) were the main insect pests. Root-knot nematode and *Tobacco mosaic virus* were the main plant pathogens. Physiological disorders observed included secondary vegetative growth at inflorescence, chlorosis, fruit cracking, and blossom-end rot. Dynamo, Solar Set, Tropic Boy, and Master No. 2 all performed well **[Table A2.3]**. Dynamo was the best overall variety; however, Solar Set was the best large tomato variety. To reduce the likelihood of a nematode population buildup, plant Master No. 2 or Dynamo. For more information on tomato varieties, refer to the section on Crop Selection in Chapter 3.

**Table A2.3.** Yield and fruit characterics of tomato cultivars, 1992.

| Cultivar | Source | Growth Habit | Average fruit weight in oz (in grams) | Total marketable weight in oz (in grams) | % Damaged Fruit | Nematode Rating* |
|---|---|---|---|---|---|---|
| Dynamo | Sakata | indeterminate | 1.87 (53) | 3.28 (1,492) | 15.1 | 0.3 |
| Solar Set | Asgrow | determinate | 7.31 (207) | 3.09 (1,403) | 29.9 | 1.7 |
| Tropic Boy | Takii | indeterminate | 6.11 (173) | 2.72 (1,235) | 39.8 | 1.3 |
| Master No. 2 | Takii | indeterminate | 4.87 (138) | 1.87 (850) | 55.0 | 0.0 |
| N-65 | University of Hawaii | indeterminate | 6.00 (170) | 1.78 (811) | 80.7 | 0.0 |
| Firebird | Sakata | indeterminate | 7.10 (201) | 1.63 (742) | 63.3 | 2.0 |
| UH8637 | University of Hawaii | determinate | 6.50 (184) | 1.45 (659) | 62.4 | 1.7 |
| Red Queen | Sakata | determinate | 5.08 (144) | 1.28 (584) | 67.0 | 1.0 |
| Red King | Sakata | determinate | 4.73 (134) | 1.17 (533) | 65.2 | 0.0 |
| Firedance | Sakata | indeterminate | 6.04 (171) | 0.95 (433) | 80.7 | 0.3 |
| Fireball | Sakata | indeterminate | 7.07 (200) | 0.84 (382) | 84.1 | 0.0 |
| Bestom | Takii | indeterminate | 7.17 (203) | 0.62 (284) | 87.5 | 0.0 |

- Fruit soluble solids ranged from 4.04 – 4.88
- Fruit pH ranged from 3.65 – 3.96
- Fruit citric acid percentage ranged from 0.27 – 0.40
- Fruit dry matter percentage ranged from 4.10 – 5.70

### 1992 Hot Pepper Variety Trial

**Field Plot** was located at the Yigo Experiment Station during the wet season. The soil is a Guam cobbly clay (clayey, gibbsitic, nonacid, isohypothermic, Lithic Ustorthents, pH = 7.5). Fourteen plants were planted in 2.95 x 14.76 foot (0.9 x 4.5 m) row/plots. Plots were replicated 1–3 times. During the course of the trial, it rained 17.4 cm (6.85 inches) between February 21, 1992 and May 14, 1992.

**Transplants** were started as seeds and transplanted on to the field on June 2, 1992.

**Harvesting** was conducted on July 8, 15, 22, 29; August 5, 12, 19, 26; September 2, 9, 16, 23, 30; and October 7, 14.

**Results and Conclusion:** Hot Beauty was the best variety based on yield, marketable fruit, and typhoon survival (Table A2.4). For more information on hot pepper varieties, refer to the section on **Crop Selection** in **Chapter 3: Production**.

**Table A2.4.** Evaluation of hot pepper varieties during the wet season in 1992.

| Cultivar | Total Marketable Yield per 10 plants in lbs (kg) | Total number of marketable fruits per 10 plants | Flowering date (days after transplanting) | Plant Survival Rate (%) on October 15, 1992* |
|---|---|---|---|---|
| Hot Beauty | 4.39 (2.00) | 309.0 | 21 | 75.0 |
| Local Selection** | 3.29 (1.50) | 297.5 | 34 | 41.2 |
| Hot Long | 2.90 (1.32) | 83.0 | 20 | 35.7 |
| Twist Green | 2.85 (1.30) | 164.0 | 20 | 14.3 |
| Long Chili | 2.53 (1.15) | 87.0 | 20 | 7.1 |
| Chain Fair | 1.68 (0.77) | 58.5 | 20 | 46.4 |

* Typhoon Omar (August 28, 1992) caused severe plant damages.
** Local selection refers to a variety grown from farmer collected seeds and whose official cultivar name is unknown.

### 1993 Eggplant Variety Trial

**Field Plot** was located at the Yigo Experiment Station during the wet season. The soil is a Guam cobbly clay (clayey, gibbsitic, nonacid, isohypothermic, Lithic Ustorthents, pH = 7.5). Six cultivars were established in plots which were replicated 3 times.

**Transplants** were started as seeds and transplanted on to the field on October 1, 1993.

**Harvesting** was conducted March 16 to October 1, 1993.

**Results and Conclusion:** Varieties resulting from crosses with Nitta were superior to other varieties tested **[Table A2.5]**. For more information on eggplant varieties, refer to the section on **Crop Selection** in **Chapter 3: Production**.

**Table A2.5.** Evaluation of eggplant varieties harvest during the dry and wet seasons in 1993.

| Cultivar | Marketable Yield (t/ha) | Flowering date (Days after Transplanting) | Fresh weight of fruit (g) | % Dry Matter of Fruit | Length (cm) | Weight (kg) |
|---|---|---|---|---|---|---|
| Nitta x Waimanalo | 60.7 | 34 | 157.4 | 6.8 | 24.1 | 3.7 |
| Nitta x Molokai | 55.4 | 40 | 135.8 | 7.2 | 23.6 | 3.7 |
| Pingtung Long | 14.8 | 29 | 117.2 | 8.1 | 23.4 | 3.5 |
| Farmers Long | 19.7 | 29 | 135.5 | 8.3 | 30.2 | 3.5 |
| Long John | 12.0 | < 28 | 127.3 | 7.2 | 25.6 | 4.1 |
| Large Fruited #29 | 13.1 | 40 | 314.7 | 7.2 | 9.5 | 9.5 |
| **Mean** | **29.3** | **33.3** | **164.7** | **7.5** | **22.7** | **4.7** |

### 1994 Eggplant Variety Evaluation of Carmine Spider Mite Infestation

**Field Plot** was located at the Yigo Experiment Station during the wet season. The soil is a Guam cobbly clay (clayey, gibbsitic, nonacid, isohypothermic, Lithic Ustorthents, pH = 7.5). Thirteen cultivars were established in plots which were replicated 3 times. The degree of infestation was determined on February 23, 1994.

**Transplants** were started as seeds on December 17, 1993, and transplanted to the field on February 2, 1994.

**Results and Conclusion:** The pest population was very high throughout the experiment. Five lines were tolerant to the mites, which include two local long green eggplants, Long Green Cruz and Long Green Gabby, and three long purple cultivars, Nitta, Nitta x Molokai, and Nitta x Waimanalo **[Table A2.6]**.

**Table A2.6.** Evaluation of eggplant varieties harvest during the dry and wet seasons in 1993–1994.

| Cultivar | Type | Fruit Color | Degree of Infestation* | Tolerance Level |
|---|---|---|---|---|
| Kurume long purple | open-pollinated | purple | 2.0 | moderately tolerant |
| Okitsu No. 1 | open-pollinated | purple | 3.0 | susceptible |
| Local selection #1** | open-pollinated | green | 1.3 | tolerant |
| Location selection #2** | open-pollinated | green | 1.7 | tolerant |
| Nitta | open-pollinated | purple | 1.3 | tolerant |
| Waimanalo | open-pollinated | purple | 2.3 | susceptible |
| Black Shine | hybrid | purple-black | 2.7 | susceptible |
| Millionaire | hybrid | purple | 3.0 | susceptible |
| Money Maker No. 2 | hybrid | purple | 3.0 | susceptible |
| Takii's Long Black | hybrid | purple | 3.0 | susceptible |
| Nitta x Molokai | hybrid | purple | 1.3 | tolerant |
| Nitta x Waimanalo | hybrid | purple | 1.0 | tolerant |
| Pingtung Long | hybrid | purple | 2.3 | susceptible |

* Degree of mite infestation was measured by scores of 1 = few, 2 = some, 3 = heavy

** Local selection refers to a variety grown from farmer collected seeds and whose official cultivar name is unknown.

## 2014 Evaluation of virus resistant tomato varieties under field conditions in northern Guam.

Sheeka Jo A. Tareyama[1], Karl A. Schlub[1], Robert L. Schlub[1], Kai-Shu Ling[2]

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[2] - USDA-ARS, U.S. Vegetable Laboratory, Charleston, SC

### Introduction

In the spring of 2007, leaf curling and yellowing were observed in a mature field of Solar Set tomatoes in Yigo, Guam. Yield loss was estimated to be 10%. Two samples were sent to Agdia Diagnostics for evaluation. Their genetic sequencing produced 89-90% matches to both ***Papaya leaf curl virus*** and ***Malvastrum leaf curl virus***. Disease severity gradually increased; thereby, prompting more samples to be collected and tested in 2011. The tomato leaf samples tested positive for the presence of *Begomoviruses* according to the *Begomovirus* Group PCR test. The forward sequence of one sample had an 87% identity to ***Ageratum yellow vein virus***. The reverse sequence of this same sample had a 90% identity to both ***Papaya leaf curl virus*** and ***Soybean crinkle leaf virus*** and an 89% identity to ***Ageratum yellow vein virus***. By October of 2011, the Yigo farm was experiencing a total yield loss and severe virus symptoms were appearing elsewhere on Guam. In 2012 the Yigo farm switched from virus susceptible variety Season Red to Lefroy Valleys **TYLCV** resistant tomatoes. After five weeks, all the varieties tested had set fruit and were asymptomatic **[Figure A2.1]**.

**Figure A2.1.** Tomato varieties Carmine, resistant to **ToMV** and **TYLCV**, on the left; Felicity, resistant to **ToMV**, **TSWV**, and **TYLCV**, in the center; and Martyni, resistant to **ToMV** and **TYLCV**, on the right grow well on the Yigo farm where a year earlier tomato production was a total loss. Seed source was Lefroy Valley vegetable seed company.

In an effort to identify the virus species with greater precision, additional samples were collected and processed at the U.S. Vegetable Laboratory. Due to the high level of sequence diversity found, it is likely that Guam has a unique strain of **AYVV**. This information along with symptoms and virus screening tests enzyme-linked immunsorbent assay (ELISA) tests, lead authors to believe in 2013 that **AYVV** to be the main virus responsible for crop losses. The likelihood that **AYVV** was the main virus responsible for the yield loss was strengthen from the results of the screening of 12 tomato samples for 17 virus, the only virus detected was **AYVV** and this was found in one sample. Analysis of 4 samples collected in Yona, Guam in December 2015, raises the possibility that the failure of tomato production on Guam is due to a complex of viruses along with the bacterium *Clavibacter m. michiganensis* **[Table A2.7]**.

**Table A2.7.** Positive test results for four tomato samples collected on 12/29/16 in Yona, Guam. *

| Leaf Symptoms | Cmm | CMV | ToMV | TBSV | PVX | AYVV |
|---|---|---|---|---|---|---|
| Yellowing | X | X | X | | | |
| Yellowing | X | | | X | X | |
| Yellowing | X | | | X | | |
| Purpling | X | | | X | X | X |

* Samples were screened for **AMV** *Alfalfa mosaic virus*, **Cmm** *Clavibacter m. michiganenesis*, **CMV** *Cucumber mosaic virus*, **GRSV/TCSV** Groundnut ringspot/*Tomato chlorotic spot virus*, **INSV** *Impatiens necrotic spot virus*, **PepMV** *Pepino mosaic virus*, **PVX** *Potato virus X*, **PVY** *Potato virus Y*, **TEV** *Tobacco etch virus*, **TMV** *Tobacco mosaic virus*, **TRSV** *Tobacco ringspot virus*, **TAV** *Tomato aspermy virus*, **TBSV** *Tomato bushy stunt virus*, **ToMV** *Tomato mosaic virus*, **ToRSV** *Tomato ringspot virus*, **TSWV** *Tomato spotted wilt virus*, **POTY** *Potyvirus* group, **AYVV** *Ageratum yellow vein virus*

### Material and Methods

During Guam's wet-season, August 2014, replicated farm trials consisting of four field were begun to compare 17 commercial tomato varieties for virus resistance and production suitability against the commonly grown variety 'Season Red'. Varieties were grape, cherry, elongate, globe, plum, roma, oval, or round, and either determinate or indeterminate **[Table A2.8]**.

**Table A2.8.** During Guam's wet-season, August 2014, farm trials were begun to compare 17 commercially available tomato varieties for virus resistance and production suitability against the commonly grown variety '**Season Red**'.

| Variety | Fruit type | Growth type |
|---|---|---|
| Olivia | Grape | Indeterminate |
| Baxter's Bush | Cherry | Determinate |
| Carmine | Cherry | Virgorous |
| Coralino | Cherry | Indeterminate, vigorous, adaptable |
| Felicity | Globe | Indeterminate, vigorous |
| Rubia | Elongate | Determinate, vigorous |
| Affinity | Grape | Indeterminate |
| Ensalada | Plum | Determinate |
| Ornela | Grape | Indeterminate |
| Sassy | Roma | Inderterminate |
| Shanty | Oval | Semi-determinate |
| Tylon | Oval | Semi-determinate |
| **Season Red** | **Cherry** | **Determinate** |
| Tovi Star | Globe | Indeterminate, vigorous |
| Tycoon | Globe | Determinate |
| Heatwave II | Roma/Round | Determinate |
| Matty | Oval | Determinate |
| Tribute | Globe | Determinate, vigorous |

A Tomato Virus Severity Scale was created and used to visually evaluated the tomato varieties for **AYVV [Figure A2.2]**.

Three times throughout the wet-season trial, fields were visually evaluated for **AYVV**, approximately one, two, and three months after transplant. Following the third virus severity evaluation, samples were collected from each field trial and pooled for Real-time PCR analysis at the USDA-ARS Vegetable Laboratory.

At the conclusion of the wet-season field trial, producers surveyed the participating farm trials and identified their top variety choices in each field.

Partial analysis of the third set of field data, identified 12 varieties with virus resistance superior to 'Season Red' and five with inferior resistance. Based on Real-time PCR of pooled samples, **AYVV** was detected in one superior variety and four of the inferior ones. When symptomless tomatoes were tested, only one of the 18 varieties were positive for **AYVV [Table A2.9]**.

**Figure A2.2.** Tomato virus severity scale used in 2014-2015 field trails is based on the range of virus like symptoms seen in test plots.

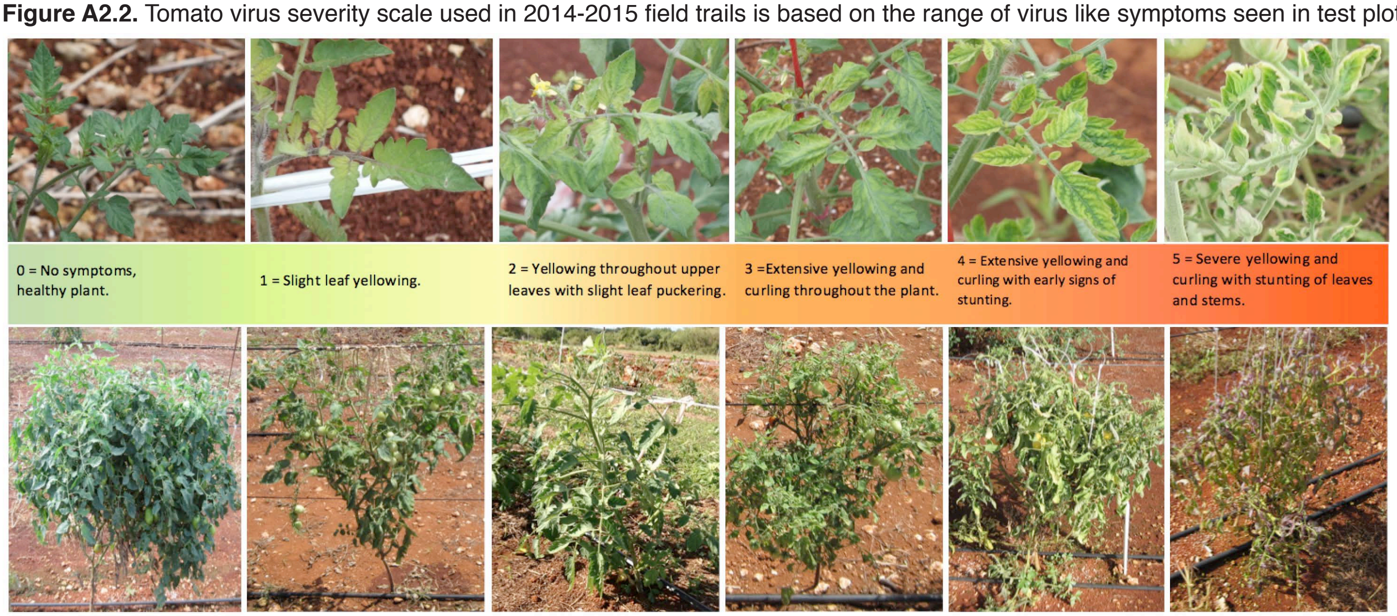


**Table A2.9.** Ranking of varieties, from resistant to susceptible, based on visual evaluation in comparison to Season Red, with corresponding Real-time PCR detection of **AYVV**.

| Field ID | Visual Evaluation[1], [2] | Real-time PCR (Ct) |
|---|---|---|
| Carmine | 7.315E+08 | 0 |
| Ornela | 7.189E+08 | 0 |
| Tylon | 7.189E+08 | 0 |
| Affinity | 85.753 | 0 |
| Olivia | 32.777 | 20.41* |
| Coralino | 10.364 | 0 |
| Felicity | 8.613 | 0 |
| Tovi Star | 5.393 | 29.51* |
| Shanty | 3.559 | 0 |
| Tycoon | 3.216 | 0 |
| Sassy | 2.234 | 0 |
| Matty | 1.049 | 0 |
| **Season Red** | **Control** | **18.38*** |
| Heatwave II | 0.745 | 0 |
| Rubia | 0.368 | 19.52* |
| Tribute | 0.250 | 29.86* |
| Ensalada | 0.123 | 26.56* |
| Baxter's Bush | 0.067 | 19.95* |

[1] Change in Odds Ratio when switching from control to variety #
[2] Values in orange are not reliable since there was an uneven spread of sick and healthy crops due to the fact that AYVV was not detected.
* Samples confirmed to have **AYVV** based on Real-time PCR analysis.

The top varieties from each field were selected and ranked by producers, which include 'Olivia', 'Carmine', 'Affinity', 'Ornela', and 'Felicity' **[Table A2.10]**.

**Table A2.10.** Producers ranking of 18 varieties grown in four northern Guam **AYVV** infected tomato crops.

| Rank | Field 1 | Field 2 | Field 3 | Field 4 |
|---|---|---|---|---|
| 1st | Ornela | Olivia | Affinity | Felicity |
| 2nd | Felicity<br>Affinity<br>Carmine | Felicity | Felicity | Carmine Olivio |
| 3rd | Olivia<br>Tylon<br>Matty<br>Baxter's bush | Carmine<br>Tovi Star<br>Ornela<br>Affinity | Carmine<br>Heatwave II<br>Olivia | Tovi Star |

## In Summary

**AYVV** and in possible combination with other virus is likely the cause for the drop in tomato produce in the past few years seen on many tomato fields in northern Guam. Over the course of the study, 2012-2016, the impact of **AYVV** on tomato production has grown. In northern Guam some growers are no longer growing tomatoes, others are planting the more expensive resistant varieties, and still others continue planting Season Red and take losses.  The total area on Guam where symptomatic plants are found is gradually increasing and will likely be present across Guam in the next 5 years.

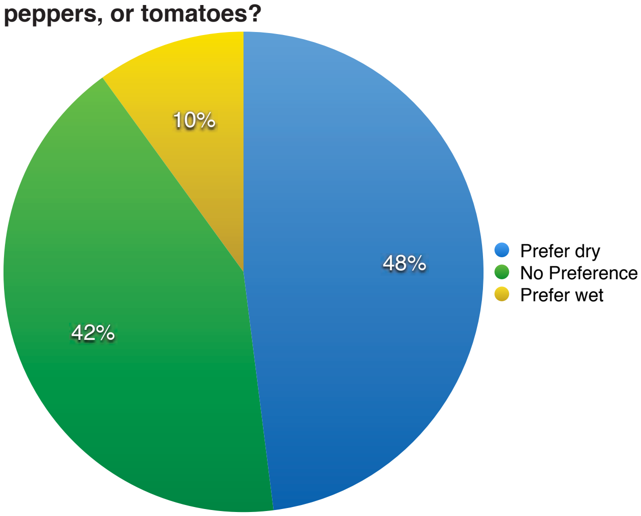
# Appendix 3 Guam Farmer Survey

**Robert L. Schlub, Extension Plant Pathologist**
**Rudy P. Estory, Agriculture Extension Assistant**
**David Nelson, Agriculture Extension Assistant**

Twenty farmers representing a cross section of the farming community of Guam participated in 2001 in a farmer survey. The objective of the survey was to determine current practices of Guam farmers.

## Seasonal Preference and Main Production Problems

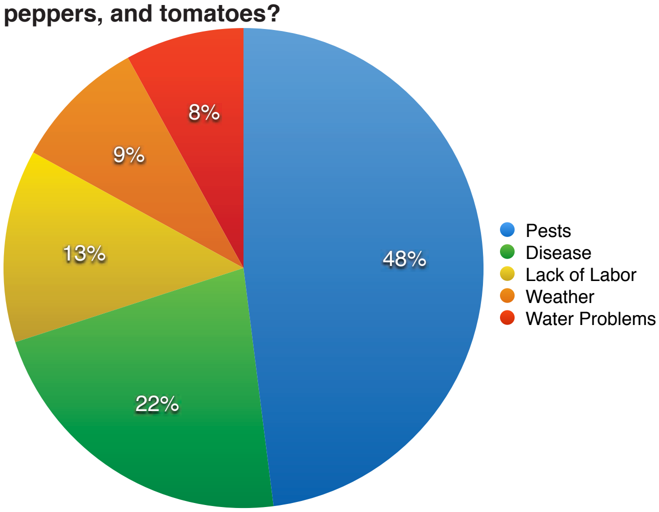
**Do you have a seasonal preference for growing eggplants, peppers, or tomatoes?**




**Dry season advantages:**
- easier to work soil
- less cracking in tomatoes
- higher tomato/pepper yield
- rainfall is not excessive

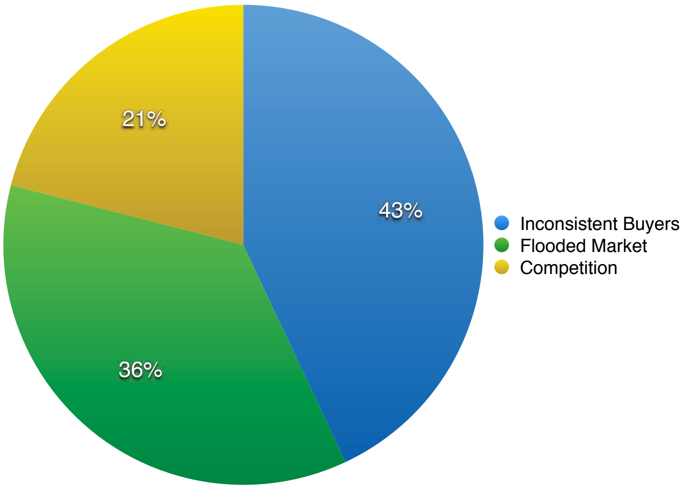
**Wet season advantages:**
- reduced need for irrigation

**What is your main problem in production of eggplants, peppers, and tomatoes?**

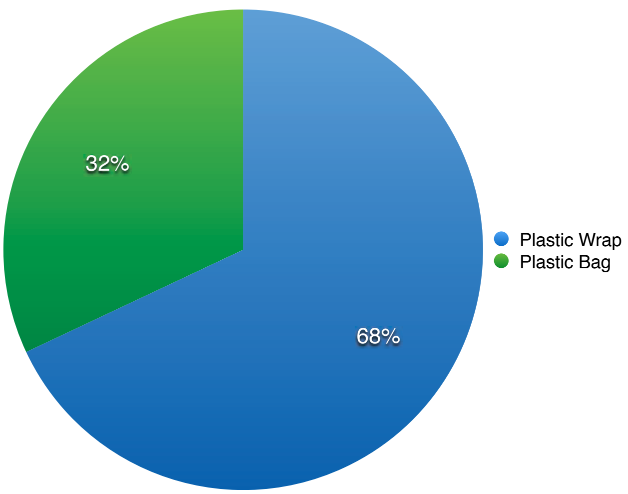


## Marketing

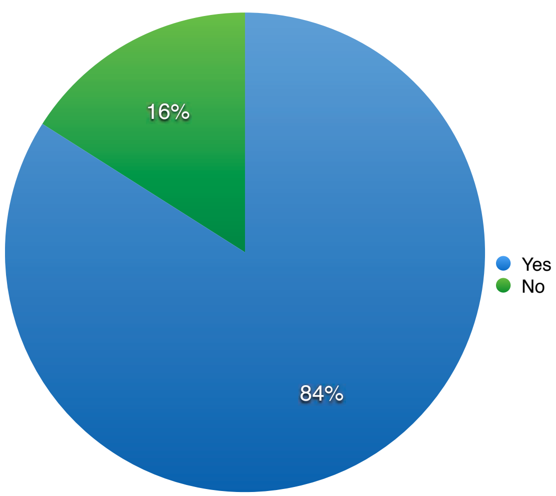
**What is your main problem in marketing?**




**How do you package your produce for market?**

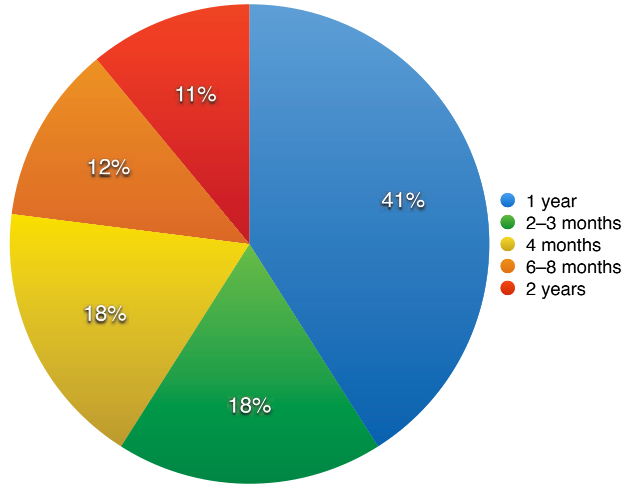



**Would you use food label information if it were made available?**

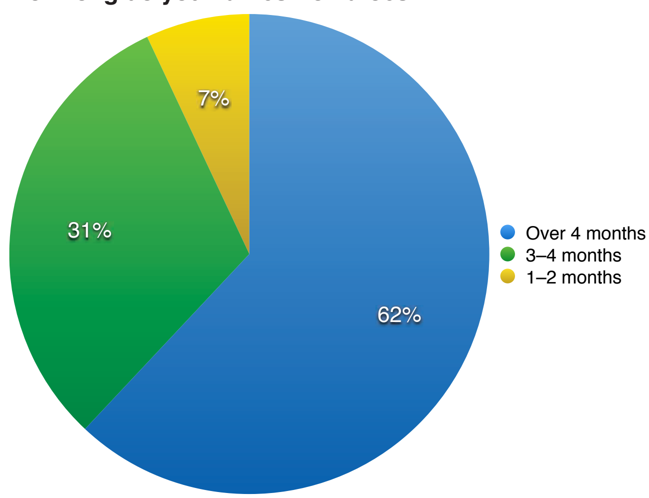



## Harvesting

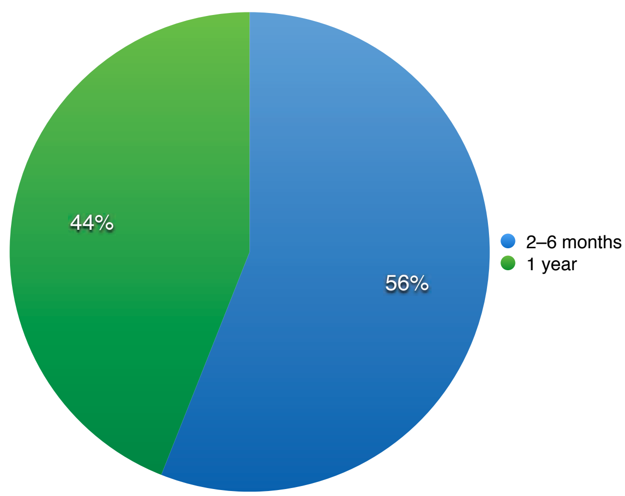
**How long do you harvest eggplants?**




**How long do you harvest tomatoes?**

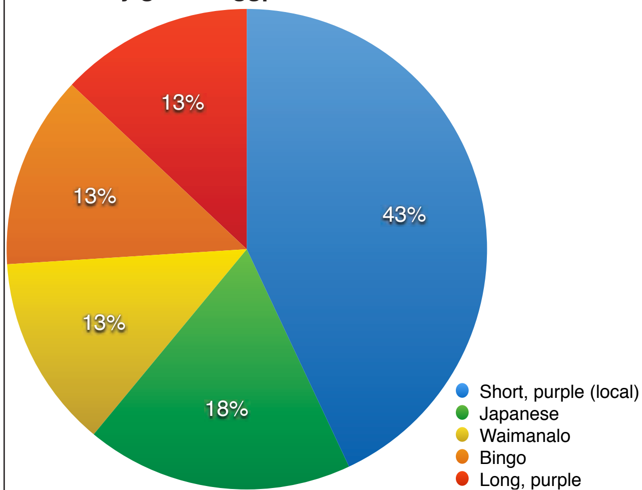



**How long do you harvest peppers?**

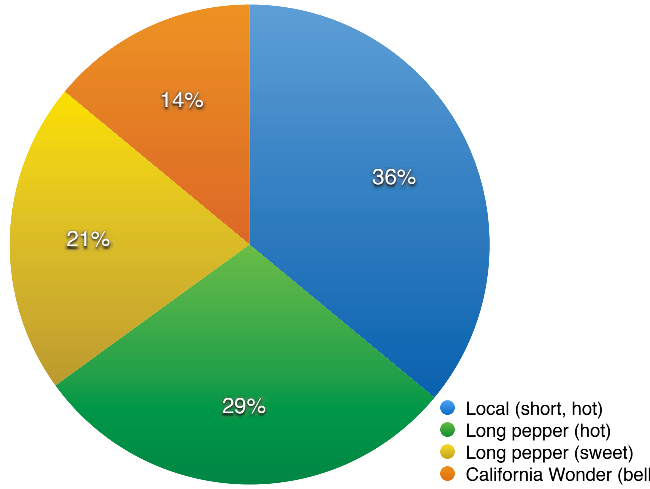


## Varieties

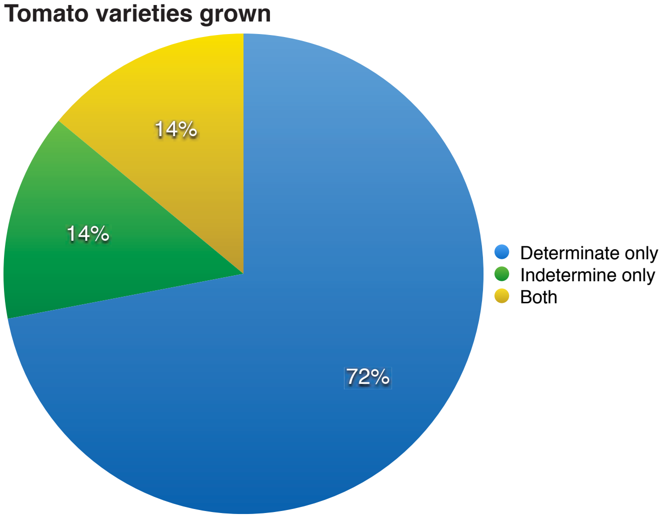
### Commonly grown eggplant varieties



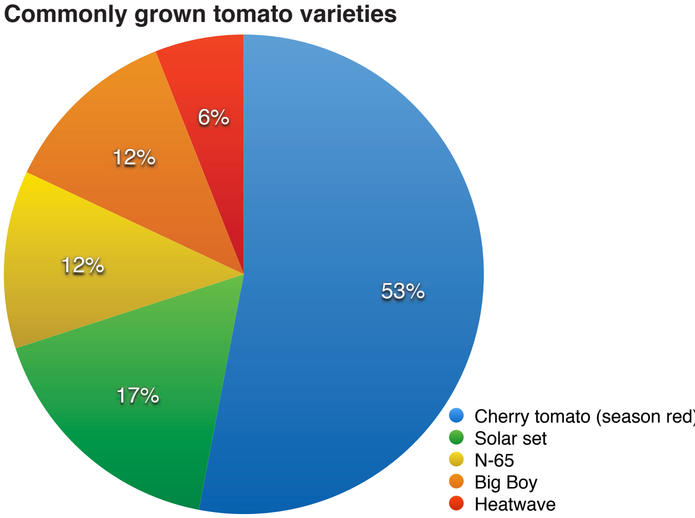

### Commonly grown pepper varieties




### Tomato varieties grown

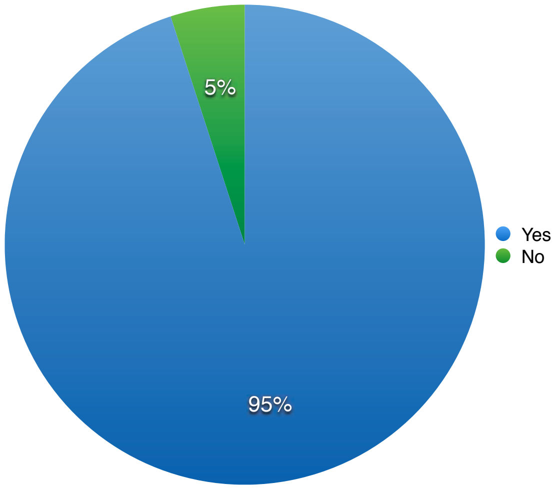



### Commonly grown tomato varieties

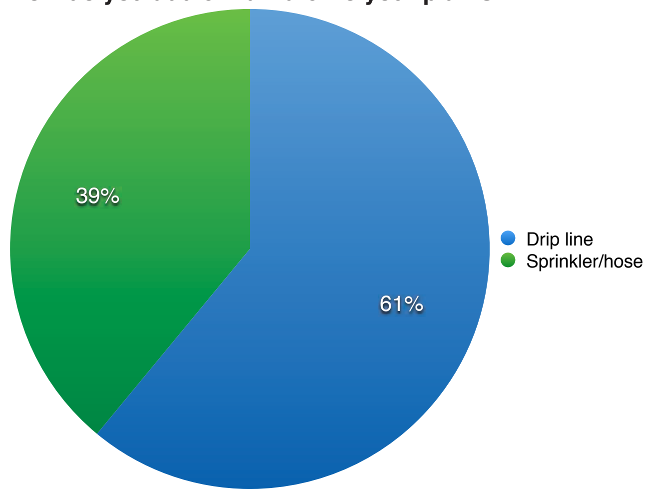


## Irrigation

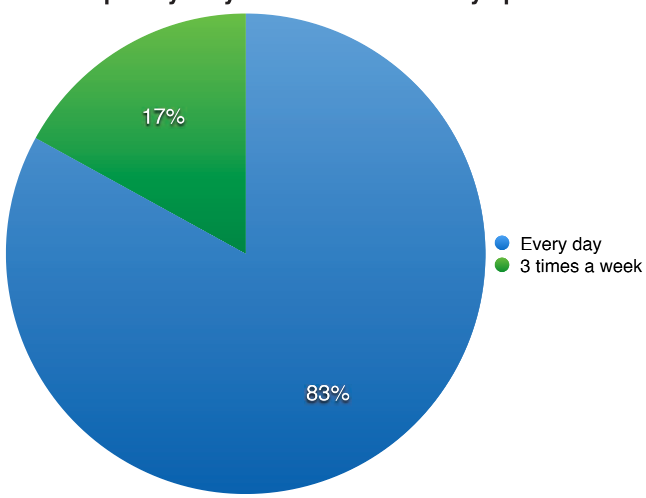
### Do you irrigate your plants?



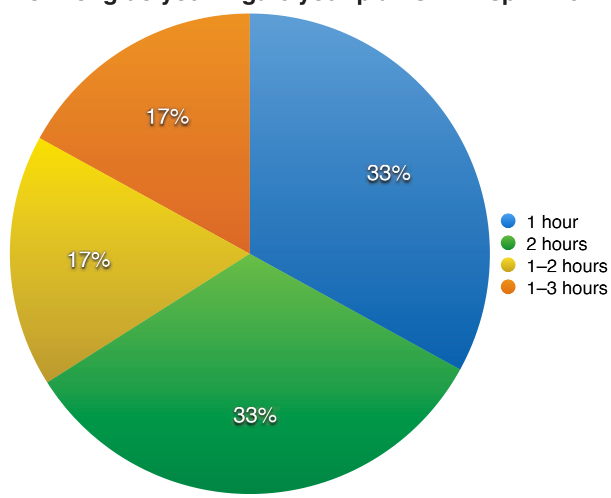

### How do you add extra water to your plants?



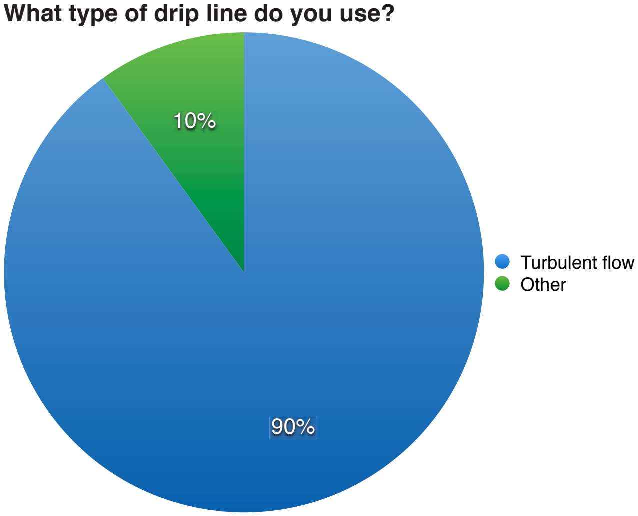

### How frequently do you add extra water by sprinkler/hose?



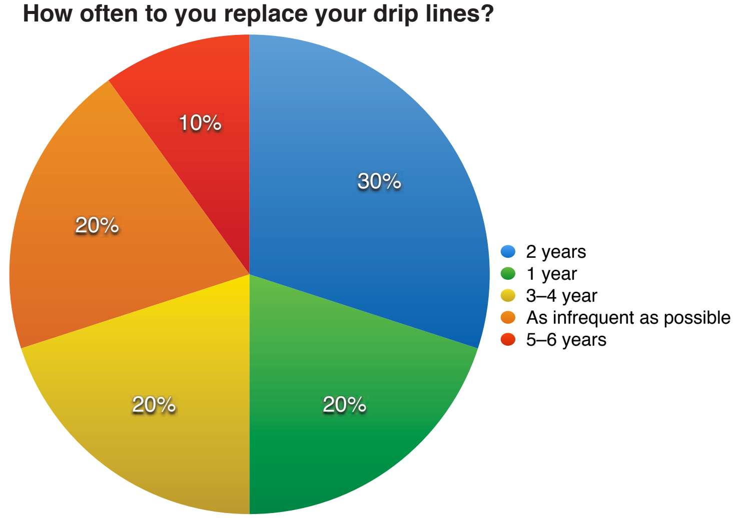

### How long do you irrigate your plants with sprinkler/hoses?




### What type of drip line do you use?

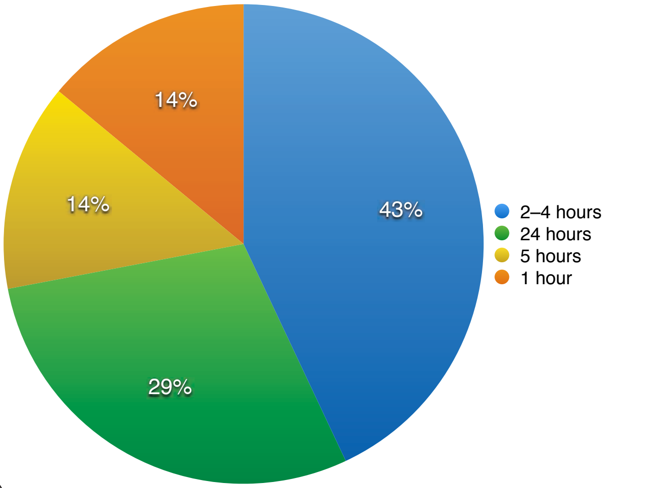



### How often to you replace your drip lines?

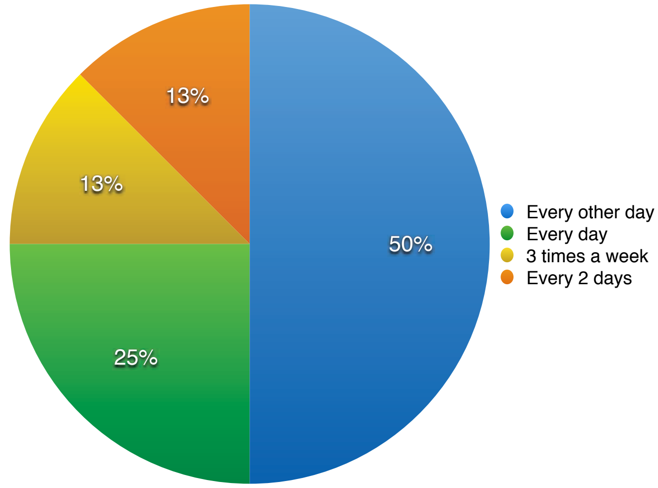


## Irrigation (continued)

### How long do you irrigate your plants with drip lines?

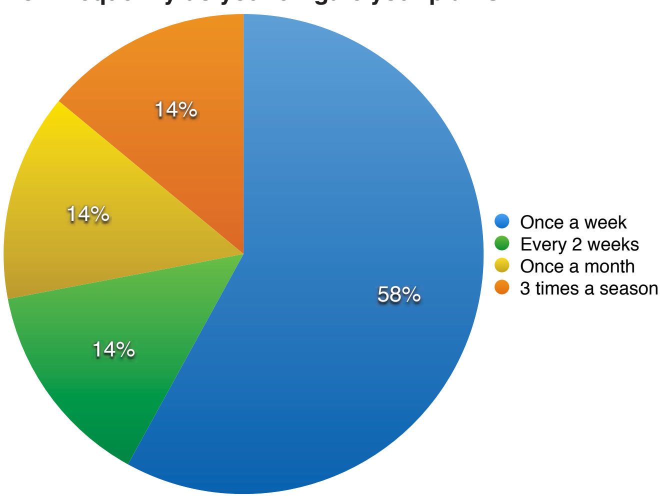



### How frequently do you add extra water by drip line?

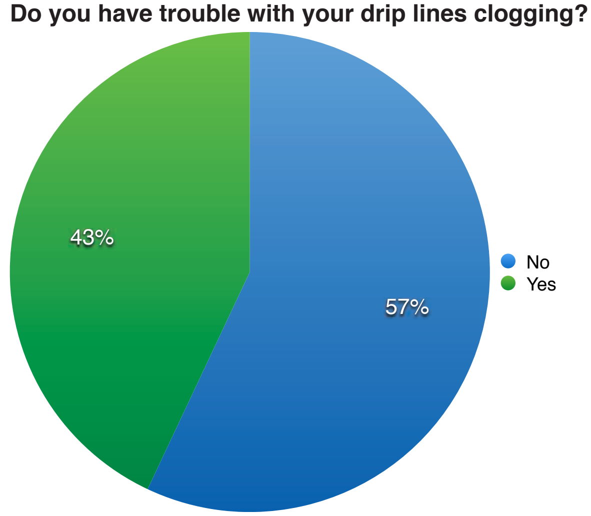



## Fertilization

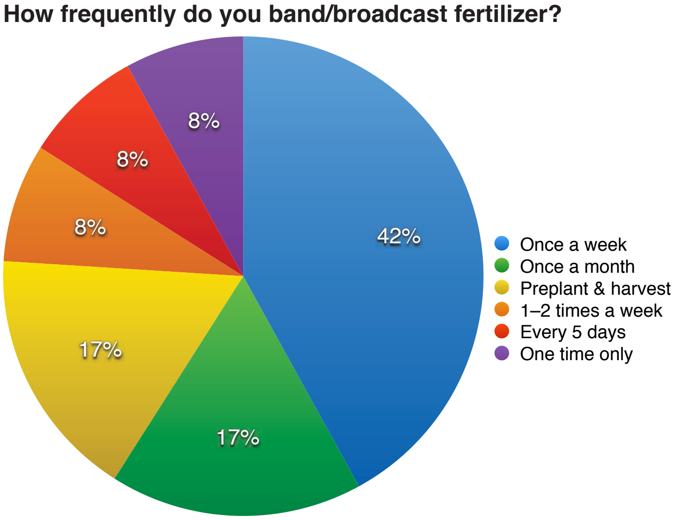
### How frequently do you fertigate your plants?



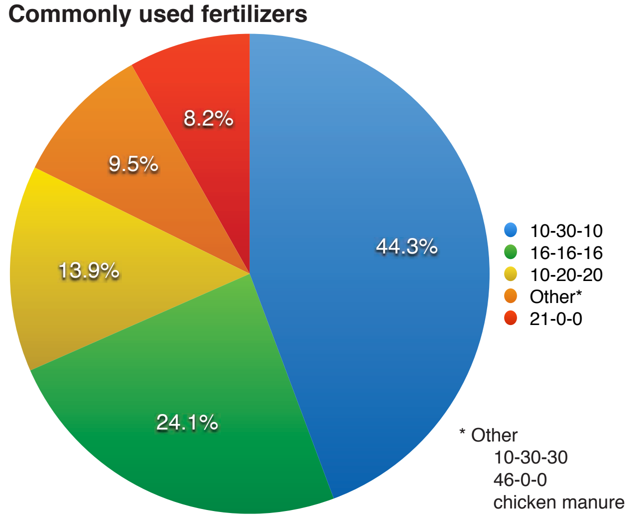

### Do you have trouble with your drip lines clogging?




### How frequently do you band/broadcast fertilizer?

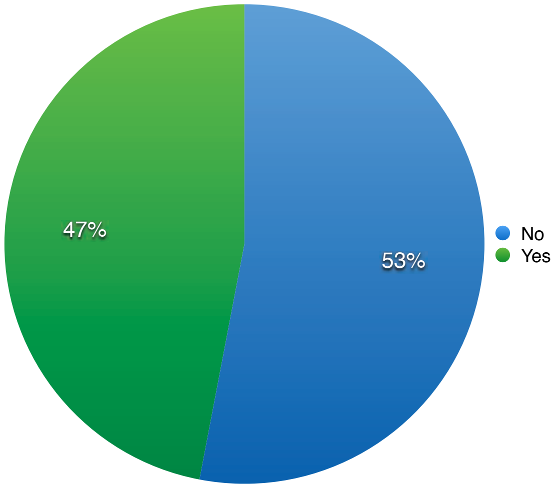



### Commonly used fertilizers

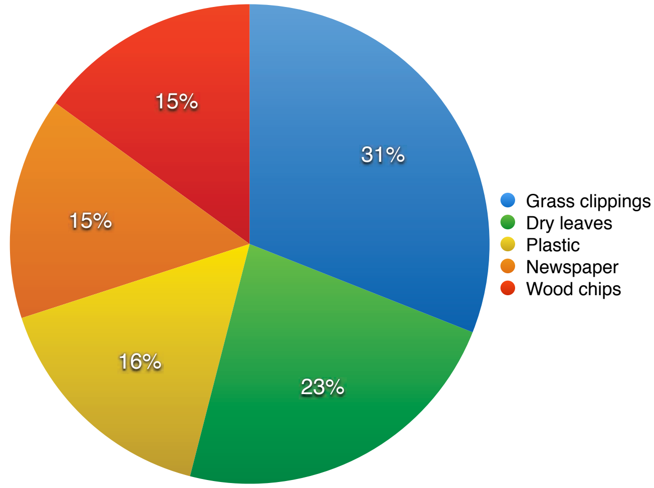


## Other Cultural Practices

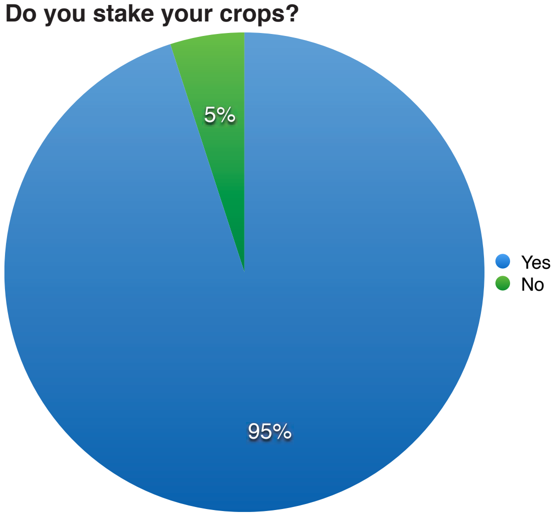
**Do you use any type of mulch?**



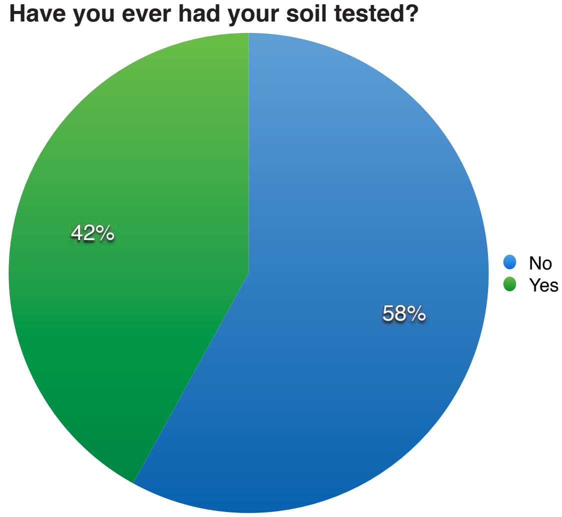

**Type of mulch used**




**Do you stake your crops?**




**Have you ever had your soil tested?**



# Appendix 4 Seed Company Information

**David Nelson, Extension Assistant**
**Robert L. Schlub, Extension Plant Pathologist**

This appendix is intended to aid growers in locating seed sources for the various varieties mentioned in previous chapters. Many of the crops found in **Tables A4.1** through **A4.4** are described in the section on **Crop Selection** in **Chapter 3: Production**.

**Table A4.1.** List of seed companies providing eggplant seeds.

| Eggplant | Cook Garden | East West Seed Company | Fuji Seed | Known-You Seed | Park Seed | Sakata Seed Company | Takii Seed Company | Twilley Seed | University of Hawaii |
|---|---|---|---|---|---|---|---|---|---|
| Batangas Long Purple | | √ | | | | | | | |
| Bingo | | √ | | | | | | | |
| Black Shine | | | | | | | √ | | |
| Black Torpedo | | | | | | | √ | | |
| Farmer's Long | | | | √ | | | | | |
| Kunume Long Purple | | | | | | | √ | | |
| Market More | | | | | | | √ | | |
| Money Maker | | | | | | | √ | √ | |
| Nitta/Molokai | | | | | | | | | √ |
| Nitta Waimanalo | | | | | | | | | √ |
| Okitsu No. 1 | | | | | | | | √ | |
| Ping-pong | | √ | | | | | | | |
| Pingtung | | | | √ | | | | | |
| Pingtung Long | √ | | | √ | √ | | | | |
| Short Tom No. 1 | | | | | | √ | | | |
| Takii's Long Black | | | | | | | √ | | |
| Waimanalo Long | | | | | | | | | √ |

**Table A4.2.** List of seed companies providing tomato seeds.

| Tomato | Carolina Seed | Guam Department of Agriculture | Harris Seeds | Kilgore Seed Company | Known-You Seed | New England Seed Company | Park Seed | Pepper Gal | Rachel's Tomato Seed Company | Sakata Seed Companty | Stoke Seed | Tomato Growers Seed Company | Takiii Seed | Twilley Seed | Totally Tomatoes | University of Hawaii |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bonney Best | | | | | | | | | √ | | | √ | | | √ | |
| Cherry Grande | | | | | | | | | | | √ | √ | | √ | √ | |
| Dynamo | | | | | | | | | | √ | | | | | | |
| Heat Wave | | | | | | | | | | | | √ | | | | |
| Hope No. 1 | | | | | | | | | | | | | √ | | | |
| Lee's Plum | | √ | | | | | | | | | | | | | | |
| Master No. 2 | | | | | | | | | | | | | √ | | | |
| N-52, N-63, N-65 | | | | | | | | | | | | | | | | √ |
| Precious | | | | | √ | | | | | | | | | | | |
| Roma | √ | | √ | √ | | √ | √ | √ | √ | | √ | √ | | | √ | |
| Season Red | | | | | √ | | | | | | | | | | | |
| Solar Set | | | | | | | | | √ | | | √ | | | √ | |
| Spring Giant | | | | | | | | | | | | √ | | | | |
| Sun Leaper | √ | | | | | | | | √ | | | √ | | | √ | |
| Sunchaser | | | | | | | | | | | | √ | | | | |
| Sunmaster | √ | | | √ | | | | | √ | | | √ | | | √ | |
| Tropic Boy | | | | | | | | | | √ | | | | | | |

**Table A4.3.** List of seed companies providing sweet pepper seeds.

| Sweet Pepper | Carolina Seed | East West Seed Company | Harris Seeds | Johnny's Seed | Kilgore Seed Company | New England Seed Company | Park Seed | Pepper Gal | Rachel's Pepper Seed Company | Stoke Seed | Tomato Growers Seed Company | Twilley Seed | Totally Tomatoes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bell Boy | √ | | | | | √ | | | √ | √ | √ | | √ |
| California Wonder | √ | √ | √ | √ | | √ | √ | √ | √ | √ | √ | √ | √ |
| Colossal | | | | | | | √ | | | | | | |
| Keystone Giant | | | | | | | | √ | √ | | | | |
| Keystone Giant Resistant III | √ | | | | √ | | | | √ | | | | √ |
| Midway | √ | | | | | | | | √ | √ | | | |
| Peto Wonder | √ | | | | | | | | √ | | | | √ |
| Yolo Wonder | √ | √ | | | √ | | | √ | √ | | | | √ |

**Table A4.4.** List of seed companies providing sweet pepper seeds.

| Hot Pepper | Carolina Seed | Guam Department of Agriculture | Harris Seeds | Johnny's Seed | Known-You Seed | New England Seed Company | Park Seed | Pepper Gal | Rachel's Pepper Seed Company | Stoke Seed | Tomato Growers Seed Company | Twilley Seed | Totally Tomatoes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asian Hot | | | | | | | | √ | | | | | |
| Golden Heat | | | | | √ | | | | | | | | |
| Habanero | √ | | √ | √ | | | √ | √ | √ | √ | √ | √ | √ |
| Hot Beauty | | | | | √ | | | | | | | | |
| Jalapeno | √ | √ | √ | √ | | √ | √ | √ | √ | | √ | √ | √ |
| Local Hot Pepper (Doni-Sali) | | √ | | | | | | | | | | | |
| Long Chili | | | | | √ | | | √ | | | | | |
| Thai Dragon | | | | √ | | √ | | √ | | | √ | | √ |

# Appendix 5 Helpful Resources

**David Nelson, Extension Assistant**
**Robert L. Schlub, Extension Plant Pathologist**

## Agencies

### Chamorro Land Trust Commission
Assists qualifying Chamorros in obtaining a dollar-per-year long term agricultural land leases.

### Guam Department of Agriculture (DOA)
Provides technical assistance and administers programs mandated by the Guam legislature, such as Forestry, Aquatic and Wild Life Protection, and Plant Protection and Quarantine. Soil and Water Conservation Districts is a DOA sub-activity. It is responsible for registration of farms for disaster assistance and agriculture water rates. For a minimal fee, farmers can have their seeds grown-out into seedlings ready to transplant. They have a number of fruit trees and landscape plants for sale to farmers and the general public and often have extra garden transplants.

### Guam Economic Development Authority (GEDA)
Assists growers in obtaining farm loans.

### Guam Environmental Protection Agency (GEPA)
This regulatory agency is responsible for protecting Guam's land, air, and water resources. GEPA has the authority to enforce the Federal Insecticide Fungicide and Rodenticide Act (FIFRA) on Guam. FIFRA governs the registration of pesticide products and safeguards consumers against fraudulent pesticide products entering Guam. In addition, the agency is charged with protecting the consumer and the environment from any potential hazards associated with the use, storage, and disposal of pesticides. It is also responsible for Worker Protection Standards and the Endangered Species Act.

### USDA-Natural Resources Conservation Service (NRCS)
An agency of the U.S. Department of Agriculture (USDA). The NRCS works hand-in-hand with people and organizations, conservation districts, and other agencies to conserve natural resources primarily on private and tribal lands. NRCS provides technical assistance to agricultural producers in the Pacific Basin who request such assistance. NRCS may also administer certain programs that provide financial assistance to qualified producers for the installation of conservation practices.

### USDA-Animal Plant Health Inspection Service and Plant Protection Quarantine (APHIS, PPQ)
Responsibilities include keeping exotic plant pests out of the U.S., including Guam and the CNMI. Updated regulatory information on plant information can be found at the USDA-APHIS, PPQ web site.
http://www.aphis.usda.gov

### A.H. Hummert Seed Co.
Professional horticultural suppliers with general merchandise.
2746 Chouteau Avenue
St. Louis, Missouri 63103
(314) 771-0646

### A.M. Leonard, Inc.
Professional horticultural suppliers with general merchandise.
241 Fox Drive
Piqua, Ohio 45356
(513) 773-2694

### Adapability
Loaded with products for independent living with many applications to home and garden.
Box 515
Colchester, Connecticut 06415
(800) 243-9232

### Agricultural Development in the American Pacific (ADAP)
A partnership between Pacific Land Grant Institutions to address current issues of interest and concern in the region.
http://www2.ctahr.hawaii.edu/adap2/

## Institutions

### Agricultural Development in the American Pacific-CTAHR Publications
http://www2.ctahr.hawaii.edu/adap2/information/pubs/adap_publications.htm

### Altso's Handy Helpers
One of the better selections of handy outdoor equipment including cordless tools, furniture, long-handled tools, loppers, trellises, and ready-made raised beds and containers that incorporate seating.
Box 1267
Galesbug, Illinois 61401
(800) 447-0048

### American Intertools, Inc.
Source of long-handled pruners made by ARS Tool Company, with interchangeable heads and multi-length handles and extensions
1255 Tonne Road
Ek Grove Village, Illinois 60007

### American Standard Company
A source for general tools. Offers a variety of lightweight tools and excellent shears.
Box 325
Plantsville, Connecticut 06479
(203) 628-9643

### Ames Lawn and Garden Tools
General garden tools: good long-handled, lightweight smaller bladed spades, cultivators, hoes, and more.
3801 Camdell Avenue
Parkersburg, West Virginia 26101
(800) 624-2654

### Brookstone Company
Many useful items for the gardener.
1655 Bassford Drive
Mexico, Missouri 65265
(314) 581-7113

### Capsicum and Eggplant Newsletter
University of Turn
DI.VA.P.R.A. - Agricultural Genetics
via Leonardo da Vinci 44
10095 GRUGLIASO TO - Italy

### Chile Head
Great pepper information on almost all varieties.
http://easyweb.easynet.co.uk/~gcaselton/chile/chile.html

### The Chile Pepper Institute
A great site for pepper enthusiasts and growers.
http://www.chilepepperinstitute.org/

### Clapper's Garden Catalog
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**Insect Pests of Micronesia**
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ARS is the principal in-house research agencyy of the U.S.D.A. It is charged with extending the nation's scientific knowledge across a broad range of programs.
http://www.ars.usda.gov

### University of San Francisco-Plant Atlas
Listing of tropical plants with description and pictures.
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### Vegetable Gardening in Containers
Sam Cotner, Texas Agricultural Extension Service, Texas A&M University.
http://aggie-horticulture.tamu.edu/extension/container/container.html

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**University of Hawaii Seed Lab**
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Email: rsakuoka@hawaii.edu

**Yates Seed Company**
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NSW 1811
Australia
http://yates.co.nz/seedsandbulbs/flowers/

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# Appendix Glossary

**adventitious root**—a root growing from stem, branch or leat tissue, not from primary root tissue.

**anthracnose**—a leaf or fruit-spot type disease caused by fungi that produce their asexual spores on a saucer-shaped structure called an acervulus.

**asexual spores**—spores that are not the result of sexual union.

**bacterium**—a one-celled microorganism much larger than a virus but smaller than a fungal spore.

**beneficial insect**—insects that are considered useful to the grower because they feed (externally or internally) on insects that are pests.

**biopesticide**—a pesticide containing naturally occurring living organisms such as fungi and bacteria that can kill insects.

**blight**—rapid dying of young tissue such as leaves, shoots and flowers.

**bloom**—young budding flowers.

**blotch**—irregular areas of discoloration, usually superficial.

**breakeven price**—The unit price (price per pound or box) that a farmer needs to obtain in the market in order to cover the cost of production and marketing.

**calcareous soil**—a soil with high levels of calcium carbonate or magnesium carbonate. Calcareous soils are formed from a mixture of fragments of sea plants and animals such as mollusk shells, coral, algal platelets.

**calyx**—the outer, usually green, leaf-like parts of a flower located at the junction of the fruit and fruit stem. In the case of eggplants, peppers, and tomatoes, the calyx is attached to the fruit at maturity. Collective term for sepals.

**canker**—an area on a stem resulting from shrinking and dying of stem tissue bordered on one or both sides by healthy tissue.

**carbohydrate**—an organic compound consisting of carbon, hydrogen, and oxygen. Formed in plants by photosynthesis. Common examples are sugars, starch, and cellulose.

**clamp connection**—bridge-like hyphal connection.

**climacteric fruit**—fruits that produce increasingly large amounts of ethylene and have increasing respiration rates while ripening.

**complete fertilizer**—inorganic fertilizers which contains all three primary elements (N-P-K).

**conidia**—asexual spores formed at the end of conidiophores.

**conidiophores**—stalks on which conidia are produced.

**cotyledons**—solanaceous crops have two cotyledons. They are a large fleshy part of the seed which serves to provide food to the embryo at the time of germination. After emergence, the cotyledons serve as a temporary foliar structure for photosynthetic processes prior to the appearance of the first true leaves. Eventually, the two cotyledons wither and fall off.

**crop budget**—a key planning tool used in agriculture to increase profits and reduce the risk of failure.

**crop rotation**—the process of switching crops grown on a section of land after each harvest.

**curl**—a puff-like distortion of a leaf.

**damping-off**—rapid death and collapse of very young seedlings near the soil line.

**depreciation**—the decrease in value of buildings, other improvements, and machinery which is caused by wear, tear, and obsolescence.

**desiccation**—loss of moisture, drying out.

**determinate growth**—growth that stops after an organ such as a flower or a leaf is fully expanded; determinate plants produce all their fruit at one time.

**dicot**—(dicotyledon) plants whose seeds have two cotyledons or seed leaves such as beans, eggplants, peppers, and tomatoes.

**die-back**—slow progressive death of shoots, branches, and roots generally starting at the tip.

**diurnal**—an occurrence having a daily cycle; a plant whose blossoms open during the day and close at night.

**drainage**—the process of removing excess water/salts from the root zone of a crop to assure its survival and optimum growth.

**Economic injury level** (EIL)—the lowest pest population that will cause economic damage.

**Economical threshold** (ET)-the pest population level at which a control tactic should be started to keep the pest population from reaching the EIL. The ET is also called the action threshold.

**emergence**—the appearance of the embryonic leaves of the crop plant above the soil surface.

**embryo**—the part of a seed which develops from the union of the egg cell (female gamete) and sperm cell (male gamete) and during germination and emergence becomes the young plants

**epidemiology**—a study of the factors determining the amount and distribution of disease.

**epinasty**—stronger growth on the upper surface than on the lower surface of petioles or leaves causing a downward curling.

**ethylene ($C_2H_4$)**—the simplest, naturally produced compound which affects plants' physiological processes. It is the natural aging and ripening hormone.

**fallow**—crop land left idle in order to restore productivity. Soil tillage or herbicides is used to control weeds.

**fertigation**—mixing fertilizers with irrigation water.

**fertilizer**—any organic or inorganic material added to soil or water to provide plant nutrients necessary for growth.

**fixed cost**—expenses that remain the same, during the production period, for any level of production. Examples: land, equipment, and insurance.

**fruiting body**—any fungal structure which contains or bears spores. It is usually black-colored.

**fungus**—non-green spore producing plants. Most are composed of mycelium. They may grow as a parasite or as a saprophyte.

**grafting**—the process of making a plant more desirable by combining it with a piece from another plant.

**germination**—the activation of the embryo (small plant within the seed) which leads to the rupture of the seed coat by the embryonic root.

**hill**—to make soil into a hill or to draw soil up around a plant's base.

**hybrid**—a plant from seed produced by crossing parents that are genetically unlike. Hybrid plants have characteristics that are superior to either parent.

**hypha** (pl. hyphae)—a single branch of fungus mycelium.

**hypocotyl**—the short seedling stem between the cotyledons and the primary root which gives rise to the stalk of the young plant.

**imperfect flower**—a flower lacking either male or female parts.

**indeterminate**—a terminal bud that is always vegetative. Vines grow indefinitely, therefore referred to as indeterminate plants.

**insecticide**—a chemical that is used to control an insect pest.

**integrated pest management (IPM)**—a management system that utilizes all methods of controlling animal pests, plant pathogens, and weeds.

**irrigation**—the process of applying supplemental water to a crop for satisfactory or optimum production.

**lesion**—well defined area of diseased tissue.

**market price**—the price for a product established by buyers (stores or consumers) and sellers (farmers or stores). Seller sell at or below market price. Buyers buy at or above market price.

**mature fruit**—a fruit with seeds that are capable of germinating and is irrespective of the fruit's color.

**microbes**—living organisms, such as fungi, bacteria, and virus, that are very small in size and have the potential to cause abnormal conditions to their hosts.

**microsclerotia**—very small sclerotia.

**monocot**—(monocotyledon) plants having a single cotyledon or seed leaf such as grains and grasses.

**mosaic**—symptom of certain viral diseases of plants characterized by intermingled patches of normal and light green or yellowish color.

**mulch**—any material placed on the ground to conserve soil moisture or prevent the growth of weeds.

**mycelium**—threadlike filaments constituting the body of a fungus.

**nematode**—wormlike, transparent organism that can often be seen with a hand-lens. They live in water or soil as a saprophyte or a parasite.

**non-climacteric fruit**—fruits that maintain low respiration and ethylene production rates while ripening.

**nymph**—an immature stage of a developing adult insect.

**organic matter**—matter found in, or produced by, living animals and plants. It contains carbon, oxygen, nitrogen, and may contain other elements.

**ovary**—an enlarged basal portion of a pistil (carpel) which becomes the edible fruit of an eggplant, a pepper, or a tomato.

**perfect flower**—a flower that has both male and female parts (hermaphroditic).

**pH**—a measure of the acidity or alkalinity of soil or water. The neutral point is pH 7.0. All pH values below 7.0 are acidic and all above 7.0 are alkaline.

**photosynthesis**—process by which green plant cells, primarily in the leaves, uses the energy from sunlight in combination with water and carbon dioxide make carbohydrates (sugars) and release oxygen.

**plant disease**—an unhealthy condition that results from an infectious agent (viruses, bacteria, fungi, etc.) or non-infectious agent (environmental factors, poor pollination, genetics).

**plant pathogen**—an infectious agent that can cause a plant disease to develop (viruses, bacteria, fungi, nematodes, parasitic plants).

**pollen**—a collective term for pollen grains.

**pollen grain**—a small, almost microscopic, yellow body that is produced within the flower's anther and contains two male sex cells (sperm).

**pollination**—the transfer of pollen from the stamen to the pistil.

**powdery mildew**—yellowish areas on leaves, stems, and fruits covered by a grayish to white layer of mycelium and spores.

**ppm**—parts per million.

**primary elements**—nitrogen (N), phosphorus (P), and potassium (K).

**protein**—organic compounds made of chains of amino acids. Good sources of dietary protein include lean meats and beans.

**relative humidity (RH)**—the ratio, expressed as percentages (%), between the quantity of water vapor present and the maximum possible at a specific temperature and barometric pressure.

**resistance**—a condition where certain pesticides are no longer effective at controlling a certain pest.

**respiration**—the process that breaks down stored foods (primarily carbohydrates and proteins) into the simple end products required to keep organisms alive.

**rot**—a state of decomposition caused by micro-organisms.

**rotation**—refer to crop rotation.

**row covers**—fine mesh materials that are placed over a crop. The mesh is small enough to keep out aphids.

**saprophyte**—organisms which are able to utilize dead organic matter for food.

**sclerotia**—small hardened mass of fungal mycelium.

**seedling**—the juvenile plant, grown from a seed.

**self-fertility**—the ability of a variety of fruit to produce viable seeds without the aid of pollen from another variety.

**senescence**—the process that follows physiological or horticultural maturity and contributes to death of tissue.

**setae**—bristle-like fungus structures usually dark and thick-walled.

**solanaceous**—belonging to the nightshade family or Solanaceae family. Eggplant, Irish potato, pepper, tobacco, tomatillo, tomato, and petunia are common examples.

**soil texture**—The coarseness or fineness of the soil. The relative proportions of sand, silt, and clay particles.

**spores**—seeds of the fungus.

**spots**—any small portion or dot of discoloration on a leaf, stem, or fruit resulting from dead or dying tissue.

**spreader-sticker**—a material that facilitates spreading and increases sticking of a pesticide.

**stipple**—few to numerous tiny shallow bleached spots.

**stunting**—dwarf or cramp growth habit.

**symptom**—the appearance of a plant when subjected to a stress condition. Yellowing, stunting, spotting, and wilting are plant symptoms.

**transplant**—a seedling that was germinated in a seedbed or tray then transferred to another location.

**trellising**—the process by which plants are trained to grow into a latticework of wood, string, or netting.

**variable cost**—expenses that can change during the production cycle. Directly related to increases or decreases in production. Examples: labor, seeds, fertilizer, packaging materials, and transportation.

**vector**—an animal able to transmit a pathogen. Insects are the main vectors of viruses.

**virus**—an infective agent too small to be seen with a conventional microscope and unable to multiply outside a living plant cell.

**water-soaked**—a symptom in which plant tissue appears wet and dark or somewhat translucent.

**whole farm costs**—costs that cannot be directly charged to a single planting of a crop or agricultural enterprise. Whole farm costs can be either fixed or variable costs. Examples: tractors, chilling units, and delivery trucks.

**wilting**—Lack of water in the leaves and/or stem causing the plant to droop.

**winged aphid**—Aphids that are winged and can fly to establish new aphid colonies.

**wingless aphid**—Aphids that have no wings but still have the ability to produce numerous offspring.

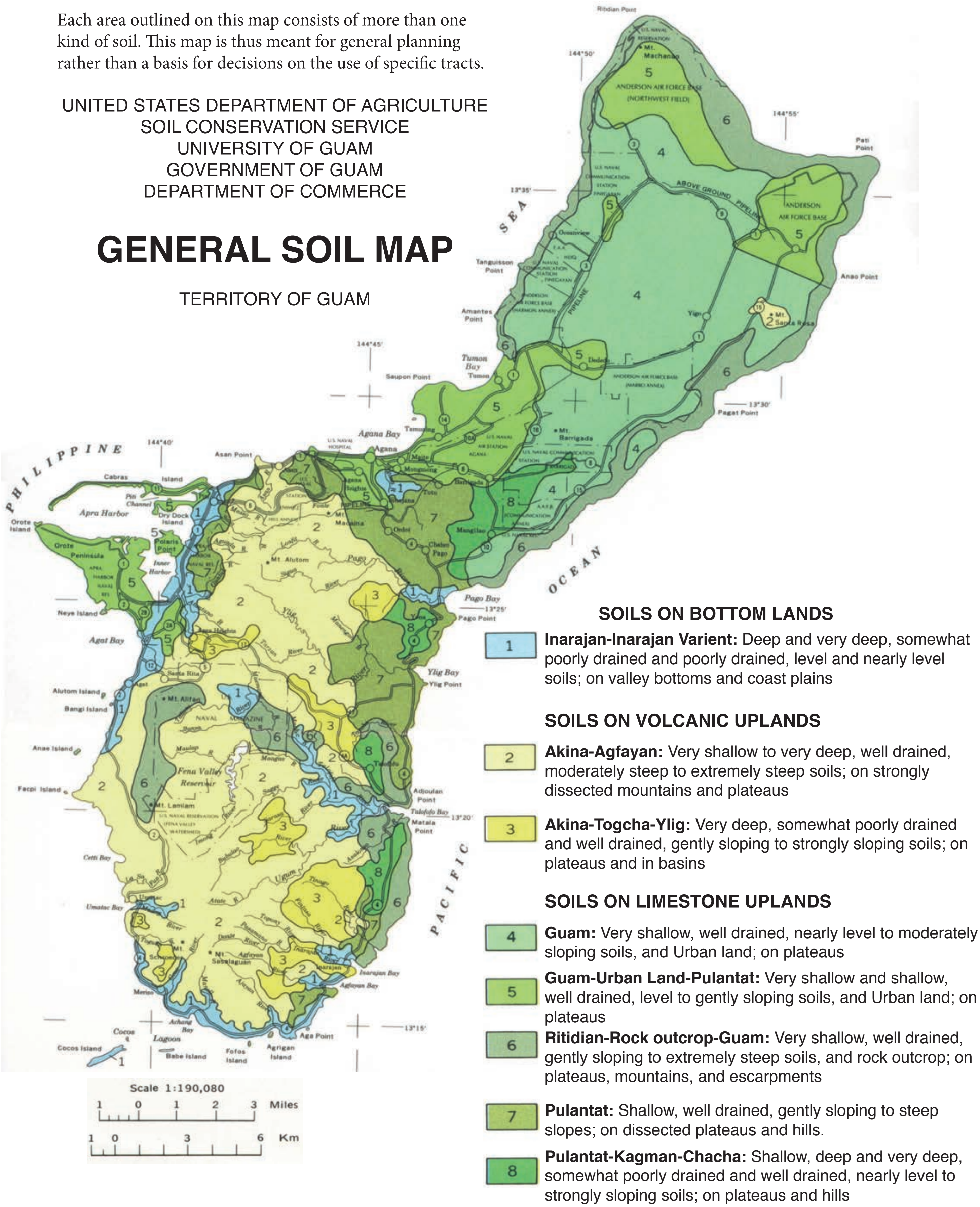
# Appendix Color Plates

Each area outlined on this map consists of more than one kind of soil. This map is thus meant for general planning rather than a basis for decisions on the use of specific tracts.

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
UNIVERSITY OF GUAM
GOVERNMENT OF GUAM
DEPARTMENT OF COMMERCE

## GENERAL SOIL MAP

TERRITORY OF GUAM



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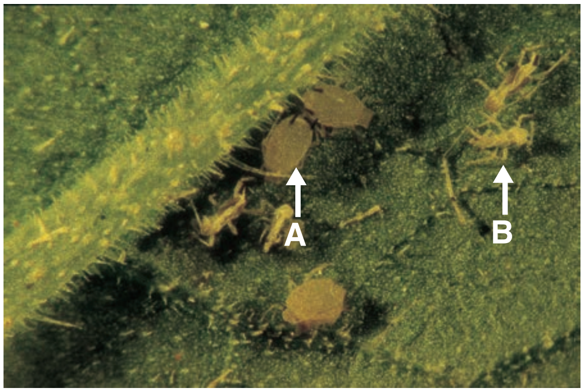



L.S. Yudin

**A.** Aphids are small, 3 mm ($^1/_8$ in), soft bodied insects that suck plant sap.
**B.** The presence of white cast skins is an indication of an infestation.

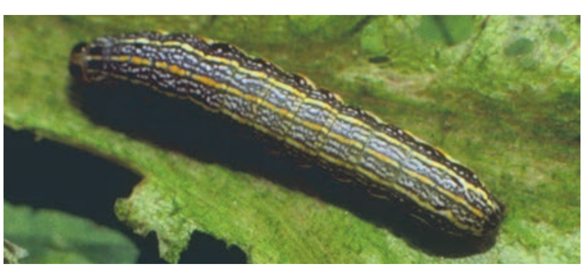
4.

General plant decline and leaf distortion are symptoms of mite damage.

5.

The green semi-looper, 1.3–2.6 cm ($^1/_2$–1 inch), feeds on the underside of leaves.
http://dh13sh.blogspot.com/2015/10/sau-o-chrysodeixiseriosoma-doubleday.html

6.



The cluster caterpillar, last larval instar, 6 cm (2.3 inches), is black with small blue and yellow spots along its side.

3.


R.L. Schlub
Dave Nelson
R.L. Schlub

**A.** Thrips are very small insects, 1 mm ($^1/_{25}$ inches). Thrips are found on the underside of leaves and in buds and blossoms.
**B.** Scarred fruit is the result of early season thrips or mite damage. They can often be found hiding under the calyx.
**C.** Tiny brown leaf scars are the result of thrips feeding injury.
**D.** Thrips feeding may cause leaves to turn from their normal green color (right) to whitish-silver (left).

**7.**

Hole in tomato stem caused by boring larva.

**8.**

Old world bollworm, Heliothis armigera (Hübner). Larva is 3–4 cm (1.2–1.6 inches) long.

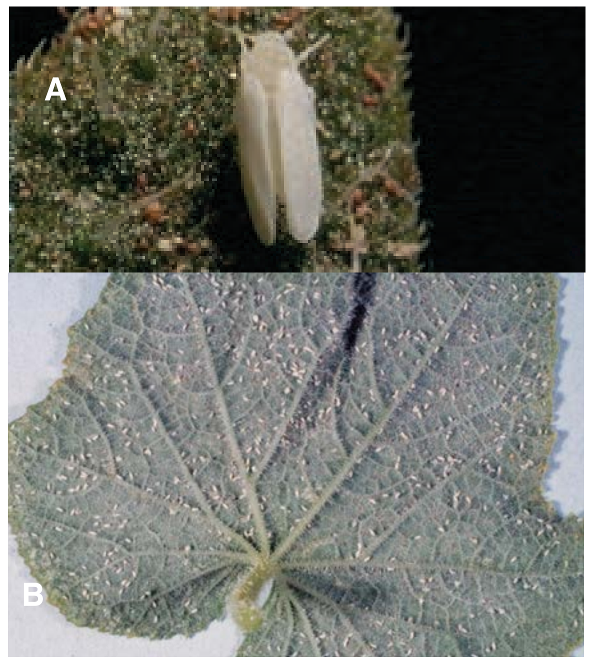
**9.**

Leaf miner damage on pepper seedling. Leaf miners get their common name from the tunnel the larvae produce underneath the leave surface.

**10.**

J. McConnell

L.S. Yudin




**A.** The silver whitefly, 2 mm ($^1/_{12}$ inches), appear like tiny white moths.
**B.** The underside of leaves which are heavily infested with whitefly adults and nymphs appears to be covered with a snowy-like substance.

**11.**

Adult leaf-footed bugs, 3.8 cm (1.5 inches), are large insects which are black with red spots on their underside.

**12.**

R.L. Schlub

Mealybug female (2 mm ($^1/_{12}$ inch)) and nymphs are covered with a powdery white waxy material.

**13.**

R.L. Schlub


Leafhopper feeding on eggplant may cause yellowing or browning of the leaf margin. Leafhopper nymphs **[A]** resemble adults **[B]** except they lack wings.

14.

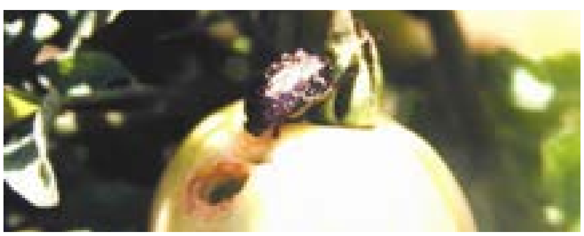
R.L. Schlub

The garden fleahopper is about 2 mm (1/12 inches) long, shiny, black, and with orange lines. They feed on young weeds and many crops causing tiny pit which appear as whitish spots.

15.

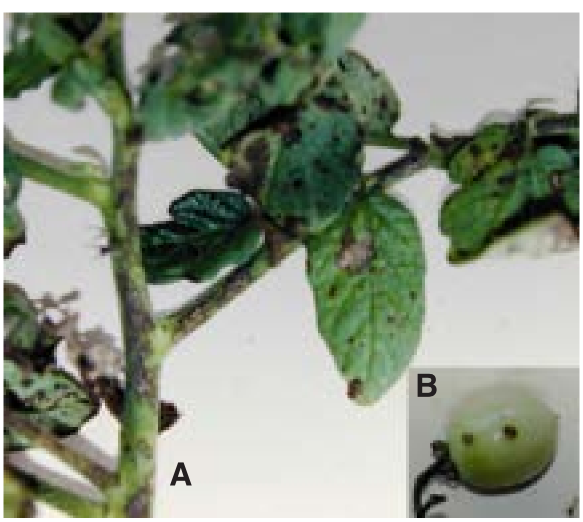

The Philippine ladybeetle is 1 cm (0.39 inches) long.
**A.** Adult stage of the Philippine ladybeetle.
**B.** Larva stage of the Philippine ladybeetle.

16.



Tomato fruit being damaged by oriental flower beetle. They are approximately $^3/_4$ inches (1.9 cm) long.

18.




**A.** Tomato leaves and stem with Bacterial Spot = BS
**B.** Bacterial spot on tomato fruit

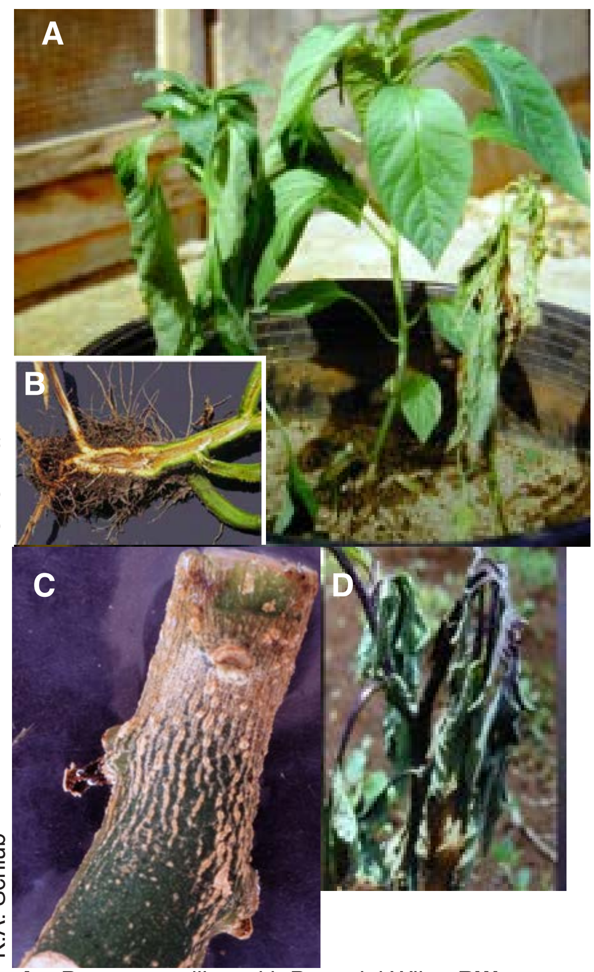
17.

Slugs feed on fruit and outer stem tissues of tomatoes. Some species reach 2–3 inches (5–7.6 cm).

19.

G. C. Wall

K.A. Schlub




**A.** Pepper seedling with Bacterial Wilt = **BW**
**B.** Pith discoloration associated with **BW**
**C.** Bacteria stream from BW infected eggplant stem
**D.** Fruit bearing eggplant dying from **BW**

**20.**

Fruit rot (**FR**) of tomato caused by anthracnose = **A**

**22.**

One cause of damping-off = **D** is the fungus Pythium. Under humid conditions, it produces a white cottony growth at the soil line.

**24.**

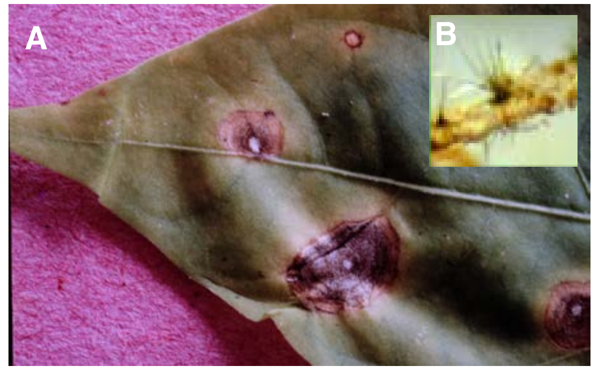
R.L. Schlub

R.L. Schlub

M. Marutani


**A.** Eggplant with light brown leaf spots and torn holes is diagnostic for Phomposis blight = **PB**
**B.** Eggplant with stem canker dotted with small Phomopsis fruit bodies
**C.** Under moist conditions, a ribbonlike mass of gelatinous spores exude from fruiting bodies.
**D.** Eggplant fruit with **PB**

**21.**

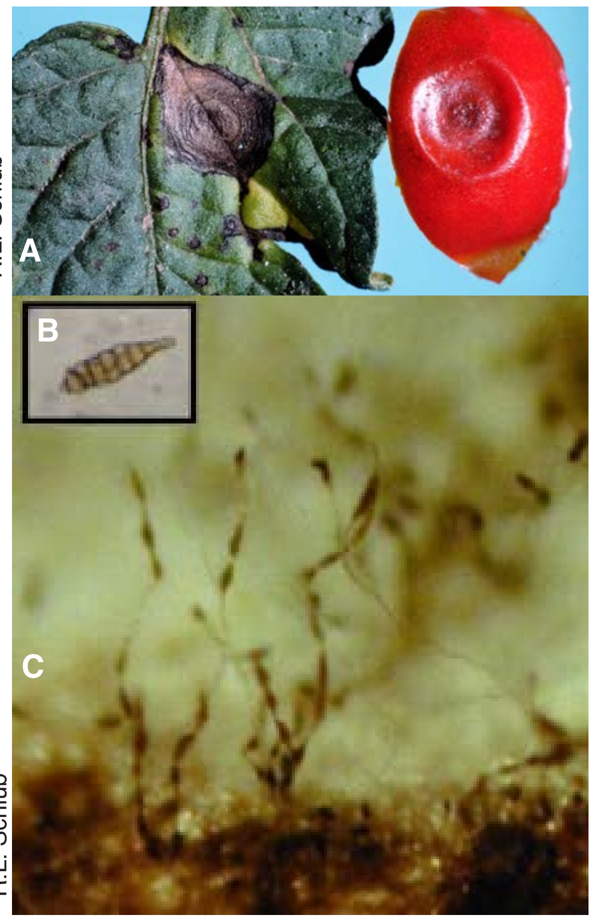



A. Pepper leaf with Cercospora leaf spot = **CLS**
B. Under the stereomicroscope, the fungus appears as small bundles of black sticks with silvery attached threads.

**23.**

R.L. Schlub

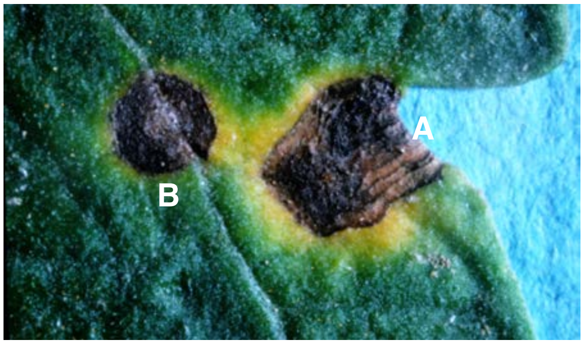
R.L. Schlub




**A.** Tomato leaf and fruit with early blight = **EB**
**B.** Alternaria conidia are beaked and multicellular
**C.** Conidia may form singly or in chains as shown here

**25.**

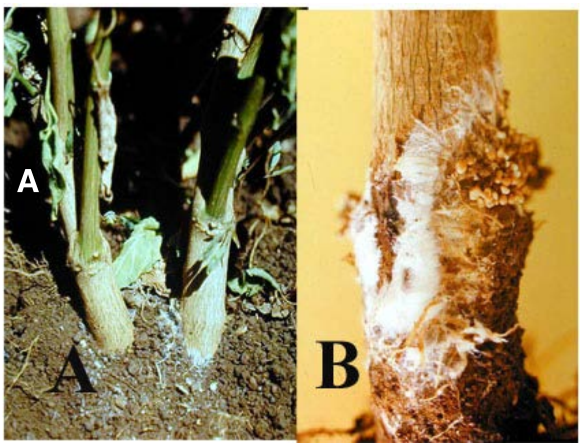
R.L. Schlub




**A.** Tomato leaf spot resulting from early blight = **EB**
**B.** Tomato leaf spot resulting from Septoria leaf spot = **SLS**

**26.**

R.L. Schlub




Pepper plants with southern blight = **SB**. Diagnotic features include:
**A.** Fungus' fan-like growth on soil an stem surface.
**B.** Presence of beads of fungus material.

**27.**

R.L. Schlub


**A.** Tomato leaf with target leat spot = **TLS**
**B.** Under the stereomicroscope, the fungus appears as thin short hairs.

**28.**

Marginal necrotic leaf lesions are often the first outward expression of bacterial canker = **BC**.
http://u.osu.edu/hightunneldiseasefacts/tomato-diseases/bacterial-canker/diagnosticians/

**29.**

T.A. Zitter


Bacterial canker = **BC** causes slightly raised white "bird's-eye spots" develop on tomato fruit when infection is heavy.

http://vegetablemdonline.ppath.cornell.edu/PhotoPages/Tomatoes/Tom_BactDiseases/Tom_BactFS2.htm

**30.**

T.A. Zitter


Bacterial canker = **BC** causes stem infection resulting in internal reddish brown necrotic tissue extending into the pith.

http://vegetablemdonline.ppath.cornell.edu/PhotoPages/Tomatoes/Tom_BactDiseases/Tom_BactFS3.htm

31.


*Cucumber mosaic virus* (**CMV**) symptoms may be striking with the development of shoestring like leaf blades or subtle as shown above with the develop of leave mottle symptoms.

http://www.omafra.gov.on.ca/IPM/english/tomatoes/diseases-and-disorders/viruses.html

32.

In the field, symptoms caused by *Tobacco mosaic virus* (**TMV**) are indstinguishable from those of *Tomato mosaic virus* (**ToMV**). On Guam, the occurrence of leaf symptoms is more common than fruit symptoms.

http://www.apsnet.org/edcenter/intropp/lessons/viruses/pages/tobaccomosaic.aspx

33.

Jack Kelly Clark

Upper leaves of plants infected with *Tomato bushy stunt virus* (**TBSV**) are yellow and curled.

http://ipm.ucanr.edu/PMG/U/D-TO-UNKA-FO.008.html

34.

*Tobacco mosaic virus* (**TMV**) symptoms on a tomato seedling.

http://www.extension.umn.edu/garden/fruit-vegetable/plant-diseases/tomato-mosaic-virus-tobacco-mosaic-virus/index.html

35.


*Ageratum yellow vein virus* (**AYVV**) symptoms include leaf curling, yellowing, puckering of younger leaves and stunting.

http://link.springer.com/article/10.1007/s10327-010-0239-0?no-access=true

36.

In Guam, *Ageratum yellow vein virus* (**AYVV**) is believed to be the predominate virus for leaf curl, yellowing, and stunting symptoms occurring in the tomatoes plants on the left. Those on the right are healthy.

37.

In Guam, infection of tomato by *Ageratum yellow vein virus* (**AYVV**) prior to transplanting is believed to be responsible for severely stunted plants occurring in some fields. Three nearly identical transplants were out-planted into pots after two weeks. Symptoms range from extreme on the left to severe in the middle and none on the right.

38.

Anthracnose (**A**) causes water soaked and sunken lesions which develop primarily on mature fruits. Dark concentric rings of fungal structures often form.

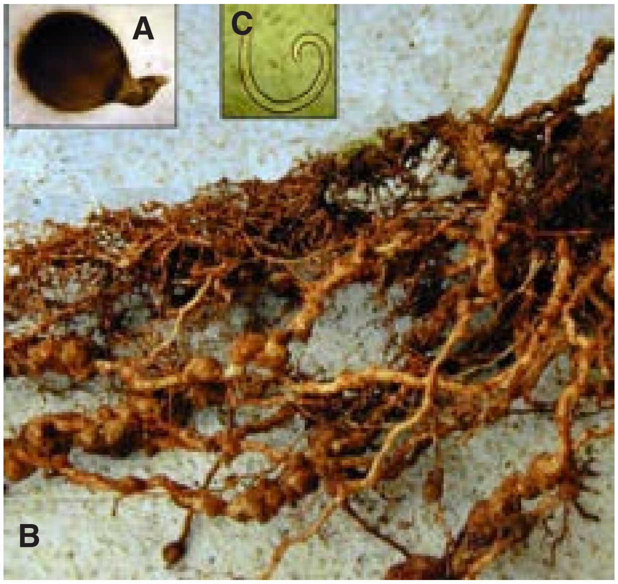
39.


R.L. Schlub

**A.** Pepper plant with distorted leaves and stunted growth are caused by a virus = **V**

**B.** Abnormally shaped fruit caused by an early season virus infection

40.




**A.** The female root knot nematode is pear shaped and measures 0.44–1.33 mm (.02–.05 inches) long and 0.33–0.70 mm (.01–.03 inches) wide.
**B.** Root galls caused by root knot nematode = **RK**.
**C.** The males and juvenile are worm shapred. They measure 1–1.55 mm (.04–.06 inches) long.

41.

The pepper plants were planted in root knot nematode (**RK**) infested soil. The variety on the left is resistant. The variety on the right is susceptible.

42.

Tomato fruit with blossom-end rot

43.

Cracking of tomato fruit associated with sudden changes in soil moisture.

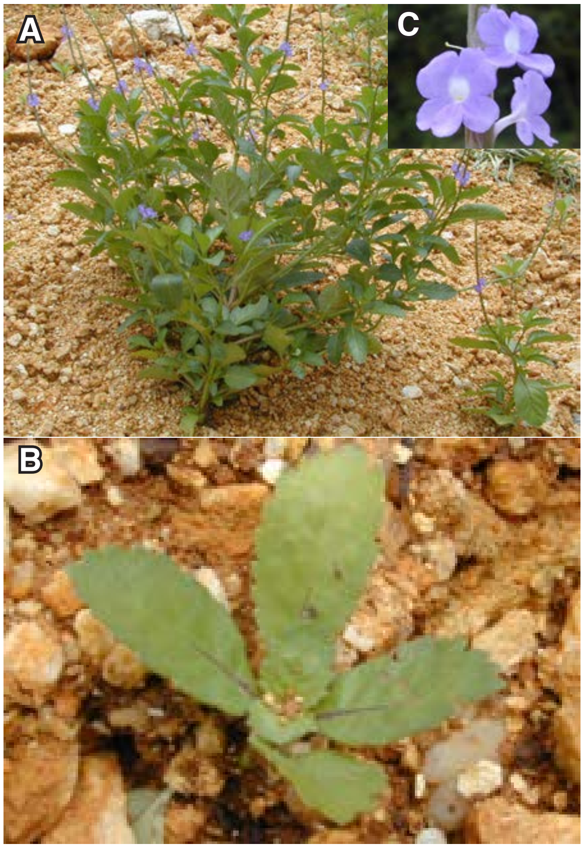
44.

***Cuscuta campestris*** Yuncker; dodder. A yellow string-like vining parasitic weed which winds around and attaches itself to its host post. It produces inconspicuous flowers (mostly white).

45.


**A.** ***Physalis angulata***, cape gooseberry, tomatas chaka is a partially erect, spreading shrub, woody at the base, 1 to 3 feet high. Flowers are solitary, bell-shaped, pale yellow with purple blotches.
**B.** The fruit is a yellow globular berry about $^{3}/_{4}$ inch in diameter contained in a pod-like structure that resembles a Chinese lantern. Seeds are small, in a juicy pulp.

46.

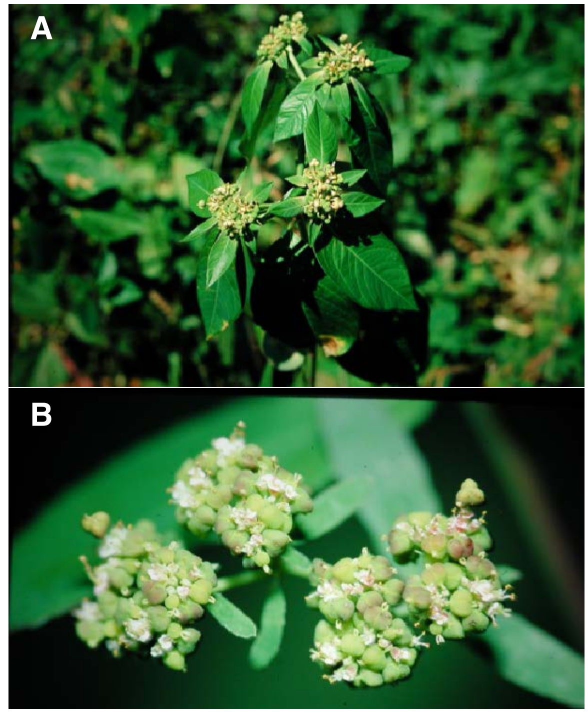



**A.** ***Stachytarpheta jamaicensis*** (L.); rat tail. Mature plants are erect, sparsely branched, perennial plant, 1 to 6 feet high.
**B.** Leaves as seen on this immature plant can be slightly hairy or smooth, pale green oblong ovate, and serrate.
**C.** Flowers pale violet, numerous on green elongated, terminal spikes, 2 to 3 opening at a time.

47.

***Chamaesyce hirta*** L.; Millspaugh. The plant has a non-erect spreading growth habit with hairy stems. Rounded flower clusters form at the junction of the stem and leaf.

48.




**A.** ***Chamaesyce heterophylla*** L.; dwarf poinsettia. Stems are green, with milky sap and nearly 1 meter tall. Uppermost leaves have red-blotched blades.
**B.** The small terminal flowers are yellowish with 1–2 small nectarines (glands).

49.

***Portulaca oleracea*** L.; pigweed, purslane plant grows along the ground. Stems are juicy, smooth, and often reddish. Flowers are small, yellow, and form at the junction of the stem and leaf.

50.

***Amaranth spinosus*** L.; kulites; kultes; spinachy amaranth. It is erect, branched and has large leaves. Flower clusters have sharp spines and form at the end of branches (kale) and at the junction of the stem and leaf (mostly female).

51.

***Pennisetum polystachyus*** (L.) Schlutes; foxtail; boksu. A loose growing, clumping, erect (1–1.5 m) grass with yellow tufts (12–18 cm).

52.

***Cenchrus echinatus*** L.; sandbur. It is an annual with a height up to 1 m with basal branching. The flower cluster are 3–10 cm with 5–15 spiny burrs.

53.

***Cyperus kyllingia*** Endl.; sedge; Cyperus. The small sedge has a three-cornered solid stem with short narrow leaves an white rounded flower clusters.

For additional information, please contact an agricultural extension agent at the Guam Cooperative Extension, College of Agriculture and Life Sciences, University of Guam, you may call 735-2080 or write to the Guam Cooperative Extension, College of Agriculture and Life Sciences, University of Guam, UOG Station, Mangilao, Guam 96923.

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