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FIELD CUCUMBER PRODUCTION GUIDELINES FOR HAWAI'I

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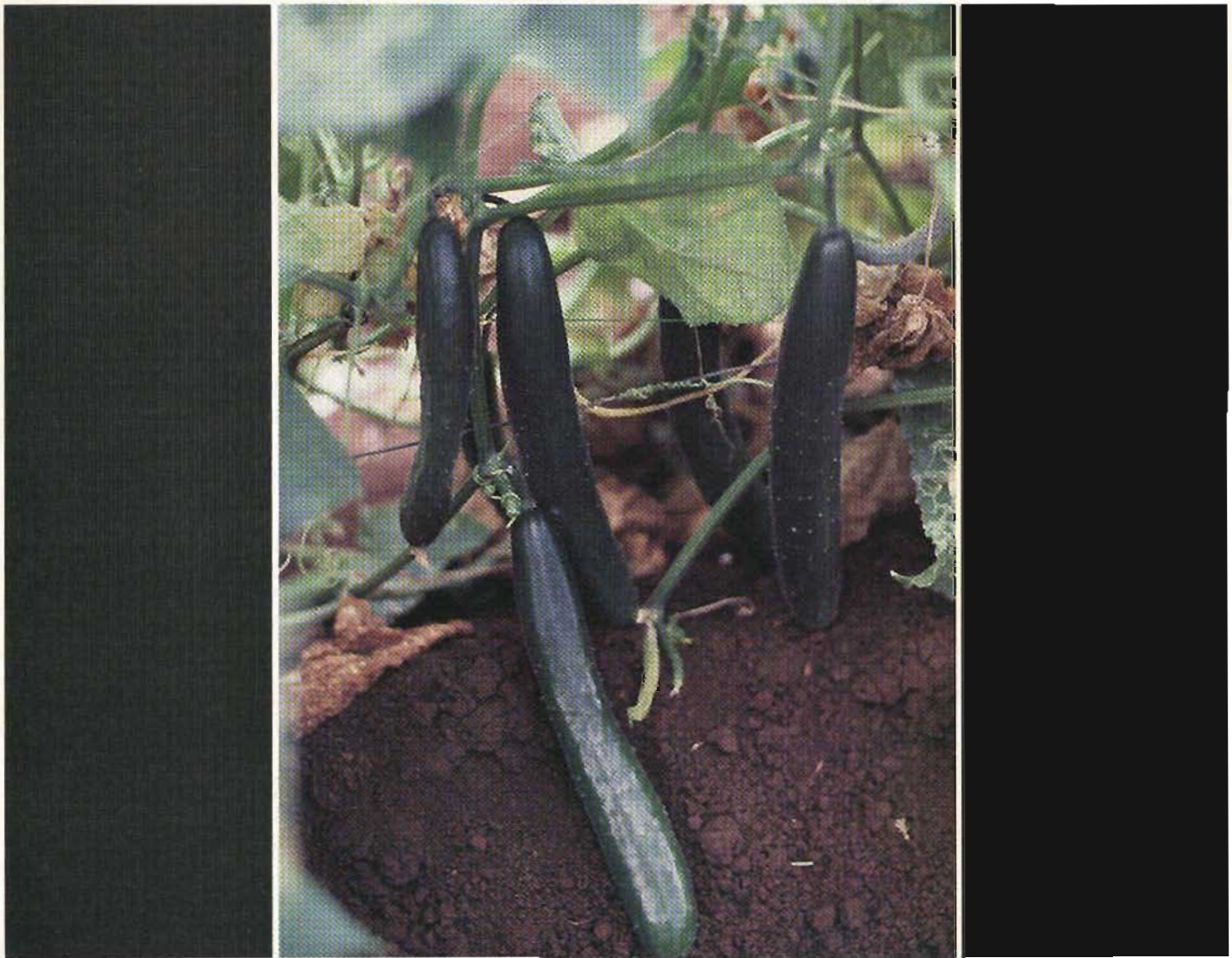

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INTRODUCTION

Cucumber (*Cucumis sativus*), a member of the Cucurbitaceae family, is a native of Asia and Africa, where it has been consumed for 3000 years. It is a popular fresh market vegetable in salads. It is also processed into kim chee and oriental-style pickles in Hawai'i. Over 60 percent of local production is in Mountain View and Kona on the island of Hawai'i, Kaua'i, and O'ahu. The crop is susceptible to serious losses from such pests as the silverleaf (or sweetpotato) whitefly, the melon fly, leafminers, mosaic viruses, and soil-borne and foliar diseases. Production volumes are 40 to 50 percent lower during the winter months when diseases are more prevalent. The pickling-type cucumbers, grown for processing in the continental United States, are not extensively grown in Hawai'i.

Crop Growth and Sex Expression

Cucumber is an annual, deep-rooted (about 3 feet or 91 cm) crop with tendrils and hairy leaves. The plants may have an indeterminate, determinate, or a compact plant habit. The compact growth habit consists of plants with shorter internode lengths than those of plants with indeterminate or determinate growth habits. Optimum growth occurs between 70 to 75°F (20 to 25°C). Growth reduction occurs below 60°F (16°C) and above 90°F (30°C).

Several flowering habits exist in cucumbers. Most cultivars are monoecious with separate male and female flowers on the same plant. Gynoecious or "all-female" cultivars produce only female flowers resulting in quantities of female flowers up to 13 times the amount produced by monoecious cultivars. The so-called "PF" hybrids produce predominantly female flowers but also produce a small number of male flowers. "Pollination" plants are often supplied to insure fertilization of "PF" types. Many cultivars grown in greenhouses such as European cucumbers are parthenocarpic. Parthenocarpic varieties require no pollination for fruit production. In fact, pollination of these cultivars causes off-shaped fruit.

The first flowers of monoecious plants are staminate or "male" followed by pistillate or "female" flowers from which fruits are produced. Sex expression in cucumber may be affected by several factors such as plant density, plant stress, temperature, and light intensity. Reduced quantities of female flowers in gynoecious cultivars may result from exposure to stress caused by high plant population densities, insect attack, wind damage, and combinations of low light intensity and high ambient temperatures. The commercially available hormone ethephon, applied at 125 to 250 ppm, increases the production of pistillate flowers in gynoecious cultivars. Cucumbers will interbreed with other cucumber cultivars but not with melons or squash. Some markets, such as the Japanese market, prefer "bloomless" fruits or fruit free of the natural film or powdery tissue that covers the skin of cucumbers and several other vegetables.

Cultivars

Cultivar selection is one of the most important aspects of the crop production process. Selection of cultivars adapted to growing conditions in Hawai'i and seed quality of the cultivars are significant production factors that deserve careful planning and consideration. Desirable traits required for local cultivars include high productivity, high fruit crispness and firmness, and resistance to watermelon mosaic virus, zucchini mosaic virus, cucumber mosaic virus, powdery mildew, and angular leaf spot (Figure 1). The market still relies on the old 'Burpee Hybrid' as a standard for fruit quality. First released in 1945, 'Burpee Hybrid' accounted for over 75 percent of cucumbers grown locally in the 1960s.

Newer commercial cultivars with resistance to important diseases such as angular leaf spot, anthracnose, cucumber mosaic virus, watermelon mosaic virus, zucchini yellow mosaic, downy mildew, powdery mildew, and scab are available. As described in the previous section, hybrid cucumber cultivars may be monoecious, gynoecious, or parthenocarpic. Parthenocarpic cultivars will produce seedless fruit in the absence of bees and pollination during the crop growth cycle. If bees are present for pollination, parthenocarpic plants will yield normal seeded fruits but fruit may be off-shaped.

Cultivars adapted to Hawai'i are listed in Table 1. Promising cultivars in Hawai'i based on trials on O'ahu

Figure 1. Important quality traits for slicing cucumbers are crispness, medium length, form, and an uniform, deep green color.

Table 1. Cultivars adapted to Hawai'i

	Fruit Length (inches)	Fruit Diameter (inches)
Western Slicing Types:		
'Burpee Hybrid II'	8	2.5
'New Market #2'	10	2.5
'Sweet Slice Hybrid'	11	2.5
'Lani Hybrid' (UH cultivar)	9	2.5
'Milo Hybrid' (UH cultivar, indeterminate monoecious)	8	2.5
'Dasher II' (gynoecious)	8	2.5
'Sakata #69'	8	2.5
'Slicemaster'	8	2.5
Slicing Oriental Types (monoecious with an upright habit):		
'Progress Hybrid'	10	2
'Tasty Gem Hybrid'	10	2
'Spring Swallow'	7	1

include 'Genuine' and 'Spring Swallow'. Other for-trial cultivars include 'Soarer', 'Southern Delight', 'Pegasus', 'Green Knight', 'Tokyo Slicer', 'Conquistador', and 'Brocade'.

FERTILIZER RECOMMENDATIONS

Soil Type

Cucumbers are adapted to a wide variety of soil types with good drainage and adequate water-holding capacity.

Optimum pH

Cucumbers do well under slight soil acidity. The optimum soil pH ranges from 5.5 to 7.0. In general, if the soil pH is below 5.8 and the available soil calcium is less than 2000 lb per acre, apply 2000 lb/acre (4.5 lb/100 square feet) of agricultural lime 8 to 12 weeks before planting. However, some Hawaiian soils may require considerably more lime. Liming to a pH of 7.2 to 7.5 plus the use of nitrate-nitrogen fertilizer sources help to reduce incidence of Fusarium wilt (caused by *Fusarium oxysporum*) in the field. Micronutrient availability may be reduced at a pH above 6.5.

Nutrient Rates and Placement

Fertilizer applications should be based on crop nutrient demands and stage of crop growth. Tissue and soil analyses help to determine how much fertilizer to apply to complement the nutrient levels already available in the soil. Soil samples should be taken and appropriate fertilizers added as recommended by University of Hawai'i soil scientists for the particular soil type. If the soil series is not known, growers should supply sufficient information about the origin of the soil sample so that the soil series can be determined through soil survey maps. Excessive fertilizer rates beyond crop needs may result in salt buildup, phytotoxic effects on plant growth, ground water contamination, delayed harvest due to excessive foliage growth, and capital losses due to purchase of unneeded fertilizer. Cucumber tolerance to salt build up in the soil ranges from moderate to sensitive.

Estimated rates of nutrient removal for N-P_2O_5-K_2O-MgO-CaO in fruits, leaves, and stems with yields of 10,000 lb/acre are 32-9-44-6-23 lb/acre, respectively. Over 80 percent of the total crop nutrient removal takes place during the fruiting stage of crop growth.

Greenhouse studies of fruit growth and nutrient uptake rates in the continental United States indicate that cucumbers respond better to nitrate than ammonium-N fertilizer sources. This results in greater Ca, Mg, and K levels in the fruit. Recommended fertilizer rates for Hawai'i are 1500 to 2000 lb/acre of 15-15-15 or similar N-P-K fertilizer. Band half of the fertilizer 3 inches to the side and 3 inches below the seed at planting. Side-dress one quarter of the fertilizer rate 3 to 4 weeks after planting and the remaining quarter 6 to 7 weeks later. With the onset of harvest, side-dress every 2 weeks with a 3:1 mixture of sulfate of ammonia (21 percent N) and muriate of potash (61 percent K) or a 1:1 mixture of urea (46 percent N) and muriate of potash at a rate of 200 lb/acre. Since N and K tend to leach, apply additional fertilizer after a heavy rain.

On soils very low in available phosphate, apply 1500 lb/acre of treble super phosphate (47 percent P) or 1500 lb/acre of monoammonium phosphate (11-52-0). If both lime and phosphates are required, they should be incorporated together 8 to 12 weeks prior to planting.

K improves deep green fruit color, firm flesh, shape, and overall yields.

Mg is required in cucumbers to help obtain a deep green fruit color. Mg deficiencies are intensified in fields that have received high N or K fertilizer rates. For soils low in Mg, apply magnesium sulfate (Epsom salt, 9.8 percent Mg) or its equivalent at 150 to 500 lb/acre. Soil Mg deficiencies can also be corrected with periodic, light, dolomitic limestone applications.

Cucumber's nutrition program should be tuned to achieve maximum yields and optimum market quality. For example, insufficient K will result in misshapen fruit or "bottlenecks". Low N restricts growth, modifies the length-to-diameter ratio of fruit, and reduces fruit set and color development. The symptoms listed in Table 2 should help diagnose specific deficiencies. However, be aware that abnormalities such as those caused by root rot and nematode infections may produce similar symptoms in plants.

Organic amendments. Manure applications improve quality and yields of vine crops. Composted manures help to improve soil texture and drainage and act as slow-release fertilizers. Apply up to 20,000 lb/acre (10 MT/acre) as a complement to calibrated chemical fertilizer applications. Chicken manure is often added at amounts of up to 1 lb/hill and is worked into the soil.

Fertigation. Available soluble fertilizers may be injected through the irrigation system in place of sulfate of ammonia and muriate of potash. N levels of 200 ppm and K levels at 250 ppm in fertigation solution are recommended for maximum cucumber yields. A schedule of

fertilizer rate applications for cucumber is listed in Table 3. Before using chemicals through irrigation systems, comply with any regulations which may apply.

Nutrient Tissue Analysis

Periodic nutrient analysis of foliage tissue is useful to obtain an estimate of a crop's nutritional status and serves as a record of crop performance. The tissue analysis should be calibrated with soil fertility levels according to soil samples taken before planting. For tissue analysis, collect the most recently matured whole leaf (petiole and leaves) located below the last open flower cluster. A representative tissue sample from a field plot consists of 25 to 50 leaves free of insects or diseases. Collect samples prior to the fruiting stage. Recommended optimum ranges for cucumbers are found in Table 4.

CULTURE AND MANAGEMENT PRACTICES

In typical commercial operations, cucumbers are grown in polyethylene-mulched beds with drip irrigation. Water and nutrient inputs are closely monitored and adjusted with drip irrigation. The plastic mulch helps control weeds, maximizes effects of water and fertilizer, and reduces incidence of fruit rots. Yields of ground culture are 40 to 80 percent of those obtained with mulch culture. Cucumbers are susceptible to damage from wind and need the protection provided by windbreaks in wind-prone areas. Examples of commonly used windbreaks include 'Tropical Coral' Tall Erythrina (*Erythrina variegata* L.) and wild cane (*Saccharum spontaneum* hybrid clone *Moentai*). Other suitable windbreaks may also be used. Where annual windbreaks are used, an in-field rotation may be conducted for the following crop by rototilling the row where the windbreak was grown, planting in the row, and preparing the bed in that area.

Time to Plant

In Hawai'i, cucumbers are planted year round at elevations from sea level to 3000 feet (0 to 1000 m) and from April to October at elevations above 3000 feet (1000 m). Cucumbers grown at high elevations often become bitter in the winter season.

Field Preparation

The field may require plowing or subsoiling to break a hard pan. The field is then disked and/or tilled to break up soil clods. Soils with poor drainage benefit from the incorporation of manure or other organic matter materials into the soil. If a soil amendment such as lime is needed, broadcast it before plowing and incorporate at a depth of 10 to 12 inches (25 to 30 cm) 8 to 12 weeks prior to planting. This allows the lime to react with the soil to correct pH assuming sufficient moisture is available in the soil. If a nematicide is used, apply at least 2 weeks prior to planting in light soils and 3 weeks prior to planting in heavy soils. Cover crops should be turned over 2 to 4 weeks (earlier for the ones that decompose faster) prior to planting cucumbers to allow for litter decomposition.

Propagation

Cucumbers are both direct seeded and transplanted in Hawai'i. Proper soil temperatures for seed germination range from 55 to 95°F (13 to 35°C). Thinning is conducted in two operations for direct-seeded crops. The first thinning occurs at the two-leaf stage leaving 4 to 5 plants per hill. The final thinning takes place about a month after seeding, leaving two plants per hill. Cucumbers can be transplanted when adverse growing conditions are expected during the initial growing stages, when expensive seed is used, or for special operations such as hydroponic cultures. About 1 to 2 lb/acre of seed is required for direct-seeded cucumbers (there are about 1100 seeds per ounce). Cucumber inoculation with Vesicular-Arbuscular Mycorrhiza fungi (*Glomus* spp.), which has been shown to improve nutrient uptake in other crops, also improves tolerance to salt stress and prevents attack from damping-off, caused by *Pythium ultimum*. However, *Glomus* seed inoculants are not currently commercially available. Seed at a depth of 0.75 to 1 inch (2 to 2.5 cm).

Spacing

Many variations of plant spacing are used. The rows are spaced 4 to 6 feet apart to allow space for spraying and harvesting in trellised fields. Plant spacing within the row is 1 to 5 feet, depending on the number of plants per hill and on vine vigor of the particular cultivar. Cultivars with vigorous lateral growth such as 'Burpee Hybrid II' should have an increased spacing. Cucumbers grown in plastic mulch may be planted two rows to a bed with rows in the bed spaced 9 inches. Greenhouse- and hydroponic-grown cucumbers are generally planted closer and may require pruning.

Training

Cucumbers may be grown in trellises or in ground culture. Trellis the oriental slicing types to prevent the

Table 2. Common nutrient deficiency symptoms in cucumber

Nutrient	Deficiency Symptoms
N	Mature leaves yellowish green to yellow; stems slender, hard, and fibrous; fruits light in color and pointed at blossom end; stunted roots turn a brownish color and then die.
P	Mature leaves change from a dark to dull green; stems slender; fruits dull green to bronze.
K	Mature leaves bluish green near veins; bronzing and necrosis of leaf margins; young leaves are puckered or crinkled; fruits constricted at stem end; plant growth slow.
Mg	Plants are small and appear weak; inter-veinal chlorosis on mature leaves, veins remain green; mature leaf edges brittle and ragged; yields are low and quality of fruit is poor.
Ca	Misshapen fruit; water-soaked and necrotic lesions on blossom end; "pillowy" fruit disorder; reduced shoot, root, and fruit growth.

Table 3. Timing and fertilizer injection rates recommended for cucumbers, beginning at transplanting

Timing (after transplanting)	Fertilizer Rates (lb/acre/week)
1st to 3rd week	2.5 lb of 20-10-20
4th to 8th week	5 lb of 20-20-20
9th to 16th week	6.25 lb of 20-20-20
4th, 8th, and 12th week	5 lb of Epsom salt

Table 4. Recommended tissue nutrient ranges for cucumber

Nutrient	Target Level[1]
N	3.3-4.0%
P	0.4-0.8%
K	2.8-4.0%
Ca	1.8-2.5%
Mg	0.4-0.5%
S	0.3%
Fe	108 ppm
Zn	23 ppm
Mn	60 ppm
Cu	8 ppm
B	25 ppm

[1]Percent dry matter content. Nutrient level of most recently matured leaf at the pre-fruiting stage (5th to 6th leaf from apex).

development of crooked fruits. Yields of Fancy and No. 1 fruits for non-trellised cucumbers will be 40 to 75 percent of those obtained with staked cucumbers. The major advantages and disadvantages of trellising a cucumber crop are listed in Table 5.

Trellises constructed along the row should be 5 to 7 feet high. Space posts at a maximum of 15 feet. An 8-gauge wire is placed on top and a 12-gauge wire on the bottom. Twine or plastic netting is used for the trellis. Three to four trips through the field are required to train the vines into the trellis until the vine reaches over the top wire. The potential also exists to double crop cucumbers following a staked tomato crop, saving the cost of staking and mulching. In addition, double cropping will result in improved fertilizer-use efficiency in the field.

Pollination

Monoecious cucumbers are dependent upon honeybees for pollination. Eight to 10 bee visits per flower are required for adequate fruit formation in cucumbers. In many states, this is obtained with one to three beehives (20,000 to 30,000 bees per hive) per production acre. Trials in California showed that placing three beehives instead of one beehive per acre resulted in an increase of 100 crates/acre of marketable fruit, earlier harvest, and reduced harvest period resulting in 33 percent less harvests. Professional beekeepers provide beehives in some states, but these services are not currently available in Hawai'i.

Pesticide applications should be managed carefully since most organic pesticides are toxic to bees. To minimize bee kills: (1) know the location of the beehives around the field; (2) avoid spraying when bee activity is high; (3) read the pesticide label to determine its toxicity to bees; (4) avoid spraying near beehives; and (5) avoid leaving puddles around the pesticide rig which might attract and poison thirsty bees.

Poorly developed or misshapen fruit may be the result of stress during the embryo-forming period of fruit growth. Any unevenness in seed formation will produce misshapen fruit. A "wasp shape", for example, may be the result of late pollination (1 or 2 days after full bloom or anthesis), which causes only the ovules at the stigma end of the fruit to produce seed. Also, fertilization of the flowers may be interrupted due to internal physiological factors such as a nutrient deficiency. Evidence indicates that B applications at rate of 0.6 lb/acre may improve pollination efficiency in B-deficient fields.

Irrigation

Cucumber requires a constant water supply to produce high quality and yields. Periods of growth when the plant is most susceptible to irrigation deficits include seed germination, flowering, and fruit enlargement. The frequency of irrigation depends largely on soil type and weather conditions. In general, for sandy soils with dry weather, the fields should be irrigated at least every other day or more often at a rate of 1 to 2 inches per week. Cucumber in Hawai'i is normally drip irrigated. Two or 3 weeks after planting, a second drip line is installed about 18 inches parallel from the one applied at planting. Thus, there is a drip line on both sides of the row. In

Table 5. Advantages and disadvantages of trellised cucumbers

Advantages:

a. Increased harvesting efficiency and greater yields
b. Improved pest management
c. Straighter fruits
d. Uniform fruit color
e. Reduction of fruit loss to soil diseases
f. More plants per acre due to closer rows

Disadvantages:

a. Extra cost of trellising materials
b. Extra labor costs to erect, dismantle, and train vines
c. Plants are more prone to wind damage

sprinkle-irrigated fields, avoid irrigation between 8 to 11 AM to prevent interference with honeybees.

PESTS

Cucumber yields are frequently reduced by a myriad of insect, disease, and weed pests. For example, over 40 different diseases are known to infest this crop. Cucumbers are especially susceptible to pest attack when growing conditions are less than ideal and when sound cultural practices have not been followed.

Integrated Pest Management (IPM)

IPM is a systems approach to reduce pest damage to tolerable levels using a variety of techniques such as natural enemies, genetically resistant plants, sound cultural practices, and, when appropriate, chemical pesticides. The IPM approach is based on proper pest identification, periodic scouting, and the application of pest management practices during the precise stage of the crop's development when no control action would result in significant economic losses. Two additional strategies of an IPM approach are (1) take pest control actions during the most vulnerable stage of the pest's life cycle to maximize results with the least possible effort, and (2) use synthetic pesticide spray applications for pest suppression only after all other pest control alternatives have been considered and exhausted. The main objectives of using alternative pest controls are to reduce the high capital costs incurred with frequent pesticide applications and to maximize the abundance of beneficial organisms.

Scouting. Periodic pest monitoring allows the producer to take control actions in a timely manner based on stage of crop growth and on pest population levels. This is more efficient than the conventional calendar approach of pesticide applications, which consists of weekly sprays whether pest pressure is high or not. Scouting consists of periodic field visits during which about five random samples should be taken. Keep a written record of pest numbers, damage levels, distribution in the field, and stage of crop growth at each sampling date. These records are helpful in developing "in-house" economic threshold levels for the major pests on the farm.

Pest management pointers. The best pest control program is that which takes preventive action well before problem pests actually infest the field. Knowledge of pest biology improves the grower's ability to design the proper pest control measures. Successful growers are those which consistently pay attention to detail in all areas of the IPM program (Table 6).

Insects

Important insect pests of cucumber include aphids, melon flies, leafminers, whiteflies, and thrips. Other pests include spider mites, caterpillars, and slugs. It is important to prevent or minimize pest problems before serious outbreaks occur, to detect pest problems early, and to select appropriate controls. The judicious use of pesticides is important in the management of resistance to pesticides, conservation of beneficials, minimization of environmental hazards, improved safety of workers in the field, and overall reduction of farm input costs.

Outbreaks of the silverleaf whitefly (previously

Table 6. Basic techniques for cucumber pest control and prevention

1. Use disease-free seed and soil.
2. Use resistant or tolerant varieties where possible.
3. Rotate with non-cucurbits.
4. Early detection of insect and disease problems.
5. Prompt removal of old crops from the field.
6. Apply recommended irrigation and fertilizer rates.
7. Proper weed management.
8. Clean farm machinery and tools to prevent soil-borne pathogen spread.
9. Apply areawide management strategies.
10. Proper recognition of beneficial and pest organisms.
11. Use pesticides only when necessary.
12. Use registered pesticides with maximum effectiveness on the target pest and with minimum adverse effects on non-target organisms.

referred to as sweetpotato whitefly) and the greenhouse whitefly are currently a major problem for cucumber production in Hawai'i. Apply insecticides only when necessary and, when possible, rotate pesticide families to delay development of insect resistance to pesticides. Insects with exploding population growth rates such as thrips, whiteflies, mites, leafminers, and aphids are especially prone to develop pesticide resistance when exposed to frequent applications of the same insecticide.

Aphids. Aphids damage cucumber plants by feeding on plant sap and by spreading important viral diseases such as papaya ringspot, zucchini yellow mosaic, and cucumber mosaic. Feeding damage by aphids can reduce plant vigor and may cause leaf deformation. Heavy aphid feeding may encourage sooty mold growth. Viral diseases spread by aphids can devastate cucumber crops. Aphids have winged forms which can fly into crops and spread viral diseases from weeds or infected plantings. Aphids in Hawai'i are generally females which reproduce without mating. Aphids can reproduce in 1 week. Therefore, several generations are produced in one growing cycle.

For control, apply insecticides as needed based on close monitoring of aphids and their natural enemies. Aphid natural enemies include ladybird beetles, maggots of syrphid flies, lacewings, parasitic wasps, and fungal diseases. Old crops should be promptly destroyed to reduce aphid movement and the diseases they carry to healthy crops.

Caterpillars. Cutworms, which include the variegated cutworm (*Peridroma saucia*) and the black cutworm (*Agrotis ipsilon*), can devastate young cucumber plants by chewing through the stems at the soil line. Cutworms are active at night. Other caterpillar pests such as loopers have generally been of minor importance in commercial cucumber plantings.

Control is warranted when high populations are present in the field before planting. Baits containing *Bacillus thuringiensis* are available for cutworm control. Control is normally not recommended when the plants are more than 1 foot tall.

Leafminers. Leafminers are small, yellow maggots that form trails beneath the leaf epidermis as they feed. The adults are small flies, about 0.0625 inch (1.6 mm) long and mostly black in color with some yellow markings. The adult flies cause small, whitish stippling on the leaves as they feed and lay eggs. The egg hatches in about 3 days and the larva begins to mine the leaf as it feeds. After 4 to 7 days, the larva drops to the soil to pupate.

Leafminers are normally a secondary pest that is kept in check by natural enemies. However, both the vegetable leafminer (*Liriomiza sativae*) and the celery leafminer (*L. trifolii*) may become primary pests in cucumber fields where intensive pesticide use has destroyed their natural enemies. This trend began in the 1950s when widespread DDT and closely related compound applications eliminated the natural enemy populations of leafminers. Tiny, wasplike parasites are the main natural enemies of leafminers. Due to the establishment of effective natural enemies and the resistance of leafminers to insecticides, the major emphasis with leafminer management is the conservation of its natural enemies. This means that registered pesticides should be applied only when necessary and should be selected for maximum control of the target pest with minimum adverse effects on beneficial insects.

A monitoring program consists of placing white styrofoam or plastic pans at the soil level below the plants throughout the field to collect larvae as they drop and pupate. Insecticides are recommended when average counts rise above 20 pupae/pan/day. Yellow sticky traps can also be used to monitor leafminers in the greenhouse. Thresholds need to be determined by the grower based on the particular environmental and crop conditions. Since contact insecticides will not reach the larvae inside the leaf, systemic insecticides are recommended. Due to their high reproductive rates, leafminers are prone to develop resistance to pesticides. The celery leafminer is more difficult to control because it develops resistance to pesticides faster than the vegetable leafminer. For best results from pesticide treatments use the recommended rates, rotate pesticide families when possible and obtain thorough foliage coverage. Cultural controls include field or greenhouse sanitation, growing less-susceptible varieties, and weed control around the field to eliminate alternate hosts.

Melon Fly. The melon fly (*Bactrocera cucurbitae*) has long been a major pest of cucumbers in Hawai'i. Melon fly damage occurs when adult female flies lay their eggs into fruits and sometimes into stems. An indentation often occurs at the site of oviposition, and the fruit may or may not become curved. The eggs later hatch into maggots which live and feed within the fruit. Infested fruit frequently rot, either in the field or after harvest. Attacks are severe on young, developing fruit, especially under high-humidity conditions after summer rains.

Traditionally, this pest has been controlled in problem areas with protein baits and an insecticide such as malathion applied to corn border rows. An advantage of

this method is that insecticides for the melon fly are applied outside of the cucumber crop and do not upset the balance of aphid and leafminer natural enemies within the crop. The importance of sanitation to manage flies cannot be overemphasized. Melon flies developing within the fruit from cucumbers and other fruiting vegetables such as melons, squashes, peppers, beans, and tomatoes may be major in-field reservoirs. Do not dispose of culled fruit harboring live melon fly larvae in areas close to the production field. Infested fruit left in the field will allow the melon fly to complete its life cycle and cause further damage. Promptly destroy old crops so that they do not serve as in-field reservoirs.

Alternate weedy hosts of the melon fly include wild bittermelon or balsam pear (*Momordica charantia* L.), ivy gourd or scarlet-fruited gourd (*Coccinia grandis* L.), wild spiny cucumber gourd (*Cucumis dipsaceus* Ehrenberg ex. Spach), and kupala (*Sicyos pachycarpus*). Wild bittermelon and ivy gourd are excellent melon fly hosts and are important reservoirs for this pest. These weeds are also reservoirs of important cucurbit virus diseases. Eight parasites and six predators are known to be natural enemies of melon flies in Hawai'i but do not provide effective control in commercial-produce operations.

Due to the prolific nature of this pest, organized areawide controls in vegetable producing areas are more effective than single-attack techniques followed by individual producers. The following factors should be considered in an integrated melon fly control program: (1) populations are likely in areas where weed hosts such as wild bittermelon and ivy gourd are present so population levels in and around the field should be evaluated; (2) honeydew secretions in or around the field from aphids, scales, or leafhopper feeding on foliage may attract melon fly populations into the field; (3) corn borders are more effective as trap crops to attract melon flies in fields where alternate weed hosts are not prevalent around the field margins; and (4) melon fly populations should be periodically monitored through trapping.

Mites. Outbreaks of carmine spider mites (*Tetranychus cinnabarinus*) occur occasionally, especially during hot, dry weather. Spider mites feed on plant sap and prefer to live on the leaf underside. Their feeding causes stippling of white areas on the leaves. Heavily infested leaves may turn yellow and drop off prematurely.

Most miticides do not kill the mites at the egg stage so several applications are required for effective control. It is important that pesticides reach the mites on the leaf undersides. Mites can be inspected with a hand lens. Natural enemies of spider mites include ladybird beetles and predaceous thrips and mites. Varietal differences exist with respect to tolerance to spider mite feeding, but no mite resistant commercial cultivars are currently available.

Root-knot Nematodes. Meloidogyne incognita are microscopic roundworms that feed on the roots of plants. Foliage symptoms from the affected root system include stunting, wilting, and leaf yellowing. Infested roots develop gall-like swellings. Adult stages of the nematode live inside these root swellings. These root galls prevent normal water and nutrient uptake by roots. Nematode numbers are often higher in sandy soils under warm, summer weather conditions. Clean fields may be infested by run-off irrigation water from nearby contaminated fields and from movement of soil or infested plant material. Soils may be tested to estimate parasitic nematode populations.

Before planting, infested cucumber fields are normally fumigated for nematode control. Grasses that are non-hosts to the root-knot nematode, such as oats, barley, wheat, and rhodes grass, may be grown before cucumbers. However, some grasses may attract undesirable cutworm populations into the field. Cultural controls to reduce nematode numbers include crop rotations, fallow, field flooding, and destruction of volunteer weedy hosts. No resistance is available to rootknot nematodes in the cucurbits.

Other nematodes that infest cucumber are the sting nematode, *Belonolaimus* spp.; the root lesion or meadow nematode, *Pratylenchus* spp.; the stubby root nematode, *Trichodorus* spp.; and the pin nematode, *Paratylenchus* spp. Yield losses from these nematodes range from moderate to heavy. In many cases, nematodes do not affect yields directly. Root lesions caused by nematodes invite bacterial and fungal infections.

Stinkbugs. Stinkbugs, ranging in length from 0.5 to 0.67 inch, feed on plant sap and inject toxins into the plant while feeding. Heavy feeding may deplete the plant of resources and reduce yields or make it susceptible to disease attack.

Thrips. Thrips are small (<0.0625 inch or 1.6 mm), slender insects. Adults usually have wings with feathery hairs that enable them to fly. Many of the important species of thrips have piercing-sucking-type mouth parts and are not capable of rasping plant tissue. In Hawai'i, the melon thrips (*Thrips palmi* Karny) and the western flower thrips (*Frankliniella occidentalis*) commonly infest cucumber plantings. Melon thrips tend to live and feed on the leaves. Leaf edges tend to curl downward

after heavy thrips feeding. Serious damage often occurs during the early crop stages. Population pressures can be especially high during hot and dry conditions. Local research has shown that cucumber tolerates substantial foliar damage before economic damage occurs. Growers should protect their crops from damage levels (an average of more than nine thrips per leaf from a sampling of 50 randomly chosen leaves in a small, 0.5 acre cucumber planting) early in the season when the highest quality fruit and most of the total yield is produced. The practice of weekly insecticide treatments to suppress melon thrips when populations are low to moderate is not warranted. Melon thrips are resistant to many organophosphate and pyrethroid insecticides. Consult with your agricultural extension agent, entomology specialist, or agrichemical representative for information on current, effective, registered pesticides.

Unlike the melon thrips, which prefer to feed on the leaves, the western flower thrips tend to live and feed in cucumber flowers. The western flower thrips can cause fruit scarring when they feed on immature fruit. Damage appears as silvery, web- or streak-like scarring which may be accompanied by fruit malformation. Laboratory analyses may be required to accurately identify the species present in your field. Natural enemies of thrips include minute pirate bugs, spiders, and predaceous mites.

Whiteflies. The silverleaf or sweetpotato whitefly biotype B (*Bemicia argentifolii*) and the greenhouse whitefly (*Trialeurodes vaporariorum*) can build up to high numbers on cucumber. A mixture of both whiteflies is frequently found on cucumber. An accurate identification of the whitefly species present is important to make correct crop management decisions. High densities of the silverleaf whitefly cause various disorders in tomatoes, squash, and leafy vegetables whereas similar densities of the greenhouse whitefly do not. Growers should learn to distinguish between the two major whiteflies. With some practice, growers can distinguish the species by examining the pupal cases with a hand lens. Whiteflies feed on plant sap and can reduce plant vigor and yield when populations are very high. Both whitefly species infest a very wide range of host plants including vegetables, ornamentals, field crops, and weeds. Whiteflies, like aphids, secrete honeydew, a sticky liquid that is a substrate for sooty mold. Whiteflies have six life stages: the egg, four nymphal stages (the fourth nymphal stage is commonly referred to as the pupal stage), and the adult.

The silverleaf whitefly was so named because of the disorder it can induce on certain cucurbits. On susceptible crops such as squash, the leaf surface becomes silvered. The silverleaf disorder, probably caused by a toxin injected by the whitefly, has not been observed on cucumber. The average life cycle is 39 days from egg to adult, but this period varies with temperature. The pupal case of the silverleaf whitefly is dome shaped and has few filaments along its outer edge. The average life cycle of the greenhouse whitefly is 32 days from egg to adult, but varies with temperature. The pupal stage is caked shaped with many tiny filaments around the outer edge.

The sweetpotato whitefly-transmitted gemini virus, which has resulted in stunting and reduced fruit size in Florida and California, has not yet been detected in Hawai'i. These viral diseases remain a great threat to Hawaiian agriculture.

Both whiteflies are resistant to many pesticides. Insecticidal soaps and oils are widely used for whitefly control. These materials require thorough coverage of the leaf underside for effective control. These insecticides are relatively mild on natural enemy populations. Areawide control strategies are necessary in areas where whitefly numbers are abnormally high. Natural enemies include parasitic wasps, ladybird beetles, and fungal diseases. Consult with your local county extension agent or entomology specialist for an update on recent developments in whitefly management and control.

Diseases

Important diseases of cucumbers include the papaya ringspot virus, zucchini yellow mosaic, watermelon mosaic, cucumber mosaic, angular leaf spot, anthracnose, damping-off (*Pythium* and *Rhizoctonia* root rot), leafspot, downy and powdery mildews, and scab. Once a disease has infested a crop, remedial action can be taken, but it is usually too late to prevent serious losses. Therefore, field and seed selection, seed treatment, rotations, water management, weed control, insect control, and other recommended sanitation practices and chemical treatments should be combined in a disease management program to prevent disease attacks in cucumber. Seed treated with a fungicide can protect the field from serious yield losses. Pay close attention to fungicide application techniques. Coverage of all sections of the field is important since unprotected spots may become undesirable sources of inoculum. Fungicide sprays are usually an integral part of cucumber production even when planting disease-resistant cultivars. Disease control is improved when fungicide treatments are initiated at the two true-leaf stage. Other diseases of cucumber

include wet rot, *Choanephora cucurbitarum*; Alternaria leaf blight, *Alternaria cucumerina*; Cercospora leaf spot, *Cercospora citrullina*; Sclerotinia stem rot, *Sclerotinia sclerotiorum*; and target leaf spot.

Angular Leaf Spot. The bacteria *Pseudomonas syringae* pv. lachrymans occur on most cucurbits but is more prevalent on cucumbers. Outbreaks are likely under continuous rainfall and temperatures from 75 to 80°F. First symptoms are small, water-soaked, angular lesions on the leaf underside. Lesions, restricted between the small, cucumber leaf veins, turn yellow, develop yellow hollows, and finally disintegrate. Under wet conditions, bacteria ooze from the lesions and later dry into white crusts. Expanding leaves which are close to full size are most susceptible to infection. Old leaves tend to be resistant. Young leaves can be infected mechanically by insects or field workers. Infected stems, petioles, and fruits also develop water-soaked lesions. Fruit lesions are more circular, turn white, and crack open. These openings allow secondary infection by other organisms. The bacteria survive on infected plant refuse and on seed. The disease is spread by wind, rain, insects, and field workers. Damaged plants with wounds from wind or sand are especially susceptible to infection.

Controls include a 2- to 3-year rotation, use of disease-free seed, and weekly sprays of a broad-spectrum fungicide such as chlorothalonil plus a Cu fungicide. Be aware that high Cu application rates may result in crop injury, especially during the early crop stages. Resistant or tolerant cultivars include: 'Centurion', 'Dasher II', 'Early Triumph', 'Floracuke', 'Raider', 'Spring 440', and 'Pointsett 76-S'.

Anthracnose. Leaf spot lesions caused by the fungus *Colletotrichum orbiculare* (*C. lagenarium*), occur on leaves, stems, and fruits, and result in serious losses in cucumber, watermelon, and muskmelon. The disease rarely affects squash or pumpkins. Lesions are distinguished by the pinkish spore masses which develop in the lesions. The symptoms first appear on the foliage as small, yellowish, water-soaked areas which later turn dark and dry out. The lesions are not restricted by the leaf veins. Severely affected vines usually die. Shallow, brownish, elongated lesions develop on infected stems and petioles. Circular, black, sunken cankers also appear on the fruits. Black specks appear on enlarged fruit lesions under humid conditions. Salmon-colored spores ooze from the black specks. Anthracnose is spread by infected seed, wind, rain, insects, and by field workers, especially during wet weather. The disease is soil-borne for over 3 years and is also carried on volunteer weedy cucurbits, such as *Commelina diffusa*, after harvest.

To prevent spreading the disease by plant refuse, it is important to destroy the crop immediately after the last harvest. Five-year rotations are also recommended on anthracnose infested areas. Weekly fungicide preventative programs at >100 psi are recommended during humid, rainy weather in areas where anthracnose is a problem. Resistance is available in some cultivars such as 'Dasher II', 'Pixie', 'Poinsett 76', 'Slice Master', and 'Sprint 440 II'.

Bitterness. Bitterness, a physiological disorder, is often observed under cool weather at higher elevations. At low elevations, excessive nitrogen fertilization may result in this disorder, but the causal factor at higher elevations has not been determined. The compounds cucurbitacin B and C are responsible for bitterness in cucumber. They are normally found at higher concentrations in the vines. In the fruit, the chemical concentrates at the stem end just below the skin. The newer cucumber hybrids are less susceptible to bitterness than older, open-pollinated ones.

Damping-off. Fungal organisms that cause damping-off include *Pythium* spp., *Rhizoctonia solani*, *Thielaviopsis basicola*, *Fusarium equiseti*, and others. Affected seedlings fail to emerge or collapse shortly after emergence. Emerged seedlings affected by *Pythium* turn a light green color and the cotyledons collapse. Water-soaked lesions also appear on the seedlings at the soil level. Lesions caused by *Thielaviopsis* are initially grey to reddish in color but turn to a coal black. A red to brown rot is more characteristic of infections caused by *Fusarium*. Humid conditions caused by close planting, poor drainage, or rainfall are conducive to damping-off.

Control of damping-off in the greenhouse includes proper soil sterilization and strict sanitation practices. In the field, cultural practices that improve drainage and wider planting distances are recommended. High-quality seed is also recommended. Cultivars resist to damping-off are not available.

Downy Mildew. Optimal conditions for *Pseudoperonospora cubensis* are cool nights between 55 to 75°F and relative humidity >95. All cucurbits are susceptible to this fungus, but yield losses are most common in cucumbers and muskmelons. Several strains of this disease may exist in cucurbits. Initial lesions, which are limited by the small leaf veins, include irregular to angular, pale green spots which appear on the upper side of leaves near the plant crown. The lesions then turn

into yellow, angular spots. The undersides of leaves later develop a downy white to grey mold, which may turn grey to purple during wet weather. Spores develop in this mold. The spores can be transmitted from plant to plant and from field to field by wind. After spores infect a new leaf, lesions develop in 4 to 6 days. The infected leaves eventually wither and die. Plant stunting and poor fruit growth result under heavy disease pressure.

The disease can be prevented with weekly fungicide treatments. Sprays are less effective once the disease has appeared in the field. Areawide monitoring programs exist in other states in which weather is monitored and growers are warned to start their spray programs when the weather is conducive to downy mildew outbreaks. Resistance is available in some commercial cultivars such as 'Dasher II', 'Marketmore 76', 'Poinsett 76', 'Sweet Slice', 'Slice Master', 'Sprint 440 II', and 'Gemini 7'. Downy mildew resistance in cucumbers is complex and involves several genes.

Gummy Stem Blight. Mycosphaerella melonis (*Didymella bryoniae*) causes lesions on leaves and stems and less frequently on the fruits. This fungus attacks all cucurbits. Seedlings die rapidly if hypococtyls or cotyledons are infected. In older plants, lesions produce a characteristic red or brown exudate at the crown of the plant and along the vines. Black spores may be seen around the infected tissue. Initial leaf symptoms are irregular circular dark spots which may be surrounded by a yellow halo and later dry up and crack. Infection starts from the leaf margins and proceeds inwards resulting in a typical leaf blight. Affected fruits have small, water-soaked, circular, brown spots which have a greasy appearance. Small, black spores may also develop in these lesions. The pathogen enters the plant through wounds caused by insects, wind, sand, or machinery. The organism survives on crop debris and cucurbit seeds for 2 years. High disease pressure can be expected in the field and in the greenhouse under wet and cool conditions.

Controls include soil sterilization and proper sanitation in the greenhouse, weekly fungicide applications, rotations, and a choice of drip instead of sprinkler irrigation. Currently, there are no resistant commercial cultivars.

Powdery Mildew. Powdery mildew, caused by *Erysiphe cichoracearum* (*Sphaerotheca fuliginea*), is a serious and common fungal disease under warm and humid conditions during overcast days. Unlike downy mildew, infestation and reproduction may occur under relative humidity as low as 46. Infection can occur at 50°F but is most likely at 80°F. All cucurbits are susceptible, but the disease is normally not a problem on watermelons. Symptoms develop primarily in 2- to 3-week-old leaves and on stems. Younger leaves are almost immune to powdery mildew. The disease is characterized by a white, powdery growth, especially on the upper side of leaves and on stems (Figure 2). At first, affected leaves appear normal. Then lesions turn yellow to brown and dry out, resulting in early leaf fall of the older leaves. The disease spreads rapidly in wet weather and a field may be wiped out in only a few days. Fruit infection is rare, but occurs in cucumbers and watermelon. The disease survives on volunteer cucurbit crops or weeds and is carried over long distances by prevailing wind currents.

Controls include maintaining a healthy and vigorous crop, removing volunteer cucurbit crops and weeds around the field, sanitation, and weekly fungicidal sprays. Recent data indicate that sodium bicarbonate (household baking soda) and potassium silicate sprays effectively control powdery mildew and other cucumber diseases. Consult with your local county extension agent or pesticide control specialist for current recommendations and for an update on current EPA regulations on the use of these products as fungicide sprays. Use of tolerant cultivars such as 'Milo', 'Dasher II', 'Marketmore 76', 'Poinsett 76', 'Sweet Slice', 'Slice Master', 'Sprint 440 II', and 'Gemini 7' offers some control.

Scab. The fungus *Cladosporium cucumerinum* affects all above-ground parts of the plant and produces the characteristic scab-like lesions on the fruit. It attacks muskmelon, pumpkin, and squash, but is most serious on cucumbers. During humid weather, a brownish fungal mat of spores develops on the fruit. Most yield losses are caused by infections of the fruit. Initial leaf symptoms include numerous angular, pale green, water-soaked lesions. The lesions turn brown with necrotic margins and then turn grey or white. Petioles and stems also develop elongated disease lesions, and internode length is often reduced. Disease spores are transmitted by wind, insects, and by field workers and machinery. It survives in the field on cucurbit plant refuse. Cool and humid weather conditions are conducive to disease outbreaks.

The disease may be controlled with periodic fungicide sprays and by planting resistant cultivars such as 'Dasher II', 'Calypso', 'Gemini 7', 'Marketmore 76', 'Poinsett 76', 'Slice Master', and 'Sprint 440 II'. Scab resistance in cucumber is due to a single dominant gene.

Fruit or Soil Rots. Soil/fruit fungal rot, caused mainly by *Pythium aphanidermatum* and *Rhizoctonia*

Figure 2. Powdery mildew can be a serious disease in cucumber. The disease is characterized by the powdery growth on the upper side of the leaves.

solani but also by *Botrytis cinerea*, other *Pythium* species, and *Rhizopus stolonifer*, is a serious disease of cucumbers in Hawai'i. The disease results in up to 60 percent yield losses. The disease infects fruit in contact with the soil resulting in rotting and fruit scars. Cottony leak, caused by a *Pythium* spp., is the most common cucumber fruit rot in Hawai'i. Fruit symptoms include a soft and watery white fungus covering the skin. Attacks by this fungus on young seedlings also causes typical damping-off. Soil rot in cucumbers caused by *Rhizoctonia* is less common in Hawai'i. Fruit lesions from *Rhizoctonia* begin as dark green, water-soaked areas. Affected tissues collapse leaving small holes in the fruit which eventually dry up. A brownish, mycelial growth on the lesions appears in affected fruits during continuous humid conditions.

Fruit rots are partially controlled with trellises and plastic mulches. Recommended cultural practices for *Pythium* control include disking the soil 3 to 4 weeks prior to planting to completely decompose old organic matter which helps to prevent the disease organism from surviving in the soil. Fungicidal sprays may be effective in controlling this disease. No cultivar resistance exists to fruit rots in the cucurbits.

Viral Diseases

Viral diseases are among the major limiting production factors for cucumber production in tropical areas. Typical symptoms include green and yellow mottling and wrinkling of the leaves, mottling and wartiness of the fruit, and general dwarfing of the plant. Cultural practices developed in the 1950s included planting of 50- to 100-foot border rows of non-susceptible crops such as sweet corn, beans, or eggplant. Growers should determine which viral diseases are prevalent in their area of production and select suitable resistant cultivars where possible. Laboratory analyses may be necessary to accurately identify the causal agent(s). Enzyme-linked immunosorbent assay (ELISA) kits have greatly simplified virus identification and are available at diagnostic laboratories.

Papaya Ringspot Virus-w Strain (PRV-w). This virus attacks all cucurbits and is the number one viral disease of cucumbers in Hawai'i. Papaya Ringspot Virus-w Strain (PRV-w) was previously referred to as Water-

melon Mosaic Virus I. The virus also infects some weed and legume species. It produces the characteristic virus interveinal chlorosis, stunting, and misshapen fruits (Figure 3). In the field the virus is transmitted by insects, workers, and farm machinery. Greatest disease pressure occurs during the summer perhaps due to the increased aphid activity.

The best approach to manage this disease is to use resistant cultivars. Some cultivars claim resistance to PRV-w but have not been extensively tested for disease or horticultural quality under local conditions. Insecticide applications may reduce aphid numbers in the field, but this alone is usually not sufficient as a control strategy. Other practices include the use of reflective mulches, elimination of volunteer weed hosts, and destroying cucurbit plants in nearby fields.

Zucchini Yellow Mosaic Virus (ZYMV). This virus, first reported in France and Italy in 1981, attacks all cucurbits. Two different strains have been identified in Florida and Connecticut. Symptoms include yellow leaves with a mosaic and distorted appearance. The whole plant is stunted. Affected fruit are also misshapen.

Control practices include use of mineral oils, reflective mulches in the early aphid infestation stage, control of alternate weedy hosts, and insecticidal aphid control. Use resistant cultivars such as 'Sweet Slice'.

Cucumber Mosaic Virus (CMV). This viral disease is of secondary importance to PRV-w and ZYMV as a production problem in Hawai'i. Several strains of this virus attack all cucurbit crops, but watermelon is affected to a lesser degree. Several weed species and crops from 12 plant families are also infested by CMV. Apple of Peru, *Nicandra physalodes* (L.) and Nasturium, *Tropaeolum* sp. are two weed hosts of CMV on Maui. Other vegetables affected by CMV include tomato and pepper. All of these plants show foliar symptoms when affected by CMV. Affected cucumber plants are stunted. Young leaves curl downwards and develop a stunted, distorted appearance. Affected fruit may turn a light green color and is misshapen, mottled, and warty.

For control, destroy alternate weedy hosts close to the field, control aphids with recommended insecticides, and use resistant cultivars. Resistant cultivars include 'Milo', 'Centurion', 'Dasher II', 'Elite', 'Early

Figure 3. Symptoms of Papaya Ringspot Virus, previously known as Watermelon Mosaic Virus I, include misshapen fruits. This disease is especially serious during summer months when aphid activity is high.

Triumph', 'Floracuke', 'Raider', and 'Sprint 440'.

Weeds

Use an integrated approach to effectively manage weeds in cucumber production. The IPM program for weed control uses weed identification, monitoring, sanitation, alternative cultural practices, and timely herbicide treatments. The first approach for weed management is to avoid planting in fields that experience heavy weed infestations. A weed map for each field helps in the design of weed control measures and provides a record of weed problems.

The benefits of proper field preparation to improve cucumber growth and minimize weed problems during the crop growth cycle cannot be overemphasized. Even soil preparation, proper soil moisture, and a preplant fertilized field will improve stand establishment and early crop growth. Cultural practices for weed control include shallow cultivation, plowing, disking, hoeing, crop rotation, cover cropping, living mulches, organic or plastic mulches, and herbicides. For effective weed control, herbicides must be applied at the correct rate and time. Therefore, read label instructions carefully to achieve maximum weed control with herbicide treatments. Surface-applied herbicides normally require rainfall or irrigation after application to maximize weed control efficiency. Cucumbers have a poor competitive ability against weeds, especially during the initial 3 weeks of growth. Weeds are normally controlled through a combination of cultural practices and herbicide treatments.

Pesticide applications should be conducted carefully because the cucurbits are among the most sensitive vegetables to herbicides. For planting selection sites, avoid fields with infestations of troublesome weeds such as nutsedge and fields which have received applications of herbicides such as Atrazine which is likely to have unfavorable residual effects on cucumber growth. Herbicides which may cause injury in cucumber because of carryover include Atrazine, Lexone/Sencor, Bladex, Milogard, Princep, Surflan, Cotoran/Lanex, Karmex/Direx, Lorox/Linex, Classic, and Scepter. Laboratory tests are available to detect Atrazine levels in cucumber leaves with apparent symptoms of herbicide injury.

Successful weed control was achieved in Florida trials with a pre-emergence herbicide application and two hoeings after planting. One or two cultivations while cucumber plants are still young also may provide acceptable weed control. The two hoeings can be substituted with a post-emergence herbicide to achieve similar effectiveness in weed control. Growing cucumbers with plastic mulch is an effective method of controlling weeds. Rows between the mulch beds can be treated with registered preemergence or postemergence herbicides for cucumbers since the cucumber roots may extend into those treated areas. Grassy weeds associated with cucumbers in Hawai'i include lovegrass, *Eragostis pectinacea*; sandbur, *Cenchrus echinatus*; and wiregrass, *Eleusine indica.* Broadleaf weeds include spiny amaranth, *Amaranthus spinosus*; spineless (smooth) amaranth *Amaranthus* spp.; Flora's paint brush (red pualele), *Emilia sonchifolia*; orange pualele, *Emilia coccinea*; Jamaica vervain (joee), *Stachytarpheta jamaicensis*; black nightshade (pōpolo), *Solanum nigrum*; pigweed or purslane, *Portulaca oleracea*; richardia, *Richardia scabra*; sow thistle, *Sonchus oleraceus*; Spanish needle, *Bidens piolosa*; garden spurge, *Euphorbia glomerifera*; swinecress, *Coronopus didymus*; and tarweed, *Cuphea carthagenensis.*

HARVEST AND POSTHARVEST PRACTICES

Timing

Time from planting to first harvest is generally 45 to 55 days for the slicing types and 52 days for the slicing oriental types, varying according to time of year, location, and prevailing weather. At higher elevations, growth will be slightly slower due to cooler temperatures. The crop is picked during a period of 3 to as many as 16 weeks depending on weather, plant vigor, and pest incidence.

Production Yields

In Hawai'i, the current average slicing cucumber yields are about 20,000 lb/acre with 6000 plants/acre, a 100 percent increase over yields obtained locally in the 1950s. Yields during the winter are 50 to 60 percent of those obtained during the summer. University of Hawai'i cultivars 'Milo' and 'Lani' produced 11 and 8 lb/plant, respectively, in Maui yield trials. Experimental marketable yields in Hawai'i range from 37,000 to 64,000 lb/acre. The average Florida yield is 25,000 lb/acre with 17,500 plants/acre. Pickling cucumbers yields in California are about 40,000 lb/acre with once-over harvest and with 60,000 plants/acre.

Maturity

The duration from pollination to harvest for slicing cucumber is 15 to 18 days and 5 to 10 days for pickling cucumber. Cucumber plants set fruit and develop over a

long period of time. Therefore, marketable fruit are ready for harvest over an extended period of time. Size of marketable fruit for slicing cucumbers ranges from 6 to 10 inches in length and 1.5 to 2.5 inches in diameter. Slicing cucumbers should be fresh, crisp, of medium size, well formed, uniform, and deep green in color. Consult the Hawai'i Grading Standards for specific requirements. The fruit is picked before it has reached full diameter and while the seeds are still small and soft. A light green or yellow skin color indicates that the fruit is overmature for picking. Minimum market length for European (parthenocarpic) cucumbers is 11 inches (28 cm) and minimum diameter is 1.5 inches (4 cm). These cucumbers weigh about 1 lb. Fruits from trellised plants are uniformly green, whereas fruits from non-trellised plants may have a yellow-green side on the section touching the ground.

Harvesting Operation

Cucumbers are picked manually. The fruit is held near the stem and clipped or snaped, not pulled, off the vines with a slight, twisting motion that minimizes "pulled ends." Pulled-off fruits have an "open wound" where the fruit skin is torn off. The fruit shrivels around this spot. The frequency of harvest is usually every other day or daily during the warm months and 2 to 3 times per week during cooler weather or at higher elevations. Fruit quality is best controlled when fruit is picked daily, especially during warm weather. Daily harvest is recommended for the oriental slicing types. In large operations, cucumbers are picked and placed in 40- to 50-pound buckets that are put in bins, which a truck takes to a packing shed. An alternative harvesting operation consists of a conveyor belt. Pickers in the field travel a few feet to the conveyor belt on which the cucumbers are placed and conveyed into a loading truck. Bruising of fruit from excessive handling and unloading is significantly reduced with the conveyor belt. Simpler harvesting aids, including hand carts to hold picking containers, also improve harvest labor efficiency.

Cucumbers should be kept in the shade until taken to the packing house where they may be hydrocooled, washed, sorted, graded, sized, packed, unitized for shipment, and shipped to their destination market. For maximum shelf-life, cucumbers should be pre-cooled to 50°F (10°C) after harvest. For maximum harvest efficiency, the field crew should be instructed to handle vines carefully during picking so that immature fruit can size properly, to harvest only when the vines are dry to prevent the spread of diseases, and to remove larger fruits from the vine to prevent the drainage of plant resources into these unmarketable fruits.

Washing

Wash water management practices is an important consideration during the handling process to prevent the spread of postharvest diseases. Decayed fruit should be culled to eliminate potential sources of inoculum. Wash water is chlorinated at 150 ppm. Fruits should be held in this water for no longer than 2 minutes in a single layer of floating cucumbers.

Packing

In the continental United States cucumbers are often waxed with one of many commercially available formulations. Water loss may reduce fruit weight by 50 percent in non-waxed fruit as compared to waxed fruit. Shrink-wrapping with polyethelene film, a common practice with greenhouse European cucumber, also extends fruit shelf life by preventing water loss. Cucumbers are normally sold in 55-pound cartons or wirebound crates. U.S. Fancy cucumbers have a maximum diameter of 2.375 inches and minimum length of 6 inches with a straight shape and very little tapering. Important postharvest diseases in cucumbers exposed to anaerobic conditions or to poor ventilation include soft rot, *Erwinia carotovora*; bacterial spot, *Pseudomonas lachyrmans*; *Pythium aphanidermatum*; and *Colletotrichum lagenarium.*

Storage

Recommended storage conditions for cucumbers include temperatures from 50 to 55°F (10 to 13°C) and 90 to 95 relative humidity. Average storage life is 10 to 14 days. At storage temperatures above 55°F (13°C), the fruit will ripen and turn from deep green to yellow. Chilling injury occurs when fruit is held below 50°F (10°C) for 2 days or longer. Cucumbers can be stored with crops such as eggplant, grapefruit, limes, potatoes, and other cucurbits but are not compatible with ethylene-producing fruits such as apples, tomatoes, bananas, and muskmelons.

Market Information

In 1992, the state of Hawai'i imported 2.3 million lb (1043 MT) of cucumbers, or 39 percent of the volume consumed locally. Over 3.5 million lb are grown annually in Hawai'i on about 250 acres. The potential for the industry is to produce 100 percent of the local demand

during the summer and 60 percent during the winter months. If the industry could produce 75 percent of local demand, the 1994 farm-gate value would be $2.7 million, based on production of 4.4 million lb (2000 MT) and an average per pound price of 46 cents.

A sound cucumber production program includes well-planned marketing. The prospective grower needs to have a good understanding of annual market trends (Figures 4, 5, 6, and 7), market competitors, consumer needs, potential buyers, and market windows. To keep abreast of changing markets and new business opportunities, producers need to be in close contact with fellow industry representatives and with other business, university, Cooperative Extension, and government organizations.

A clear understanding of the farm's financial situation at all times during the annual production cycle is also essential to a marketing program. Updated farm financial records and the input of financial information in budget generators will help the grower to cut overhead and improve efficiency of production. Updated financial information and well-organized farm records are also helpful in the loan application process, in assessment of crop losses by unexpected pest outbreaks, and in making timely production and financial decisions in order to take advantage of potential investment opportunities or unexpected market windows.

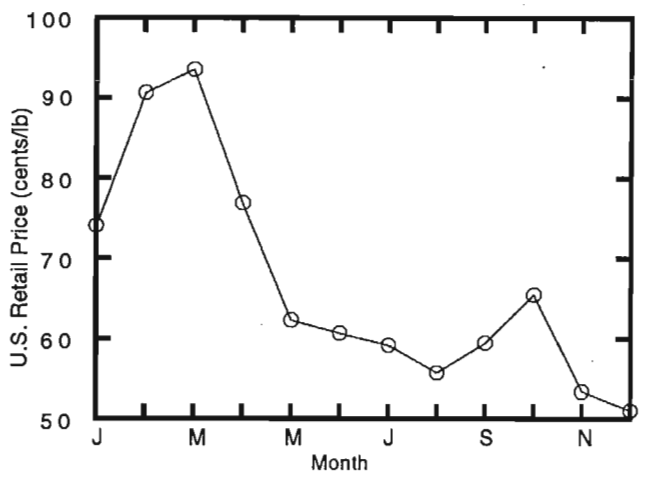

Figure 4. Average monthly retail price for cucumbers in the United States, 1992.

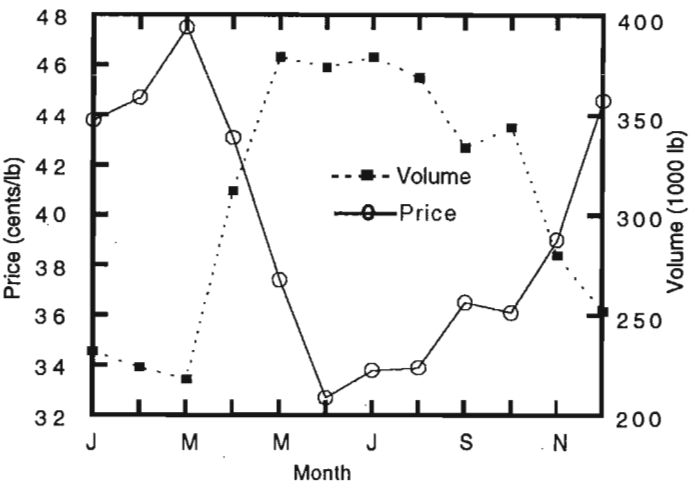

Figure 5. Average monthly farm-gate price and market volume for cucumbers in Hawai'i, 1986 to 1992.

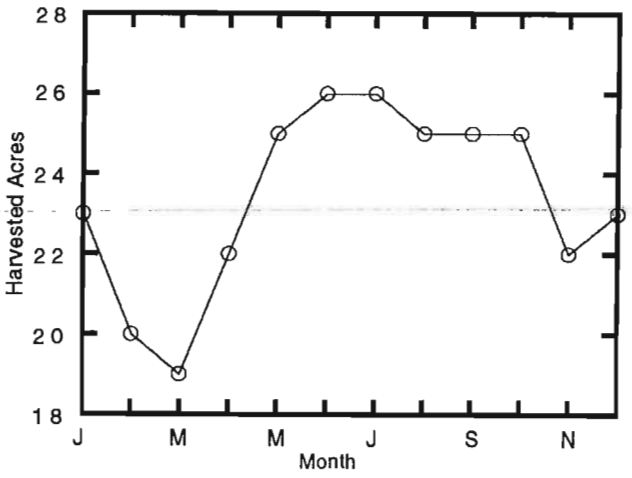

Figure 6. Average monthly harvested acreage for cucumbers in Hawai'i, 1987 to 1992.

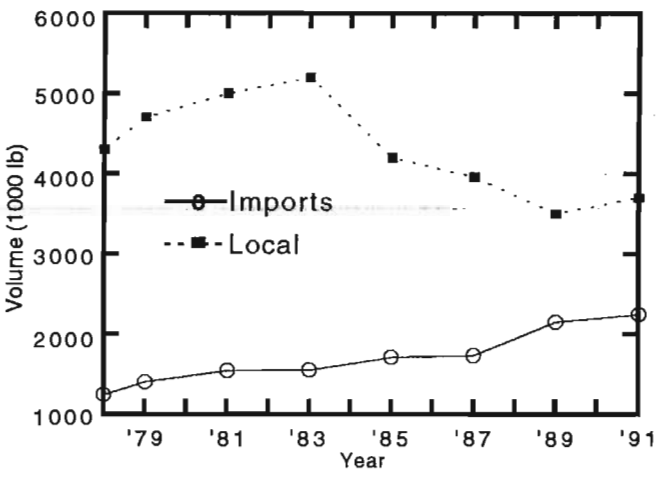

Figure 7. Hawai'i cucumber imports and local production, 1978 to 1991.

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