Lettuce Production Guidelines for Hawaii

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INTRODUCTION

Lettuce (*Lactuca sativa L.*) is the most popular amongst the salad vegetable crops. This crop, a member of the Sunflower or Compositae Family, is a native of the Mediterranean Basin. Leafy types have been cultivated for over 2,500 years, it was grown by the ancient Greeks, and different types were later developed by the Moors. Local production currently accounts for about 18% of the total volume consumed in Hawaii. Major areas for production in Hawaii include Mt. View and Waianae for leafy and semi-heads, and Kula and Kamuela for iceberg types. However, small pockets of production are found throughout the state, and lettuce is also grown year-round in most home- and community gardens. Local production decreased by >35% over the past few years due to the tomato spotted wilt virus, a devastating thrips-transmitted disease. More recently, silverleaf whitefly, Bemicia argentifolii, outbreaks have also affected lettuce production throughout the state. Hydroponic, greenhouse, "mixed," and specialty lettuce production has recently gained popularity in the state. Benefits of hydroponic production are improved water and fertilizer use efficiency, pest control, product quality, and sanitation practices. Lettuce is low in nutrients and energy content. A pound of lettuce contains 95% water, 56 calories, 3.9 g protein, 0.3 g fat, 86 mg calcium, 2.2 mg iron, 1,420 mg vitamin A, and 54 mg ascorbic acid. "Mixed lettuce" production includes green leaf, red leaf, butter, and romaine types. These crops are often planted alongside endive, escarole, oriental vegetables, herbs, and other leafies. Smaller operations focus on high quality produce and cater to farmer's markets, or to hotels, restaurants, and other high-end food service companies, but the volume of high quality specialty products is also increasing in main-stream retail stores.

Plant Growth

Several lettuce types are available commercially, including head (crisphead or iceberg), butterhead (bibb, Boston), leaf, cos or romaine, and stem lettuce. Heads of crisphead types are > 6 inches in diameter and weigh 1-2 lbs each. The 'Great Lakes' group of head lettuce, based on the original 1941 release, has traditionally been planted in Hawaii. Although most lettuce is green, specialty types may be red or red and green. The plant is an annual herb with a milky latex in the leaves and stems. Lettuce has a shallow root system with a 1 foot deep (30 cm) effective bulk root mass.

Climatic Requirements.

Both leafy and head types are adapted to growth at high elevations in Hawaii due to the cooler temperatures. Head types do well at low elevations only during the cooler parts of the year. Heading types require rather

exacting temperatures between 50-70F (10-20C). Optimum growth occurs between 60-70F (15-20C). Heading is prevented and sled stalks form between 70-80F (20-27C). Cool nights are necessary for good quality. With high night temperatures, lettuce becomes bitter. Tip burning also occurs at high temperatures. Lettuce cultivars can be selected for their tolerance to the different environmental conditions found throughout the year in Hawaii. Leafy and semi-head lettuces may be grown year-round at many lower elevation sites.

Cultivars

Cultivar selection is one of the most important decisions made during the crop production process. Selection of cultivars with disease resistance that are adapted to local growing conditions are significant production factors which deserve careful planning and consideration. Cultivars recommended for Hawaii are listed in Tables 1 and 2. Other promising cultivars based on trials conducted in Molokai include Mesa 659, Romulus, Empire MF, Green and Bronze, Red Sail (a leafy type), and Mignonette (semi-head). Semi-head cultivars used for hydroponic production in Kauai and Hawaii include Ostinata, Salina, and Green Mignonette. Leafy types used in hydroponics include Red Sails and Green Ice. Varieties with potential for production in Central Oahu (John McHugh, pers. comm.) include 'PS 33189', a head-type from Petoseed and the red leaf variety 'Vulcan' from Sakata. Important quality characteristics for lettuce are size, compactness, sweetness, and succulence. These traits are often correlated with earliness to harvest. Plants which have a delayed harvest due to poor fertility, disease, or environmental factors, often show several disorders such as tipburn or bitterness.

Table 1. Head Lettuce Cultivars Recommended for Hawaii[1].

Nov.-Feb.	at 500-1,500 ft. elevation: Fulton, Minetto.
	at 1,000-1,500 ft: Mesa 659, Ithaca, Salinas, Calmar, Great Lakes 659, Mesa 659
Apr.-Sep.	at 1,500-3,000 ft elevation: Mesa 659
	at 2,000-3,000 ft: Mesa 659, Ithaca, Salinas, Calmar, Great Lakes 659, Mesa 659
	at >3000 ft: Great Lakes 118, VanMax
Sep.-Mar.	at 1,500-3,000 ft. elevation: Salinas
	at 2,000-3,000 ft: Salinas, Empire, Great Lakes R-200
	at >3,000 ft: Vanmax, Vanguard

[1] Lettuce growth will vary depending on slope, soil type, wind and rainfall patterns, and many other micro-environmental conditions which may extend the adaptability of some cultivars outside of the altitude and seasonal boundaries described in this table. Growers are encouraged to continually test new varieties on small plots in their farms.

Table 2. Semi-Head, Romaine, and Leafy Lettuce Cultivars Recommended for Hawaii[1].

Semi-head year-round at 0-3000 ft. elevation: Manoa (Green Mignonette), Anuenue
Romaine, Year-round at 1000-3000 ft.: Parris Island Cos, Green Tower, and Valmaine
Romaine, Nov.-Mar. at 500-1000 ft.: Parris Island Cos, Green Tower, and Valmaine
Romaine, Apr.-Oct. at >3,500 ft.: Parris Island Cos, Green Tower and Valmaine
Green leaf, Oct.-Mar. at 0-2000 ft.: Black Seeded Simpson, Grand Rapids, Salad Bowl.
Royal Oak Leaf, year-round at 0-3000 ft.
Red leaf, Oct.-Mar. at 0-2000 ft.: Red Sails, Super Prize, Royal Red M.I.
Endive (Escarole), year-round at 1,500-3,000 ft: Salad King, Broad-leaved Batavian.

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FERTILIZER RECOMMENDATIONS

Soil type

Lettuce does best in well drained, slightly acid to neutral, high organic matter content soils. A study of lettuce growing on 13 different soil types in England determined that phosphorus soil availability accounted for the single largest variation in yield among the different soil types. Yields were reduced when the P in the soil solution was below 1 ppm. The optimum pH is 6-6.5.

Nutrient Rates and Fertilizer Placement

Fertilizer applications should be based on crop nutrient demands and stage of crop growth. Tissue and soil analysis will 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 Hawaii soil scientists for the particular soil type. Excessive fertilizer application beyond crop needs may result in soluble salt buildup, phytotoxic effects on plant growth, groundwater contamination, and capital losses due to purchase of unneeded fertilizer. Lettuce has a moderately low salt tolerance. Soluble salt injury results in poor germination and reduced head size. Yield losses can occur when the electrical conductivity of the soil solution exceeds 1.3 dS/m. Nutrients removed in a 16,000 lbs/Acre crop are (in

lbs/Acre): N, 70; P, 15; K, 110; and Ca, 15. Approximately 70-80% of the total NPK nutrient uptake occurs during the last three weeks of growth in head lettuce. Lettuce responds favorably to high P and chicken manure preplant applications. Recommended fertilizer rates are 500-900 pounds of 10-30-10 preplant and 350 lbs ammonium sulfate sidedressed 3-4 weeks later. Another side-dress treatment alternative is 100 lbs of urea or 200 lbs ammonium sulfate 5-6 weeks after seeding for semi-head and 6-8 weeks after seeding for head lettuce or romaine. Band the preplant fertilizers 2-3 inches to each side and below the level of the seed, or alternatively broadcast in the planting bed or broadcast and incorporate in the seed bed.

Phosphorus deficient soils may result in increased bacterial infection rates in lettuce, and in some cases in a delay of harvest by several weeks compared to well fertilized plants. Lettuce deficient in P, does not show the typical reddish pigmentation and leaf "feathering" observed in other vegetables. The only symptom of P deficiency in lettuce is stunted growth. Adequate N levels are also associated with "sizing," solid heads, and earliness of maturity in lettuce. N deficient fields often result in delayed harvests, need for repeated harvests, or in failure of heads to achieve marketable size and quality. Lettuce with N deficiency appears lighter green. Corrective N applications on visually N-deficient plants are effective in the early vegetative stages but a 3-10 day delayed harvest will occur. However corrective N applications on N-deficient plants during the head-formation stage will not prove helpful in increasing head size and final yields. Nitrapyrin banded at 1 qt/Acre may help to improve normal plant nitrogen use efficency. Fertilizer injection through the irrigation system and increased frequency of applications may also help to improve plant nitrogen use efficiency and reduce leaching.

In soils with high soluble salt levels an alternative placement scheme is to broadcast K in the bed and to band the N and P. Phosphorus uptake by the plant is improved when banded together with an ammonium-N fertilizer source. Because of degree of nutrient uptake, and fertilizer use efficiency, higher fertilizer rates are required during winter than on the warmer summer months. Well decomposed farmyard cattle manure, free of weed seeds is a good fertilizer source for lettuce production. Common rates between 3-15 MT/Acre are broadcasted and plowed or disked in the field prior to planting. Additional N side-dressings are recommended when using manure as the primary fertilizer source. The added organic material into the soil from animal or green manure provides several benefits to lettuce production including improved soil physical condition, and greater nutrient and moisture availability to the crop. Cover crops, as annual or short-fallows (13 weeks) with lettuce, can also effectively improve soil structure and fertility, improve nutrient cycling, and reduce leaching of nitrates. Effective lettuce cover crops tested in Salinas, California were oilseed radish (Raphanus sativus), white senf mustard (Brassica hirta), white mustard (Brassica alba), rye (Secale cereale), and annual ryegrass (Lolium multiflorum).

Tip burning may occur under high temperature and low moisture conditions. Losses may be minimized with 2-4 weekly calcium chloride sprays at 5-10 lb/Acre or calcium nitrate sprays at 10-15 lbs/100 gal/Acre. Calcium sprays are most effective on leafy types but may be effective on head-types if applied prior to heading. Correct slight magnesium deficiencies with 2-4 weekly sprays of Epsom salts at 5-

10 lbs/100 gal/Acre. Seedlings may be injured by high levels of ammoniacal-N fertilizers; symptoms include early season root burn and leaf yellowing. Fertilizer injury late in the season causes outer leaf wilting and a reddish discoloration of the roots (see Fertilizer injury in the Disease Section).

Commercial fertilizer mixes are available for nutrition of hydroponically grown lettuce. Typical nutrient concentrations for hydroponic lettuce nutrient solutions are, in ppm: N, 150; P, 50; K, 200; S, 45; Cl, 35; Ca, 175; Mg, 45; Mn, 0.5; Cu, 0.1; Zn, 0.3; B, 0.5; Mo, 0.1; and Fe, 3; at a solution conductivity of about 2 dS/m.

Nutrient Tissue Analysis

Periodic nutrient analysis of foliage tissue (Table 3) provides an estimate of a crop's nutritional status and serves as a record of crop performance. The tissue analysis should be on-farm calibrated with soil fertility, according to soil samples taken prior to tissue sampling. For tissue analysis, collect a young mature whole wrapper leaf. A representative tissue sample from a planting block will consist of 25 to 100 collected leaves free of insects or disease. Leaf yellowing associated with N deficiency became noticeable in Arizona when NO_3-N mid-rib levels went below 5000 ppm. Adequate recommended levels were > 8000 ppm. Tissue sampling dates at the early vegetative stage or at the end of head formation, were highly correlated with final yields in the Arizona trials. Calcium tissue levels are lower in the heart leaves (0.50%) than in the basal leaves (1-2%).

Table 3. Recommended nutrient ranges for lettuce[1].

Nutrient	Range	Target level
N	2.5-4.0%	3.5%
P	0.4-0.6%	0.45%
K	4.0-7.5%	5%
Ca	0.9-2.0%	1.0%
Mg	0.3-0.7%	0.35%
S	0.1-0.3	0.1%
Fe	50-150 ppm	130 ppm
Zn	25-50 ppm	40 ppm
Mn	30-55 ppm	50 ppm
Cu	5-10 ppm	8
B	15-30 ppm	20
Mo	NA	.03

1. Young mature wrapper leaf sampled prior to heading. Higher N (4-5%) concentrations will be found if young matured leaves are sampled in the early growing stages (6-8 leaf stage).

CULTURE AND MANAGEMENT PRACTICES

In Hawaii lettuce is most commonly grown on bare-ground culture and under sprinkler irrigation. Lettuce can also be grown under plastic and organic mulch culture which may result in improved fertilizer and water

use efficiency and in improved weed control. Drip irrigation is also effective for lettuce production especially at high elevations or during the winter months.

Time to Plant

In Hawaii, head lettuce grows well year-round at high elevations, and during the winter also at lower elevations. The leafy and semi-heads can be grown at lower elevations year-round, especially if over-head irrigated. Tables 1 and 2 list the recommended planting dates for lettuce in Hawaii.

Field Preparation

The soil should be deep plowed wherever practicable. If cattle manure is used, plow 3 to 15 tons per acre 6-8 inches deep. If direct-seeded, work the soil to a fine texture to insure good seed germination. Make beds 4 to 8 inches high and about 2 to 5 feet wide depending on lettuce type and number of rows (1-3) per bed. Generally, transplanted plantings have narrower beds. In non-irrigated areas that experience droughts, flat culture is recommended to minimize the effects of limited water supply on the crop.

Propagation

Lettuce is normally transplanted in Hawaii, at 2-4 weeks after sowing, to assure proper stand establishment. Lettuce seeds germinate best at 60-70F (15-20C), and will fail to germinate at > 81F (27C). Direct-seeded lettuce is often primed to overcome thermodormancy when planting during hot weather. Several companies offer primed lettuce seed. Pelleted seed is also available commercially and greatly facilitates planting by hand or with precision planters. The amount of seed required for transplanting head lettuce is 3-6 oz but 1 lb/Acre is normally needed for direct seeding. For leafy types, 2-5 oz of seed required is required for transplanting and 2-3 lbs for direct-seeding. Open-pollinated seed requires a dry storage period prior to sowing. High quality seed germinates in 2 days at 75F (24C) and emerges 3-4 days after sowing. Typical spacings for Hawaii are listed in Table 3. Lettuce seed quickly loses viability when exposed to high temperatures and humidity. It should be refrigerated at all times except when it is being planted.

Table 3. Planting Distances for Lettuce in Hawaii [1].

Lettuce type	Between Rows (inches)	Between Plants (inches)
Head	15 - 18	12 - 15
Romaine	15 - 18	12 - 15
Semi-head	8 - 12	8 - 12
Leaf	15 - 18	10 - 12
Endive (Escarole)	15 - 18	8 - 12

[1] Lettuce is normally planted on 2 to 3 rows per bed, with 2 to 3 feet alleys between the beds. Hydroponic lettuces are frequently spaced at 2 plants per square foot in the growing bench.

Transplanting

Advantages of transplanting lettuce compared to direct seeding include less seed required, less bird damage, easier weed control, and higher water, land, and fertilizer use efficiency because the plants are in the field for a shorter period of time. Lettuce seedlings are started by sowing in flats that have various set spacings of "cell-type" cavities. The seeds are dropped into each cavity by hand where a cut envelope or creased sheet of paper and a pencil are used to singulate seeds. Vacuum seeders or double sheet sliding plexiglass seeders greatly facilitate seeding. The trays are lightly misted with water at least twice daily. Seedlings should emerge within 3-4 days. Four or five days after seeding, each cavity is thinned to one plant. Usually these trays are suspended on pipe or T-bar racks which allows for each cavity's roots to be air-pruned. Air-pruned roots will have an immediate head-start in establishing a transplanted seedling.

Transplanting into the field is normally done manually or semi-manually. Semi-manual transplanting includes planters riding on platforms close to the ground that cut furrows in the soil and seedling blocks are set in these furrows or dropped in a timely fashion to establish proper plant spacing.

Transplanted lettuce is dependent on a healthy root mass to absorb moisture and nutrients. Proper seedling fertilization will have an effect on salable yields. The optimum "starter fertilizer" of seedlings prior to transplanting is 6 grams of an 8-32-8 homogeneous fertilizer per liter of growing media (23 grams per gallon) plus 200 ppm of a 13-24-24 plus micronutrients foliar fertilizer applied in the irrigation misting water. Excessive fertilization results in soft seedlings and too little fertilizer will result in anemic seedling growth.

Irrigation

Almost all of the local lettuce is sprinkler irrigated. For optimum growth, a lettuce crop requires a constant and relatively abundant supply of moisture throughout the growing period. Fluctuations in soil moisture, especially during the later stages of development, are detrimental to optimal growth and head formation. Too much water during this period along with high temperatures may result in loose, puffy heads in heading types of lettuce. Dry conditions during this period, on the other hand, may induce premature bolting. Lettuce is preferably sprinkle irrigated in the early morning. Head and leafy lettuce types require about 1 inches of water (27,225 gallons) per week per acre. Windy areas may require more water. Evaporation pans can be used to estimate evapotranspiration losses and to schedule timing of irrigation. Water use by a transplanted drip-irrigated lettuce crop yielding 29 MT/Acre (including rainfall) was determined to be 209 mm (8 inches) in Kamuela based on Summer, Fall and Spring experiments conducted over 5 years. Average daily consumptive use rate for lettuce in Kamuela is about 0.15 inch per day or about 1 inch per week.

Hydroponic Lettuce Production

Hydroponic lettuce production involves intensive growing practices and results in high quality and high value lettuce. These growing operations are conducted in greenhouses. Leafy and semi-head cultivars are grown and are usually planted at a density of 2 plants per square foot. One to three week-old seedlings are transplanted and the time from transplanting to harvest ranges from 4 to 7 weeks. Highly technological systems exist wherein the nutrient solution is aerated or circulated and where there is precise control of the nutrient solution. Recently, the University of Hawaii has developed simpler and less expensive, non-circulating hydroponic growing systems for lettuce.

Pots or recycled aluminum cans. Four-inch pots or 12 oz recycled aluminum beverage cans are filled with growing media and are placed through openings in a plastic topcover and supported by the bottom of a 4 inch high tank which is half-filled with nutrient solution. Extra holes are placed in the pots and cans to facilitate natural root aeration. The nutrient solution is not aerated nor circulated. Additional nutrient solution must be added to replace the amount consumed, but each increment of added nutrient solution should not exceed 1 inch or else crop injury results.

Forestry tubes. Tapered, plastic forestry tubes (1.5 inch diameter by 8 inches long) filled with growing medium are supported by the topcover of an 8 inch high tank filled with 3 to 4 inches of nutrient solution which is **not** aerated nor circulated. Initially, the growing medium is wet by direct contact with the nutrient solution and movement through the tubes is by capillary action. Later, as the nutrient solution level drops below the bottom of the tubes, roots emerge from the tubes and continue to take up adequate water and nutrients to sustain growth. No additional fertilization, watering, or monitoring is required from transplanting until harvest.

PESTS

Lettuce yields may be reduced by many insect and disease pests. Integrated pest management (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 integrated management approach are (1) taking pest control actions during the most vulnerable stage in the pest's life cycle to maximize results with the least possible effort, and (2) using 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. These actions will also protect the consumer and the environment.

Insects

Important insect pests of lettuce include caterpillars, aphids, leafminers, leafhoppers, mites, thrips, and whiteflies. Silverleaf and greenhouse whiteflies outbreaks are currently a major problem for lettuce production in Hawaii. Apply insecticides only when necessary and, when possible, rotate pesticide families to delay development of insect resistance to the pesticides. Insects with exploding population 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 family. Pest controls should be conducted while disturbing populations of beneficials as little as possible, or when possible to enhance their numbers. For example, research in Salinas, California, identified sweet alyssum (Alyssum maritimum) border-rows as attractants of natural enemies in lettuce fields.

Aphids (Potato Aphid, Macrosiphum euphorbiae (Thomas), and Green Peach Aphid, Myzus persicae (Sulzer))

Aphids feed on plant sap, which may reduce plant vigor. Aphids may also act as vectors of lettuce mosaic virus, introduce toxins into the plan which results in localized tissue death, and their feeding contaminates the foliage with honey dew. The green peach aphid has over 250 different host species including lettuce, celery, carrot, potato, tomato, and many weeds. Growers should use timely insecticide applications as needed based on close monitoring of aphids and their natural enemies. Aphid natural enemies include lady beetle and lacewing larvae predators, tiny wasp parasitoids, and diseases. Soaps and oils can be mixed with insecticides to improve kill efficiency and to help reduce resistance buildup. Aim to achieve control prior to lettuce heading.

Beet armyworm (Spodoptera exigua (Hübner))

These are caterpillars that feed on the green portion of the foliage, leaving a transparent cuticle on the leaves. Small larvae are found singly or in groups. Older larvae, 1-1.25 inches long, have a dark brown dorsal surface and a light green stripe on each side, which separates the lower lighter surface. Larvae move from plant to plant in the field in search of fresh foliage. Serious damage often occurs early in the planting season in which entire plants may be affected. Controls should be implemented when eggs and young larvae are detected in the field. Beet armyworms are difficult to control with Bts (*Bacillus thuringensis* based biopesticide, a bacteria specially formulated for insect control, is commercially available under several trade names, and is referred to as Bt).

Black Cutworm (Agrotis ipsilon (Hufnagel))

Cutworms can devastate young lettuce plants by chewing through the stems at the soil line, and may also infest lettuce throughout the growing season. Later generations may also enter the head. Cutworms are active at night. Eggs are laid in groups of 5-12 under the leaves. Larvae hatch in 3-6 days, remain under clods or plant debris during the day and feed at night. Larvae are greyish brown to greenish,

with a few dark markings, and are 1.5-1.75 inches long. Later, instars burrow 2-4 inches deep into the soil to pupate. Control is warranted when high populations are present in the field before planting. Baits containing Bacillus thuringiensis are available for cutworm control.

Cabbage Looper (Trichoplusia ni (Hübner))

Caterpillars loopers are recognized by their looping movement. Adult moths lay eggs on the leaf underside. Larvae emerge in about one week and develop into light-green caterpillars, 1.25-1.5 in long. Young larvae are found on outer leaves and are relatively easy to control. Looper infestations occur from lettuce emergence until harvest. Older larvae that move into the head are more difficult to control. Under high pressure levels, initiate spray treatments when eggs are first detected and continue until the end of the season. Loopers are difficult to control with Bts. A nuclear polyhedrosis virus was shown to effectively control cabbage looper in lettuce, but this potential biocontrol agent is not currently available as a commercial product. Moths can be effectively screened out in greenhouse lettuce production.

Corn Earworm (Heliothis zea (Boddie))

Attacks by the corn earworm are sporadic but can be quite destructive on lettuce. Eggs are laid singly on the leaf underside. Emerged larvae penetrate the lettuce heads which makes it difficult to monitor its populations in the field. Larvae are about 1 inch long, with various colors and stripes along the lateral surface. Controls are most effective when eggs and young larvae are first detected in the field, and before larvae have penetrated the head.

Leafminers (Liriomiza spp.)

Leafminers are normally a secondary pest that is kept in check by natural enemies. Leafminers are small yellow maggots that form trails beneath the leaf epidermis as they feed. When fully grown, the larvae drop to the soil to pupate. Because contact insecticides won't reach the larvae inside the leaf, systemics are recommended.

Nematodes

Nematodes that attack lettuce include sting, stubby-root, awl, and root knot (*Meloidogyne* spp). Root-knot nematodes are microscopic roundworms that feed on the roots of plants. Symptoms on the foliage caused by the affected root systems include stunting, wilting, leaf yellowing, and delayed maturity. Infested roots develop gall-like swellings. Adult stages of the nematode live inside these swellings in the roots. Before planting, lettuce fields are often chemically fumigated for nematode control. Several grasses, that are nonhosts to the rootknot nematode, such as oats, barley, and wheat, may also be grown prior to planting lettuce, to reduce soil nematode populations. Soils may be tested to estimate the population of

parasitic nematodes. A combination of chicken compost and solarization were effective in controlling root knot nematodes in the San Joaquin Valley of California.

Mites (Vegetable mite, Tetranychus neocalidonicus Andre, and Carmine spider mite, Tetranychus cinnabarinus (Boisduval)).

Mite outbreaks may occur during hot, dry weather. The presence of mites is indicated by the bronze, greasy appearance of the stems and leaves. The carmine spider mite completes its life cycle in about a week. Lettuce leaves may become stripped with light-colored dots when the mites feed. Leaves may later turn yellow and drop. Silk webbing may be present when infestation is heavy. Wettable sulfur and other miticides are effective against mites.

Thrips

In Hawaii, three thrip species: western flower thrips, (Frankliniella *occidentalis* (Pergande)), F. schultzei (Trybom), and Thrips tabaci Lindemann), are predominant vectors of TSWV. Thrips reduce plant vigor when feeding on lettuce in large numbers, and their feeding leave scars in the foliage. The minute feeding scars are silvery in appearance but turn into larger necrotic lesions during shipping and storage. Preliminary work indicated that 4.5 ft high barriers were not effective in preventing thrips movement between planting plots. Further exploratory work is required in this area. White was the most effective color for traps, out of 14 colors tested in Kula, Maui, to effectively monitor thrip populations in the field. Thrips' natural enemies are lady beetles, lacewing larvae, parasitoids, and fungal diseases. However, rainfall provides the most effective "natural" control of thrips. After a period of rainfall, monitor thrips populations before re-starting insecticide treatments.

Whiteflies (Silverleaf whitefly, Bemisia argentifolii and Greenhouse whitefly, Trialeurodes vaporariorum (Westwood))

Recent silverleaf whitefly outbreaks have caused considerable losses in lettuce fields statewide. The main symptom is a stunted growth and delayed maturity. Full canopy coverage with registered insecticide sprays is necessary to reach the eggs and adults on the leaf underside. Area-wide control strategies may be necessary in places where whitefly numbers are abnormally high. During the 1981 outbreaks in Arizona and California, B. argentifolii became an important vector for lettuce infectious yellows which produced stunting, interveinal yellowing of affected leaves, and resulted in 50-75% yield reductions. No work has been conducted to date in Hawaii to determine if B. argentifolii is a vector of lettuce viral diseases.

The greenhouse whitefly is also common in Hawaii. Parasitic wasps and predators help to keep the greenhouse whitefly below damaging levels. In contrast to the silverleaf whitefly, lettuce can sustain greater population levels of the greenhouse whitefly without yield reductions. Control strategies will therefore vary

depending on the specific whitefly species in the field. Before conducting any pest control measures, identify the whitefly species that is actually present in the field.

Diseases

Bacterial Leaf Spots

Pseudomonas, Xanthomonas, and Erwinia species are responsible for five bacterial spot and rots of lettuce. Soft rot (discussed below) is caused by Erwinia, and leafspot and slime are caused by a combination of Erwinia, Pseudomonas, and Xanthomonas. All three diseases penetrate the plant through stomata or through wounds created by mechanical means or by previous pest injury. Cool and moist conditions favor disease development as the plant reaches maturity. A 6-8 hr period of surface moisture in the leaf, is required for infection to occur. Diagnosis in the field is difficult because secondary organisms often attack plants affected by bacterial diseases. Symptoms observed in plants from which bacterial organisms are isolated are often associated with physiological disorders including russet spots caused by ethylene damage, brown stain and pink rib caused by CO_2 damage, and rib discoloration and tip burn caused by localized calcium deficiency. Symptoms associated with bacterial attack include varnish spot, vein browning, brown spot, slimy rot, wilt, core rot and plant decay. Lettuce symptoms from bacterial attack occur on older leaves and on the basal section of the head while tip burn affected plants show symptoms in the inner head section. Bacterial leaf spot and slime symptoms first are small watersoaked internodal leafspots close to the leaf tips. The leafspots can often be observed early in the plant growth. The watersoaked spots develop into brown lesions with necrotic areas in the lesion centers. The leafspots then expand throughout the external and internal leaves leading into decay of the entire head. Several other plant species, including several alternate weedy hosts, are affected by these bacteria (Table 4). Destruction of alternate weedy hosts and protective copper based bactericide applications are recommended for leaf spot control. Effective control may also be obtained when applications are made as soon as symptoms are observed in the field. The critical period for control is during heading up to maturity. Use a spreader-sticker with the spray treatment, especially during rainy weather.

Table 4. Host Ranges of Pseudomonas, Xanthomonas, and Erwinia in Hawaii.[1]

Pathogen Host crop	P. cichorii	P. marginata	P. viridiflava	X. vitians	E. carotovor
Lettuce	x	x	x	x	x
Chicory	x	x	x	x	x
Endive	x	x	x	x	x
Chrysanthem	0	0	0	0	x
Burdock	x	x	x	0	x
Eggplant	x	x	0	x	x
Tomato	x	x	x	0	x
Pepper, bell	x	0	0	0	x
Cucumber	x	x	x	0	x
Ch. cabbage	x	x	x	x	x
Radish	x	0	0	0	x
Cabbage	x	0	x	0	x
Barley	x	0	0	0	0
Oats	x	0	0	0	0

Characteristic symptoms are for P. chichorii= clear edge dark green; P. marginata= purple lesion; P. viridiflava= long spindle lesion, clear edge; X. vitians= marginal V-shaped lesion; E. carotovora= soft rot.

[1]Table from Alvarez (1981).

Beet Western Yellows

This viral disease was not identified in Hawaii until the 1970s. Its appearance in the field is sporadic and more likely affects cos lettuce types. The virus causes typical yellows symptoms which include irregular chlorosis of older leaves, interveinal chlorosis, and leaf brittleness, rolling and thickness. Aphids, the vectors for this disease, remain infective for over 25 days after feeding on a diseased plant. Other hosts of this disease include sugar beet, radish, cauliflower, turnip, cabbage, watermelon, pea, clover, geranium, petunia and weeds such as cheese weed, jimson weed, sowthistle, pigweed, and apple of peru. Controls, as with other viral diseases, include field sanitation and aphid control.

Bolting (Physiological)

Lettuce tends to flower or bolt when exposed to high temperatures and dry conditions. Cultivars vary in their tendency to bolt.

Bottom rot (Rhizoctonia solani)

Initial symptoms for this fungi are slimy rotting of the lower leaves in contact with the soil and rust-colored, sunken spots on petioles and mid-ribs. As the disease spreads, the lesions expand, spread, become darker and result in decay of the entire plant. Control is difficult. Keep the foliage dry and the fertilizer level low so that foliage growth is not overly succulent. The disease is more severe under moist and warm

conditions, such as those experienced during summer months. Planting on raised beds improves drainage and is a good control method. Once established, the disease can survive in the soil for several years. The disease is not controlled effectively with flooding. Other control methods include to avoid successive lettuce plantings on the same field; improved drainage; deep plowing; and fungicide applications directed to the base of the plants at heading. Avoid disturbing the soil after application of protectant fungicides for bottom rot management. Rotate with crops such as sweet corn and onion.

Brown stain (postharvest disorder)-

A few minute superficial tan spots first appear on the leaf surface near the lower part of the midrib or on the midrib. As the disease progresses, the lesions enlarge and coalesce over much of the leaf, and often occur on the inner leaves of the head. Brown stain is caused by excess carbon dioxide (>2.5%) in storage and is thought to be related to metabolism of phenolics. Some cultivars seem to be more susceptible than others.

Brown Rib or Rib Blight (postharvest disorder)

Brown rib occurs on the outer head leaves, causing yellowing or tan discoloration. The cause is not known, but the disorder seems to occur most often at high temperatures.

Crown and Head Rot (Botrytis cinerea)

Crown and Head Rot or Gray Mold occurs during cool and moist Winter and Spring months, and symptoms are observed in the plant as it approaches maturity. The fungus produces a slimy brown decay on the leaf underside. A characteristic feature that helps identification is the presence of abundant dense gray spores. The fungus requires free standing water on the foliage for infection to occur. This disease remains in the soil for many years, so short-term rotations will be ineffective in heavily infested locations. To reduce spread in the field irrigate early in the morning to allow the leaves to dry rapidly and apply protectant fungicides. For effective fungicidal control thoroughly cover the lower leaves, stems, and the bed surface.

Damping-off (Rhizoctonia solani, Pythium spp.).

R. solani is the primary organism associated with damping off. Pythium spp. is associated with damping-off but more often causes root-rot (plants affected by root rot show stunting and yellowing but not the typical damping-off symptoms). Pythium enters the plant through the roots while Rhizoctonia penetrates through the cortical tissues of the stem at the root-crown level. Damping-off may occur at both pre- and post-emergence, however the latter is the most serious problem in lettuce production. Affected plants coalesce soon after emergence. Severe damage may occur prior to transplanting. This disease is promoted by cool and wet field conditions. To prevent damping-off, use high quality seed , treated seed, rotations, and plant on raised beds. The biocontrol organisms, Trichoderma harzianum, Gliocladium virens,

and the bacteria Enterobacter cloacae were shown to control Pythium damping-off of lettuce, but this has not been tested in commercial operations.

Downy Mildew (Bremia lactucae Regel)

This fungus is a serious disease, in the greenhouse and in the field, under high moisture (> 88 RH) and low temperatures ≈ 55F (13C). Seven to eight races of this disease have been identified. It easily mutates and quickly overcomes cultivar resistance and fungicide efficacy. The disease can infest lettuce at any stage of its growth. Symptoms are first observed on outer leaves. Initial symptoms are sharply angled light green discolorations, located within the veins, on the leaf underside. On these lesions, a white fungal growth develops when environmental conditions are favorable. The affected tissue eventually turns necrotic and the entire leaf is destroyed. Extensive damage can occur in short periods of time. While seedlings can be killed, older plants are normally only stunted and suffer cosmetic defects which render the product unmarketable. The fungal spores are wind-borne and can also be spread by splashing rain. Free standing water provided by rain, fog or dew, is required at night for spore germination. Ideal conditions for infection are 5-7 hours of free water and 50-70F (10-20C). The disease survives in the soil on decomposing plant debris, and may also be found on weedy hosts. Most damage is due to yield losses, and to product deterioration during postharvest handling. Disease epidemics are sporadic from year to year. It is managed by using resistant cultivars, with fungicide applications (which provide inconsistent results), crop rotation, and sanitation. Spatial separation of sequential plantings is recommended but this is often not possible in commercial operations. Fungicide treatments begin early in the season and continue at 7-14 day intervals.

Drop (Sclerotinia sclerotiorum (Lib.) Mass.)

Lettuce drop, caused by soil fungi, is common during cool and moist Winter and Spring months. Symptoms on the lower leaves are first observed as the plant approaches maturity. Initially, the lower leaves in contact with the soil show wilting and collapse. The lower, outer leaves and stems then develop slimy rotting followed by whole plant collapse. High moisture and cool temperatures are essential for disease development. The fungus requires free standing water on the foliage for infection to occur. Characteristic features of drop include the white, cottony, mycelial growth during moist weather, and the black sclerotial bodies on the leaf underside. The sclerotial bodies form 1/2 inch irregular shapes. Drop survives in the soil for 2-3 years. Most infections occur through hyphae and sclerotia present in the soil. Control is difficult, but it helps to keep the foliage dry and the fertilizer level low so that growth is not overly succulent. Other possible controls include rotatation with non susceptible crops such as sweet corn, onion, spinach, or small grains; plowing at a 6 inch depth during field preparation; field flooding for 6 weeks; and fungicide treatments. Other crops affected by Sclerotinia include bean, carrot, celery, cole, cucurbit, and solanaceous crops. For effective fungicidal control, provide thorough coverage of lower leaves, stems, and of the bed surface.

Lettuce Mosaic Virus

Lettuce Mosaic is an important viral disease worldwide. It is seed born in lettuce but not in endive. It is transmitted by aphids in a non-persistent manner, aphids remain infective after feeding on a diseased plant, only for a short period of time. Infection of seedlings may result in 50% yield reductions. Seedlings with seedborne virus have misshapen cotyledons, the first true leaf is misshapen and has a dark green mottling appearance. These plants remain stunted, yellowish and fail to form heads. Field-borne symptoms, which appear 10-15 days after infective aphids have fed on lettuce, include vein clearing, mosaic, mottling, yellowing, stunting, distortion, internal necrosis in some heading cultivars, and delay or failure to head. Affected leaves often fall backward and margins may show serration. Boston and Bibb types show stunting and yellowing. Romaine types may also show leaf surface blisters. Symptoms on endive often are chlorotic dots on the green leaf. Primary source of the virus is infected seed. Spread in the field is primarily due to aphid transmission because seed-borne infectivity is only 1-4%. In the past mosaic virus contributed to significant losses ranging from 20% in the spring to 100% in the summer. Hosts of lettuce mosaic cover over 12 plant families and include groundsel (Senecio vulgaris L.), prickly sowthistle (Sonchus sp.), pea, zinnia (Zinnia elegans Jacq.), marigold (Tagetes sp.), globe amaranth, cineraria, aster (Aster spp.), cheeseweed, lambsquarter, escarole, spinach, and endive. Controls include use of mosaic virus-free or MTO certified seed (Mosaic Tested Zero, 0:30,000), removal of alternate weedy hosts, and aphid control in the field. The use of certified seed in Hawaii has essentially eliminated this problem in the field. Plow and incorporate remaining lettuce foliage soon after harvest. Also, try to prevent growing lettuce close to aphid-rearing crops such as radish, Chinese cabbage, and carrot.

Pink Rib, Pseudomonas marginalis

Pink Rib usually occurs on overmature heads, causing a diffuse pink area at the midrib base. The symptoms intensify during shipping and storage extending toward the leaf veins. The cause of Pink Rib, previously believed to be a physiological disorder, is now known to be caused by the bacterium Pseudomonas marginalis. In research conducted in Florida, Pink Rib symptoms were observed when lettuce was inoculated with the bacterium and then placed in storage at 35 and 47F (2 and 8C). Brown discolorations occurred when the inoculated lettuce was then held at 60-72F (15-22C). It is most commonly seen on lettuce that has been field packed for shipment and storage. The symptoms are observed on bruised areas of the head.

Russet Spotting (postharvest disorder)

Symptoms of russet spotting are observed in mature heads as numerous small olive brown spots on the lower midribs of the outer leaves. Both leaf sides show symptoms but the inner leaf side is mostly affected. Greater injury affects the entire head, including interveinal areas. The symptoms develop beginning 4 days after exposure to excessive ethylene levels of 20-35 ppm at 35-60 F (2-15C). It may be more severe on overmature lettuce or lettuce produced in hot, dry areas. To reduce incidence of this disorder maintain storage temperatures just above freezing, and ventilate properly. Sources of ethylene include ripening fruits and gasoline engines.

Soft rot (Erwinia carotovora sub.sp. carotovora)

Bacterial soft rot is the major disease of head lettuce in Hawaii. Yield losses may be 10-15% during Summer, and up to 75% during cool-wet Winter and Spring months. The disease penetrates the plant through wounds caused by mechanical means or by previous pest attack. Soft rot spreads fast in the field under warm weather. Disease control is difficult once it has established in the field. Disease damage continues to increase after harvest, during the handling, storage, and shipping stages. Soft rot is normally observed in the field at or near maturity. Initial symptoms include leaf wilting, and light brown to red discoloration of the stem-end. The stem pith becomes water-soaked, macerated, and develops a greenish color. Extensive stem rotting results in wilting of the lettuce head. The plant collapse symptoms are similar to those observed on plants affected by lettuce drop. Several lettuce cultivars have been shown to be tolerant to soft rot. These cultivars include Ithaca, Minetto, Empire, Fulton, Vangard, Vanmey, and Salinas. Calmar is very susceptible to this disease and Sa659 moderately susceptible. Protective copper based bactericides are recommended for soft rot control. The critical period for control is during heading up to maturity. Use a spreader-sticker with the spray treatment, especially during rainy weather.

Tomato Spotted Wilt Virus

The symptoms of spotted wilt are many tiny spots on the younger leaves, and stunted plants which fail to head and then rot. Symptoms also include bronzing, downward leaf curling, and extensive tissue necrosis. It takes one to two weeks between the time initial symptoms are detected, and final plant collapse. First symptoms are often evident soon after transplanting, and up to 100% of plants may succumb by harvest time. The virus is transmitted by thrips in a persistent manner, that is, thrips remain infective for long periods of time. Over six different strains of this virus have been identified on over 46 plant families and 200 plant species. Important alternate hosts of this virus include solanaceous crops, jimson weed, physalis, petunia, pigweed, bidens, purslane, nasturium, dahlia, floras paintbrush, and many other ornamentals. Typical controls such as a regular spray program and roguing were found not to be very effective for spotted wilt control due to the high thrips populations in the field (> 0.5 million/Acre). Alternative practices may include planting in isolated fields and leaving the field fallow for at least three

weeks to allow for soil inhabiting thrips pupae to hatch and disperse or die before planting a new crop. No resistance to spotted wilt virus has yet been identified or bred into commercial lettuce varieties.

Tipburn (Physiological)

Tipburn, a physiological disorder caused by localized calcium deficiency in the foliage, develops under hot weather and fast growing conditions. Greater incidence was found in Maui when maximum monthly temperatures rose above 85F (29C) and when monthly minimum temperatures rose above 55F (13C). The disease normally develops as lettuce approaches market maturity. Initial symptoms, which first develop on young inner leaves, are small translucent spots close to the leaf margins. These lesions darken, leaf margin tissues die, and affected tissues provide openings for secondary bacterial pathogens. Tipburn can be controlled by planting tolerant cultivars, increasing soil calcium supply prior to planting, liming highly acid soils, foliar calcium sprays on leafy-types, slowing growth through lighter fertilizer application (particularly N), and by keeping an ample and uniform supply of soil moisture. Tipburn symptoms initiated in the field will progress during storage, but healthy heads will not develop tipburn after harvest. Other vegetables affected by tipburn include cabbage, brussel sprouts, cauliflower, and endive. Head types are generally more susceptible to tipburn than leafy lettuce. Initial work on tipburn management identified chemicals that reduced lettuce growth rates and also resulted in reduced tipburn incidence. Calcium sprays are often ineffective, especially on head lettuce, because calcium is inefficiently translocated to those leaf tissues deficient in calcium. In hydroponic lettuce, reducing water nutrient levels at night or circulating 100 ppm calcium nitrate solutions at night reduced incidence of tipburn in butterhead lettuce compared to plants receiving a constant complete nutrient solution. Also, shading with up to 35% shade cloth can reduce tipburn during hot summer months.

Weeds

An integrated approach can be used to manage weed competition in lettuce production. The IPM program for weed control uses identification, monitoring, sanitation, alternative cultural practices and timely herbicide applications. A weed map for each field helps in the design of weed control measures and is a record of weed problems in the field. Cultural control practices for weed control include shallow cultivation, plowing, disking, hoeing, crop rotation, cover cropping, living mulches, pre-irrigation and herbicide treatment prior to planting, organic or plastic mulching, and herbicides. The benefits of proper field preparation can not be overemphasized to improve lettuce growth and minimize weed problems during the crop growth cycle. Activated charcoal at a rate of 1 lb per 2,000 linear ft on a 2 inch wide band is recommended to reduce injurous damage on seedlings from herbicides. This activated charcoal is applied as a 1 to 5% slurry with water.

Young lettuce seedlings are poor competitors against weeds. Therefore, properly prepare the planting beds before herbicide application for adequate preemergence weed control. Two or three weedings

may be required for a crop of lettuce. Shallow cultivations help in weed control plus this helps to prevent the development of surface crusting when cultivating after a heavy rain. Also, transplanting rather than direct seeding, greatly facilitates weed control. Important weeds of lettuce in Hawaii include: cheeseweed (Malva parviflora L.), purslane, (Portulaca oleracea L.), galinsoga (Galinsoga parviflora Cav.), amaranth (Amaranthus viridis L.), sowthistle (Sonchus oleraceus, annual bluegrass (Poa annua L.), mustard (Cardamine spp.), and crabgrass (Digitaria pruriens Buse).

HARVEST AND POSTHARVEST PRACTICES

Timing

Lettuce is harvested when heads have developed the appropriate density and market size. Harvest should be conducted before heads bolt, crack, yellow, or turn bitter. Time to harvest is 70-100 days if direct seeded and 45-65 days if transplanted for head-types; 50-60 days for direct-seeded Manoa lettuce; 80-85 for direct seeded, and 55-65 for direct seeded Romaines. Time to harvest is at least 1 week longer in winter than in summer. Head lettuce fields are harvested up to four times per year. Improved cultivars and cultural practices have led to greater crop uniformity in the field and up to 90% of the crop may be removed in one harvest.

Production Yields

Average yields in Hawaii for the different lettuce types are: head type, 19,000 ; romaine, 15,000; semi-head, 17,000; leaf, 12,000; and endive (escarole), 10,000 lbs/Acre/crop. Monthly yields from sequential plantings are affected by rainfall (Fig. 1), as well as by losses from spotted wilt virus in the summer (Fig. 2). Experimental yields of head lettuce grown in the Spring in Kula were 25,000 lbs/Acre. Maximum experimental yields in the Big Island for drip irrigated head lettuce were 49.7 MT/Ha, with average per-head weight of 2.2 lbs (1.0 kg). Average head lettuce commercial yields in Florida for 1989-1990 were 21,600 lbs/Acre. Good head lettuce commercial yields in the U.S. are 30,000 lbs/Acre at plant populations of 31,000 plants/Acre, and per head-weight of 1.9 lbs. Good yields for endive in the U.S. are 16,000 lbs/Acre at 31,000 plants/Acre and per head-weight of 0.5 lbs. The goal of hydroponic lettuce production is to produce 9 crops per year with an average yield of 300 grams/sq. ft./crop.

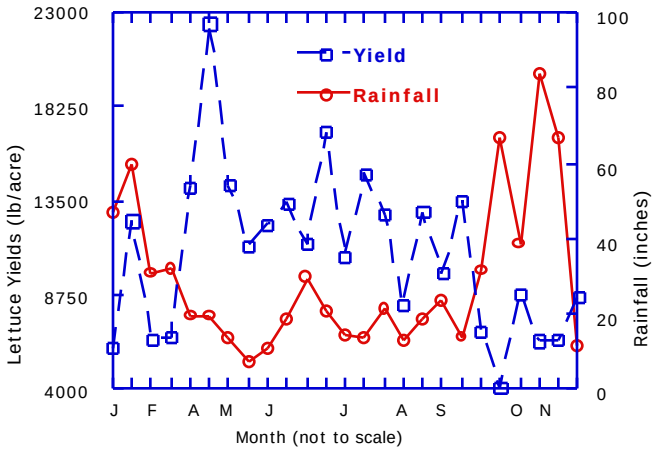

Figure 1. Mean monthly head lettuce yields as affected by rainfall, in Volcano Experiment Station (4000 ft elevation). Data based on 25 experiments conducted over 8 years (Hartmann et al., 1981).

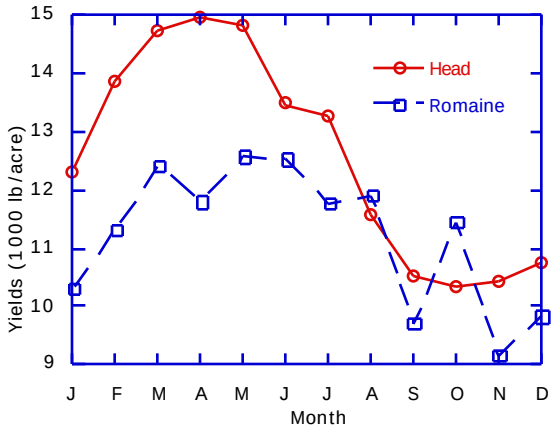

Figure 2. Monthly state-wide commercial yields for head/semi-head lettuce, and romain lettuce as reported by the Hawaii Department of Agriculture, 1986-1992.

Harvesting Operation

Labor accounts for the largest costs in harvesting lettuce. Time to harvest per carton in California was reduced from 12.7 minutes in the early 1960s to 3.6 minutes in the early 1970s due to increased harvest, trimming, and packing efficiency. Film wrapping lettuce heads however increased the time to harvest a carton to 11.2 minutes, for a commercial field harvesting crew operation. During harvest heads are cut at the soil surface with a long knife, leaving as many of the wrapper leaves uninjured as possible.

Four to five wrapper leaves are normally left on the head. To minimize wrapper leaf damage, a crop should not be cut when the heads are wet. Remove soiled and spoiled leaves on the base of the head before packing. Discard all heads showing traces of disease infection. Leaf and bibb lettuces should be harvested early in the morning or in the late afternoon or else wilting will occur. In operations where quality and handling practices are carefully tuned, it is more cost-effective to pick "firm" rather than "hard" heads, resulting in savings of up 7-11 lbs per carton. In California, picking crews are normally divided in "trios", which consist of two cutters and one packer per "trio." The members of the "trio" rotate jobs, and are paid by the carton. Head lettuce is field packed in cardboard cartons having two tiers of 12 heads, and weigh a minimum of 50 lbs/carton. Heads in the bottom layer are placed butts-down, and in the top layer butts-up to prevent latex dripping on the foliage. Semi-head, leaf lettuce and endive are usually packed in containers based on weight rather than count. For each additional two wrapper leaves left on the head at harvest, about 5 pounds are added to a 50 lb carton.

Handling Practices

Lettuce is a perishable commodity and should be handled accordingly. The key to successful delivery of fresh lettuce to market depends upon immediate removal of field heat and for the product to be kept under proper temperature and humidity. Usually growers on neighboring islands, away from the Honolulu markets, vacuum cool harvested lettuce. Vacuum cool for 15-20 minutes. This will result in about a 2.5% weight loss of the heads. If foliage is dry, sprinkle it before vacuum cooling. Temperature is brought down to about 32F (0C). Bibb lettuces are especially fragile during handling and should not be directly exposed to ice water for long periods of time.

Shipping and Storage

Recommended shipping and storage temperature for all lettuces and endive is 32 F (0C) and 95 RH. Expected storage life for head lettuce is 2 - 3 weeks, and for leafy types 1-2 weeks. Permeability films have been developed to extend the shelf-life and postharvest quality of the pre-packed chopped and shredded lettuce, which are popular in restaurants, institutions, salad bars, and home consumer packages. The gaseous concentrations of film packages are important. Off-flavors may develop at O_2 levels below 1% and with CO_2 levels above 10%. Target levels in modified atmosphere packages are of 5% CO_2 and 1-3% O_2 at 41 F (5C).

Market Information

In 1994, the state imported about 23 million lbs of lettuce, representing 92% of the head/semi-head lettuce, and 73% of the romaine lettuce consumed in the state. The potential for the industry is to produce 60-80% of local demands year-round. If the industry produced 70% of local demand, the 1994 farm

gate value would be $9.7 million, based on average per pound price of 53 cents for head lettuce and 38.5 cents for romaine.

California and Arizona produce >80% of the lettuce consumed in the United States, and are thus the major competitors for locally-grown lettuce. Costs of 1992 winter head and leaf lettuce production in the Imperial Valley, California were >$3,200 per Acre with harvest costs accounting for over 50% and pest control about 10% of total costs. Costs of production in Monterey County, California for 1992 head lettuce harvested from April to October was about $4,200 per acre ($5.62 per carton), with contract harvesting accounting for 62% of total production costs. Costs of production in 1992 for head lettuce in South Florida were >$3,500 with fixed costs (land rent, machinery, management, and overhead) accounting for 20% of total costs.

A solid lettuce production program is based on sound and well planned marketing. Prospective growers should understand annual market trends (Figures 3-6), market competitors, consumer needs, potential buyers, and market windows. To keep abreast of changing markets and new business opportunities, keep close contact with fellow industry representatives and with other business, university, Cooperative Extension, and government organizations.

Essential to sound marketing is also a clear understanding of the farm's financial situation at all times during the annual production cycle. Updated farm financial records and the input of financial data 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 to take advantage of potential investment opportunities or unexpected market windows.

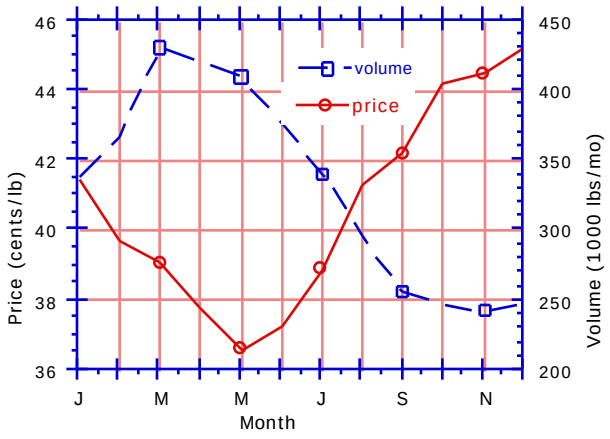

Figure 3. Average monthly price and volume for head and semi-head lettuce in Hawaii, 1986 to 1994.

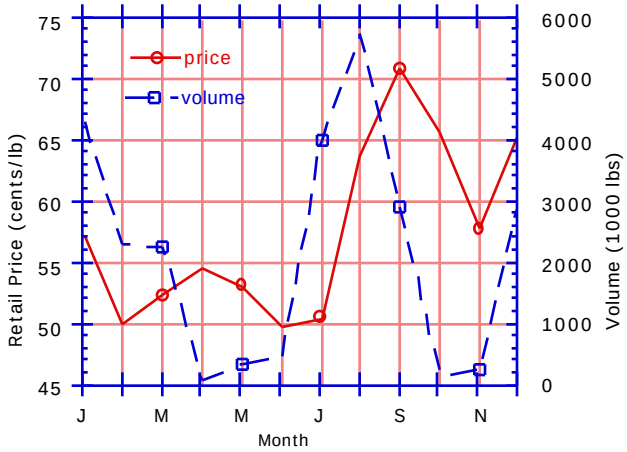

Figure 4. Monthly retail price and volume of imports for lettuce in the United States, 1992.

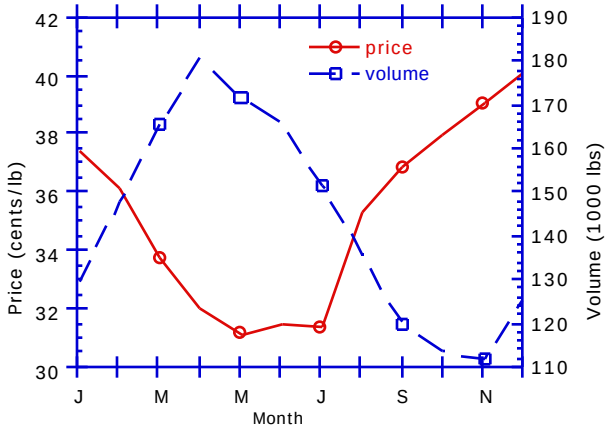

Figure 5. Average monthly price and volume for romaine lettuce in Hawaii, 1986 to 1994.

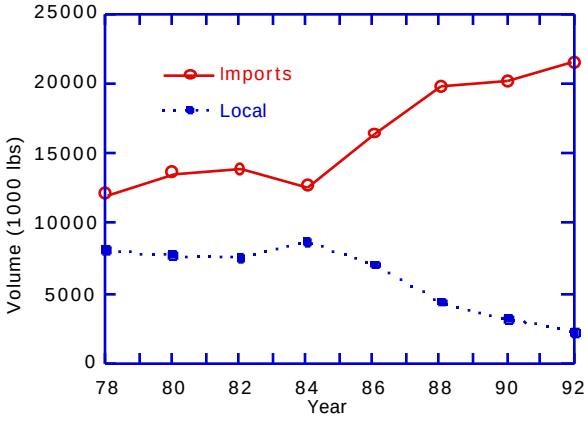

Figure 6. Hawaii head and semi-head imports and local production, 1978 to 1992.

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