Research Extension Series 164
630 US ISSN 0271-9916
April, 1995

Lettuce production guidelines for Hawaii

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Acknowledgements

The authors thank the following CTAHR colleagues for assistance in preparing this publication: Mr. Steven Fukuda (Cooperative Extension Service, Oahu County) and Mr. Richard Nakano (CES–Hawaii County) for contributing information on lettuce production practices, Mr. Randall Hamasaki (CES–Oahu County) for reviewing the manuscript, Dr. Kenneth Takeda (Department of Horticulture, CTAHR) for providing reference materials and photographs, and Mr. Dale Evans (Publications and Information Office) for editorial assistance.

The Library of Congress has catalogued this serial publication as follows:

Research extension series / Hawaii Institute of Tropical Agriculture and Human Resources. — 001-
— [Honolulu, Hawaii] : The Institute, [1980-
v. : ill. ; 22 cm.
Irregular.
Title from cover.
Separately catalogued and classified in LC before and including no. 044.
ISSN 0271-9916 = Research extension series - Hawaii Institute of Tropical Agriculture and Human Resources.
1. Agriculture—Hawaii—Collected works. 2. Agriculture—Research—Hawaii—Collected works. I. Hawaii Institute of Tropical Agriculture and Human Resources. II. Title: Research extension series - Hawaii Institute of Tropical Agriculture and Human Resources.
S52.5R47 85-645281
630'.5—dc19
AACR 2

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Butterhead lettuce is popular because of its taste and delicate texture.

Lettuce Production Guidelines for Hawaii

Hector Valenzuela, Bernard Kratky, and John Cho

LETTUCE, *Lactuca sativa*, is the most popular salad vegetable. Lettuce is related to the sunflower, in the botanical family Compositae, and is native to the Mediterranean region. Leafy lettuce types have been cultivated since at least the time of the ancient Greeks 2500 years ago, and different types were subsequently developed by the Moors.

In Hawaii, local production currently accounts for about 18 percent of the total amount of lettuce consumed. Major production areas in Hawaii include Mountain View and Waianae for leafy and semi-head lettuces and Kula and Kamuela for iceberg types. Smaller areas of production are found throughout the state, and lettuce is also grown year-round in most home and community gardens. Hawaii's commercial production decreased by more than 35 percent 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.

Production of hydroponic, greenhouse, "mixed," and specialty lettuces has recently become popular in Hawaii. Benefits of hydroponic production are improved water and fertilizer use efficiency, pest control, product quality, and sanitation practices. "Mixed lettuce" production includes green leaf, red leaf, butter, and romaine types, often planted with endive, escarole, oriental vegetables, herbs, and other leafy crops. Smaller farms often focus on high-quality produce and cater to farmers' markets or hotels, restaurants, and other high-end food service purchasers, and mainstream retail stores are also increasing the volume of high-quality specialty lettuces carried.

Lettuce is an annual herb with a milky latex in the leaves and stems. The plant has a shallow root system with a root mass extending about 1 ft into the soil. The major lettuce types available commercially include 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 lb each. The 'Great Lakes' group of head lettuces, based on a cultivar released in 1941, has traditionally been grown in Hawaii. Although most lettuces are green, specialty types may be red, or red and green.

Lettuce is low in dietary nutrients and energy content. A pound (454 g) of lettuce contains 95 percent water, 56 calories, 3.9 g protein, 0.3 g fat, 86 mg calcium, 2.2 mg iron, 1420 mg vitamin A, and 54 mg ascorbic acid.

Climatic requirements

Both leafy and head types grow best at high elevations in Hawaii due to the cooler temperatures. Head types grow well at low elevations only during the cooler parts of the year, having a rather strict temperature requirement between 50 and 70°F (10–20°C). Optimum growth occurs between 60 and 70°F (15–20°C). Heading is prevented and "sled stalks" form at temperatures between 70 and 80°F (20–27°C). 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 Hawaii based on their tolerance of the different environmental conditions found throughout the year. For example, leafy and semi-head lettuces may be grown year-round at many lower-elevation sites.

Cultivars

Selection of a cultivar is one of the most important decisions made during the crop production process. Disease resistance and suitability for local growing conditions are significant production factors deserving careful planning and consideration. Cultivars recommended for Hawaii are listed in Table 1. 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 on Kauai and Hawaii include 'Ostinata', 'Salina', and 'Green Mignonette'. Leafy types used in hydroponics include 'Red Sail' and 'Green Ice'. Cultivars with potential for use in central Oahu include 'PS 33189', a head lettuce from Petoseed Co., Inc., and the red-leaf variety 'Vulcan' from Sakata Seed Corp. (John McHugh, personal communication). Important quality characteristics for lettuce cultivars are size, compactness, sweetness, and succulence, traits that are often correlated with earliness of harvest. When harvest is delayed due to poor soil fertility, disease incidence, or adverse environmen-

Table 1. Lettuce cultivars recommended for Hawaii.

Type	Planting season	Elevation (ft)	Cultivars
Head	Nov.–Feb.	500–1500	Fulton, Minetto
		1000–1500	Mesa 659, Ithaca, Salinas, Calmar, Great Lakes 659
	Apr.–Sep.	1500–3000	Mesa 659
		2000–3000	Mesa 659, Ithaca, Salinas, Calmar, Great Lakes 659
		>3000	Great Lakes 118, VanMax
	Sep.–Mar.	1500–3000	Salinas
		2000–3000	Salinas, Empire, Great Lakes R-200
		>3000	Vanmax, Vanguard
Semi-head	year-round	0–3000	Manoa (Green Mignonette), Anuenue
Romaine	year-round	1000–3000	Parris Island Cos, Green Tower, Valmaine
	Nov.–Mar.	500–1000	Parris Island Cos, Green Tower, Valmaine
	Apr.–Oct.	> 3500	Parris Island Cos, Green Tower, Valmaine
Green leaf	Oct.–Mar.	0–2000	Black Seeded Simpson, Grand Rapids, Salad Bowl,
Royal Oak leaf	year-round	0–3000	
Red leaf	Oct.–Mar.	0–2000	Red Sails, Super Prize, Royal Red M.I.
Endive (escarole)	year-round	1500–3000	Salad King, Broad-leaved Batavian

tal factors, lettuce plants often have disorders such as tip burn or bitterness.

Lettuce growth varies with land slope, soil type, wind and rainfall patterns, and other micro-environment conditions. These variations may extend the adaptability of some cultivars beyond the boundaries of altitude and season given in Table 1. Growers are encouraged to continually test new varieties in small plots on their farms. It is advised that seed packets purchased should carry the label "MT0" (mosaic tested, zero in 30,000), which indicates that the seed has been tested for mosaic virus.

Soils and fertilizers

Soil type

Lettuce grows best in soils that are well drained with pH slightly acid or neutral and a high organic matter content. The optimum pH is 6–6.5. Soil phosphorus (P) availability is important. A study of lettuce growing on 13 different soil types in England found that P availability accounted for the greatest variation in yield. Yields were reduced when the P in the soil solution was below 1 ppm.

Nutrient rates and fertilizer placement

Fertilizer applications should be based on the crop's nutrient demand and stage of growth. Soil analyses help determine how much fertilizer to apply to complement the nutrients available in the soil. Soil samples should be taken for each distinct soil type on the farm. Fertilizer applications in excess of the crop's needs may result in buildup of soluble salts, phytotoxic effects on plant growth, groundwater contamination, and economic losses due to wasted fertilizer. The University of Hawaii's Cooperative Extension Service can provide assistance with interpreting soil analyses and developing fertilizer application programs.

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 lb/acre crop are (in lb/acre) 70 N, 15 P, 110 K, and 15 Ca. Approximately 70–80 percent of the total NPK uptake occurs during the last three weeks of growth in head lettuce. Lettuce responds favorably to large preplant applications of phosphate and chicken manure. One recommended fertilizer schedule is 500–900 lb of a 10-30-10 formulation applied prior to planting and 350 lb of ammonium sulfate side-dressed 3–4 weeks later. An alternative side-dress treatment is 100 lb of urea or 200 lb of ammonium sulfate applied 5–6 weeks after seeding for semi-head lettuce and 6–8 weeks after seeding for head lettuce or romaine. Preplant fertilizers should be applied in a band 2–3 inches to each side of and below the level of the seed. Alternatively, broadcast the fertilizers over the planting bed or broadcast and till them into the seedbed.

Soils deficient in P may contribute to increased bacterial infection of lettuce and may delay harvest by several weeks, compared to plants with adequate P. Lettuce deficient in P does not show the typical reddish pigmentation and leaf "feathering" observed in some other vegetables. The only symptom of P deficiency in lettuce is stunted growth.

Adequate nitrogen levels are associated with good size, solid heads, and earliness of maturity in lettuce. Soils deficient in N often cause delayed harvest, the need for repeated harvests, or the failure of heads to achieve marketable size and quality. Lettuce deficient in N is light green. Corrective N application to visually N-deficient plants can be effective if done in the early vegetative stages, but will likely result in a 3–10 day delay in harvest. Corrective N applications on N-deficient plants during the head-formation stage seldom prove helpful in increasing head size and final yield. Injecting fertilizers through the irrigation system and applying fertilizers more frequently may improve plant nitrogen use efficiency and reduce losses of N due to leaching.

In soils with high soluble salt levels, an alternative fertilizer placement scheme is to broadcast the potassium in the bed and band the N and P. Phosphorus uptake is improved when phosphate is banded in mixture with an ammonium-N fertilizer. Greater amounts of fertilizers are needed during winter than in the warmer summer months, because lettuce grows more rapidly during cool weather.

Well decomposed farmyard cattle manure free of weed seeds is a good fertilizer for lettuce. Applications of from 3 to 15 tons/acre may be spread and plowed or disked into the soil before planting. Additional N side-dressings are recommended when manure is the primary fertilizer. Organic material added by animal manure or a green manure crop benefits lettuce production by improving the physical condition and moisture retention of the soil, as well as adding nutrients. Growing an annual cover crop or allowing fallows periods (e.g., 3 months) between lettuce crops can also improve soil structure and contribute to soil fertility through nutrient cycling and reduced leaching losses, especially of nitrates. Cover crops found effective for lettuce 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 burn may occur when the weather is hot and dry. Losses may be minimized by spraying calcium chloride (5–10 lb/acre) or calcium nitrate (10–15 lb/100 gal/acre) weekly over a 2–4 week period. Calcium sprays are most effective on leafy types but may be effective on head lettuces if applied before heading. Slight magnesium deficiencies may be corrected with two to four weekly sprays of Epsom salts at 5–10 lb/100 gal/acre. Seedlings may be injured by high levels of ammonia-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.

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

Plant tissue analysis

Periodic analyses of nutrients in the leaf tissue provide an estimate of the crop's nutritional status. Nutrient levels in the tissue can be evaluated using the levels given in Table 2. The tissue analyses data should also be compared with available soil nutrient levels as indicated by analyses of soil samples from the field.

For tissue analysis, collect a young, mature, whole wrapper leaf free of insect damage or disease symptoms. A representative tissue sample from a planting block is a composite of 25 to 100 leaves. Remove soil from leaves by gently wiping or washing, preferably with rainwater, and blot excess water with paper towels. Lettuce leaves contain much water and should be quickly taken to the laboratory before rotting occurs.

Calibration of tissue nutrient levels with crop yield and quality requires exacting experimentation. For example, leaf yellowing associated with N deficiency became noticeable in Arizona when nitrate-N levels in the leaf midrib went below 5000 ppm. Adequate recommended levels were > 8000 ppm. Tissue samplings at both the early vegetative stage and the end of head formation were highly correlated with final yields in the

Table 2. Recommended nutrient ranges for lettuce[a].

Nutrient	Range	Target level
	percent	
N[b]	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
	ppm	
Fe	50–150	130
Zn	25–50	40
Mn	30–55	50
Cu	5–10	8
B	15–30	20
Mo	NA	0.03

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

Arizona trials. This means that tissue sampling for nitrate-N early in the crop growth period can be an accurate indicator of the soil N status.

Studies have found that tissue levels of calcium are lower in the heart leaves (0.5%) than in the basal leaves (1–2%).

Culture and management

In Hawaii, lettuce is most commonly grown in bare-soil culture under sprinkler irrigation. Lettuce can also be grown using plastic or organic mulch, which may result in improved fertilizer and water use efficiency and better weed control. Drip irrigation is also effective for lettuce production, especially at high elevations or during the winter months.

Time to Plant

Head lettuce grows well in Hawaii year-round at high elevations and during the winter at low elevations. The leafy and semi-head types can be grown year-round at low elevations, especially if irrigated by overhead sprinklers. Table 1 gives the recommended planting dates for lettuce in Hawaii.

Field Preparation

The soil should be plowed deeply wherever practicable. If cattle manure is used, plow 3–15 tons per acre to a depth of 6–8 inches. If lettuce is to be direct-seeded, work the soil to a fine texture to ensure good seed germination. Make beds 4–8 inches high and about 2–5 feet wide, depending on the 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 ensure proper stand establishment. Lettuce seeds germinate best at 60–70°F (15–20°C) and will fail to germinate above 81°F (27°C). When planting during hot weather, seed of direct-seeded lettuce is often primed to overcome thermodormancy; several companies offer primed lettuce seed. Pelleted seed is also available commercially and greatly facilitates planting by hand or with precision planters. Lettuce seed quickly loses viability when exposed to high temperature and humidity. It should be refrigerated at all times except when it is being planted. Open-pollinated seed requires a dry storage period before sowing.

The amount of seed required for transplanting head lettuce is 3–6 oz/acre, but 1 lb/acre is normally needed for direct seeding. Leafy types require 2–5 oz of seed for transplanting and 2–3 lb for direct seeding. High-quality seed germinates in 2 days at 75°F (24°C) and emerges 3–4 days after sowing. Typical plant spacings for lettuce in Hawaii are given in Table 3. Lettuce is normally planted in two or three rows per bed with 2–3-ft alleys between the beds. Hydroponic lettuce is frequently spaced at two plants per square foot.

Transplanting

The advantages of transplanting lettuce compared to direct seeding include less seed required, less bird damage, easier weed control, and higher efficiencies in the use of water, land, and fertilizer because the plants are in the field for a shorter period of time. Lettuce seedlings are started by sowing in flats with "cell-type" cavities. The seeds are dropped into each cavity by hand; a corner-cut envelope or a creased sheet of paper and a pencil are used to singulate seeds. Vacuum seeders or double-sheet sliding plexiglass seeders make seeding much easier. After sowing, the trays are lightly misted

Table 3. Plant spacings for lettuce in Hawaii.

Lettuce type	Between rows	Between plants
	(inches)	(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

with water at least twice daily. Seedlings should emerge within 3–4 days. Four or five days after seeding, plants are thinned to one per cavity. Usually the trays are suspended on pipe or T-bar racks, which allows for each cavity's roots to be air-pruned. Air-pruned roots provide a head start in establishing transplanted seedlings.

Transplanting into the field is normally done manually or semi-manually. In semi-manual transplanting, the workers ride on platforms close to the ground; the platforms cut furrows in the soil, and seedlings are set or dropped in the furrows in a rhythm that establishes a regular plant spacing.

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

Irrigation

Almost all of Hawaii's 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. During head formation, too much water combined with high temperatures may result in loose, puffy heads. Dry conditions during this period, on the other hand, may induce premature bolting.

Early morning sprinkler irrigation is preferred. Head and leafy lettuce types require about 1 inch of water (27,225 gal/acre) per week, but in windy locations they may require more. Evaporation pans can be used to estimate evapotranspiration losses and to schedule timing of irrigation. In Kamuela, water use by a transplanted, drip-irrigated lettuce crop yielding 29,000 kg/acre was determined to be 209 mm (8 inches), including rainfall, based on experiments conducted in summer, fall, and spring over five years. Water use by lettuce in Kamuela averaged about 0.15 inch per day, or about 1 inch per week.

Hydroponic production

Hydroponic production systems produce high-quality and high-value lettuce using intensive growing practices in greenhouses. Leafy and semi-head types are usually planted two per square foot. Seedlings are transplanted at 1–3 weeks of age and harvested 4–7 weeks later. Systems are often technically sophisticated, with aerated or circulated nutrient solutions and precise control of the nutrient concentrations and pH. Recently, the University of Hawaii has developed simpler and less expensive non-circulating hydroponic growing systems for lettuce, two examples of which follow.

In one method, hydroponic lettuce is grown in 4-inch plastic pots or 12-oz recycled aluminum beverage cans filled with growth medium and placed through openings in a plastic cover on a 4-inch deep tank. The containers rest on the bottom of the tank, which is half-filled with nutrient solution. Many holes are made in the pots and cans to increase root aeration. The nutrient solution is neither aerated nor circulated. Additional nutrient solution must be added to replace solution consumed, but each increment of added solution should not exceed 1 inch, or crop injury results.

Another method uses plastic tapered forestry tubes (1.5 inch top diameter by 8 inches long) filled with growth medium and supported by the cover of an 8-inch deep tank filled with 3 to 4 inches of nutrient solution that is neither aerated nor circulated. Initially, the tubes are in contact with the nutrient solution, and water moves into the growth medium by capillary action. As the nutrient solution level drops below the tubes, roots grow down from the tubes to maintain contact with the solution. No additional fertilizer or watering are required.

Pest control

Numerous insect and disease pests can reduce lettuce yields. One method to reduce pest damage to tolerable levels is integrated pest management (IPM), a "systems approach" to pest control. IPM uses a variety of techniques including natural enemies, genetically resistant plants, modified cultural practices, and, when appropriate, pesticides. The IPM approach is based on proper pest identification, periodic scouting, and the precise timing of control actions. Pest management controls should be applied during the critical stage of the crop's development at which failure to act would result in significant economic losses. Two additional strategies of an IPM approach are (1) taking pest control actions during the most vulnerable stage in the pest's life cycle, thus maximizing results, and (2) using synthetic pesticide spray applications for pest suppression only after all alternative controls have been considered or tried. Using alternative pest controls in preference to pesticides reduces costs incurred with frequent pesticide applications and helps maintain levels of beneficial organisms. Nonchemical control actions may also protect consumers and the environment.

Insects

Important insect pests of lettuce include caterpillars, aphids, leafminers, leafhoppers, mites, thrips, and whiteflies. Silverleaf whitefly and greenhouse whitefly outbreaks are currently a major problem for lettuce producers in Hawaii. Growers are advised to apply insecticides only when necessary and, when possible, rotate pesticide chemical families to delay development of insect resistance. Insects characterized by "exploding" populations, such as thrips, whiteflies, mites, leafminers, and aphids, are especially prone to developing resistance to pesticides when exposed to frequent applications of insecticides in the same chemical family. Pest controls should be conducted so as to disturb populations of beneficial insects as little as possible or, when possible, to enhance their numbers. For example, research in Salinas, California, found that sweet alyssum (*Alyssum maritimum*) planted as border rows in lettuce fields attracts insects that are natural enemies of certain pests.

Aphids

The potato aphid, *Macrosiphum euphorbiae* (Thomas), and the green peach aphid, *Myzus persicae* (Sulzer), feed on plant sap, which may reduce plant vigor. Aphids may also act as vectors of lettuce mosaic virus, introduce toxins into the plant resulting in localized tissue death, and contaminate the foliage with honey dew during feeding. 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 before lettuce heading.

Beet armyworm

The beet armyworm (*Spodoptera exigua* (Hübner)) is a caterpillar that feeds on the green portion of the foliage, leaving a transparent cuticle on the leaves. Small beet armyworm larvae are found singly or in groups. Older larvae are 1–1.25 inches long, with a dark brown dorsal surface and a light green stripe on each side that 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, when entire plants can be affected. Controls should be implemented when eggs and young larvae are detected in the field. Beet armyworms are difficult to control with BT-based biopesticides, which contain *Bacillus thuringensis,* a bacteria specially formulated for insect control.

Black cutworm

Cutworms (*Agrotis ipsilon* (Hufnagel)) can devastate young lettuce plants by chewing through the stems at the soil line. They can infest lettuce throughout the growing season. Later generations may also enter the lettuce head. Cutworms are active at night. Eggs are laid in clusters of 5 to 12 under the leaves. Larvae hatch in 3–6 days and remain under soil clods or plant debris during the day until night, when they feed. 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 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

Cabbage looper caterpillars (*Trichoplusia ni* (Hübner)) are recognized by their looping movement. Adult moths lay eggs on the underside of the leaf. Larvae emerge in about one week and develop into light-green caterpillars 1.25–1.5 inches long. Young larvae are found on outer leaves and are relatively easy to control. Looper infestations can occur from lettuce emergence until harvest. Older larvae that move into the head are more difficult to control. Under high infestation levels, initiate spray treatments when eggs are first detected and continue until the end of the season. Loopers are difficult to control with BT. 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. In greenhouse lettuce production, moths can be effectively screened out.

Corn earworm

Attacks by the corn earworm (*Heliothis zea* (Boddie)) are sporadic but can be quite destructive to lettuce. Eggs are laid singly on the leaf underside. Emerged larvae penetrate the lettuce heads, making it difficult to monitor corn earworm 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, before larvae have penetrated the head.

Leafminer

Leafminer (*Liriomiza* spp.) is 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 do not reach the larvae inside the leaf, systemic insecticides are recommended.

Nematodes

Nematodes that attack lettuce include the sting, stubby-root, awl, and rootknot nematodes. These microscopic roundworms feed on the roots of plants. Leaf symptoms caused by the affected root systems include stunting, wilting, leaf yellowing, and delayed maturity. Roots infested by rootknot nematodes (*Meloidogyne incognita*) develop gall-like swellings. Adult stages of the nematode live inside these swellings in the roots. Lettuce fields are often fumigated for nematode control before planting. Grasses that are not hosts of the rootknot nematode (such as oats, barley, and wheat) may be grown as cover crops before planting lettuce to reduce soil nematode populations. Soils may be tested to estimate the population of parasitic nematodes. A combination of chicken-manure compost and soil solarization was effective in controlling rootknot nematodes in the San Joaquin Valley of California.

Lettuce roots with a severe infestation of rootknot nematode

Mites

Outbreaks of vegetable mite (*Tetranychus neocalidonicus* Andre) and carmine spider mite (*Tetranychus cinnabarinus* (Boisduval)) may occur during hot, dry weather. The presence of mites is indicated by the bronze, greasy appearance of stems and leaves. The carmine spider mite completes its life cycle in about a week. Lettuce leaves may become striped 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 thrips species are predominant vectors of tomato spotted wilt virus (TSWV): western flower thrips (*Frankliniella occidentalis* (Pergande)), *Frankliniella schultzei* (Trybom), and *Thrips tabaci* Lindeman. Thrips reduce plant vigor when feeding on lettuce in large numbers, and their feeding leaves scars on the foliage. The minute feeding scars are silvery in appearance but turn into larger necrotic lesions during shipping and storage. Studies have indicated that barriers 4.5 ft high were not effective in preventing thrips movement between planting plots; more study of thrips movement is needed. For monitoring thrips populations in the field, white was the most effective of 14 colors tested for traps in Kula, Maui. Natural enemies of thrips are lady beetles, lacewing larvae, parasitoids, and fungal diseases. However, rainfall provides the most effective "natural" control of thrips. After a rainy period, monitor thrips populations before resuming insecticide treatments.

Whiteflies

Silverleaf whitefly (*Bemisia argentifolii*) and greenhouse whitefly (*Trialeurodes vaporariorum* (Westwood)) are present in Hawaii. Recent silverleaf whitefly outbreaks have caused considerable losses in lettuce fields statewide. The main symptom of whitefly damage is stunted growth and delayed maturity. Full canopy coverage of insecticide sprays is necessary to reach the eggs and adults on the leaf underside. Areawide 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 and interveinal yellowing of affected leaves and resulted in 50–75 percent reductions in yield. 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 often kept below damaging levels by parasitic wasps and predators. In contrast to the silverleaf whitefly, greater population levels of the greenhouse whitefly can be present without lettuce 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 present.

Diseases

Bacterial leaf spots

Pseudomonas, Xanthomonas, and *Erwinia* species are responsible for five bacterial spots 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 leaf stomata or through wounds resulting from mechanical damage or previous pest injury. Cool and moist conditions favor disease development as the plant reaches maturity. A 6–8 hour 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

Table 4. Host Ranges of *Pseudomonas, Xanthomonas*, and *Erwinia* in Hawaii (Alvarez 1981).

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

[a]Characteristic symptoms: *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.

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 initially 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 to decay of the entire head. Several other plant species, including several weedy alternate hosts, are affected by these bacteria (Table 4). Destruction of weedy alternate hosts and application of protective copper-based bactericides 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 from heading-up to maturity. Use a spreader-sticker with the spray treatment, especially during rainy weather.

Beet western yellows

Beet western yellows was not identified in Hawaii until the 1970s. Its appearance in the field is sporadic and more likely to affect cos lettuce types. The virus causes typical yellows symptoms including 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 beet western yellows include sugarbeet, radish, cauliflower, turnip, cabbage, watermelon, pea, clover, geranium, petunia, and weeds such as cheeseweed, jimsonweed, sowthistle, pigweed, and apple of peru. Controls, as with other viral diseases, include field sanitation and aphid control.

Bolting

Lettuce's physiological response to high temperatures and dry conditions is a rapid onset of flowering known as bolting. Cultivars vary in their tendency to bolt.

Bottom rot

Initial symptoms of damage by the bottom rot fungus (*Rhizoctonia solani*) are slimy rotting of the lower leaves in contact with the soil and rust-colored, sunken spots on leaf petioles and midribs. As the disease spreads, the

Bottom rot fungus damage to head lettuce

lesions expand, spread, become darker, and result in decay of the entire plant. Control of bottom rot 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, warm conditions such as those experienced during summer months. Planting on raised beds improves drainage and helps control bottom rot. Once established, the disease can survive in the soil for several years and is not effectively controlled by flooding. Other control methods include avoiding successive lettuce plantings in the same field, improving drainage, plowing deeply, and applying fungicide directed to the plant base at heading. Avoid disturbing the soil after applying protective fungicides for bottom rot management. Rotate lettuce with crops such as sweet corn and onion.

Brown stain

Brown stain is a postharvest disorder indicated by a few, minute, superficial tan spots first appearing 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 are found 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 the metabolism of phenolics. Some cultivars seem to be more susceptible than others.

Lettuce drop symptoms are common during cool and moist weather

Brown rib or rib blight

Brown rib is a postharvest disorder of the outer head leaves, occurring as yellowing or a tan discoloration. The cause is not known, but the disorder seems to occur most often at high temperatures.

Crown and head rot

Crown and head rot, or gray mold (*Botrytis cinerea*), occurs during cool, moist winter and spring months, and symptoms are observed in the plant as it approaches maturity. The fungus produces a brown, slimy decay on the leaf underside. A characteristic feature that aids 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, 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 is the primary organism associated with damping off. *Pythium* 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 the pre- and postemergence stages, but the latter is the most serious stage for damping off 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, crop rotations, and raised beds. The biocontrol organisms *Trichoderma harzianum, Gliocladium virens,* and *Enterobacter cloacae* were shown to control *Pythium* damping off of lettuce in experiments, but their efficacy has not been tested in commercial operations.

Downy mildew

Downy mildew (*Bremia lactucae* Regel) is a serious fungus disease in both greenhouses and fields under high moisture (> 88% RH) and cool temperatures around 55°F (13°C). Seven or eight races of this disease have been identified. It easily mutates and quickly overcomes cultivar resistance and fungicide efficacy. Downy mildew can infest lettuce at any stage of growth. Symptoms are first observed on outer leaves. The initial symptoms are sharply angled, light green discolorations between 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 that render them unmarketable.

The fungal spores are wind-borne and can also be spread by splashing rain. Free-standing water from rain, fog, or dew is required at night for spore germination. Ideal conditions for infection are 5–7 hours of free water and temperatures of 50–70°F (10–21°C). 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 product deterioration during postharvest handling. Downy mildew epidemics are sporadic from year to year. It is managed with resistant cultivars, 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

Lettuce drop caused by the soil fungus *Sclerotinia sclerotiorum* (Lib.) Mass. is common during cool and moist winter and spring months. Symptoms are first observed on the lower leaves as the plant approaches maturity. Initially, lower leaves in contact with the soil show wilting and collapse. The lower, outer leaves and the stems then develop slimy rotting, followed by collapse of the whole plant. 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 cottony, white mycelial growth during moist weather, and black sclerotial bodies on the leaf underside. The sclerotial bodies form ½-inch, irregular shapes.

Drop survives in the soil for two to three years. Most infections occur through the presence of the hyphae and sclerotia 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 nonsusceptible crops such as sweet corn, onion, spinach, or small grains; plowing to 6 inches depth during field preparation; flooding fields for six weeks; and treating with fungicides. 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 the bed surface.

Lettuce mosaic virus

Lettuce mosaic is an important viral disease worldwide. It is seed-borne in lettuce but not in endive. It is transmitted by aphids in a nonpersistent manner; aphids remain infective only for a short period of time after feeding on a diseased plant. Infection of seedlings may result in 50 percent reductions in yield. Seedlings with seed-borne virus have misshapen cotyledons, and the first true leaf is misshapen and has a dark green, mottled appearance. Infected plants remain stunted and 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.

The primary source of the virus is infected seed. Disease spread in the field is primarily due to aphid transmission, because seed-borne infectivity is only 1–4 percent. In the past, mosaic virus contributed to significant losses, ranging from 20 percent in the spring to total loss in the summer. Hosts of lettuce mosaic cover more than 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 using mosaic virus-free or MT0-certified seed (Mosaic Tested zero, 0:30,000), removing weedy alternate hosts, and controling aphids in the field. The use of certified seed in Hawaii has essentially eliminated this problem in the field. Growers should plow soon after harvest to incorporate remaining lettuce foliage. Also, try to prevent growing of lettuce close to aphid-rearing crops such as radish, Chinese cabbage, and carrot.

Pink rib

Pink rib (*Pseudomonas marginalis*) usually occurs on overmature heads, causing a diffuse pink area at the leaf midrib base. The symptoms intensify during shipping and storage by extending toward the leaf veins. Pink rib was believed to be a physiological disorder but is now known to be caused by the bacterium *Pseudomonas marginalis*. Research conducted in Florida found pink rib symptoms when lettuce inoculated with the bacterium was placed in storage at 35 and 47°F (2 and 8°C). Brown discoloration occurred when the inoculated lettuce was subsequently held at 60–72°F (15–22°C). Pink rib 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.

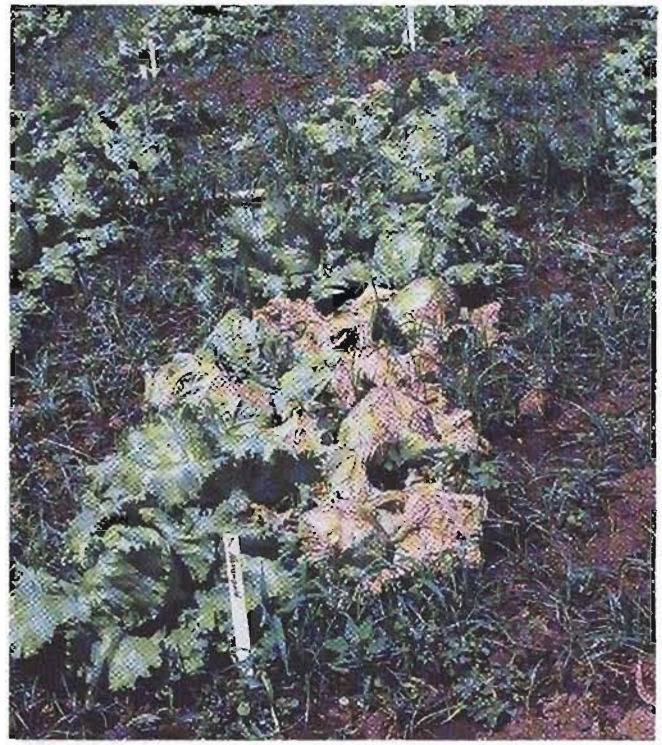
Russet spotting

Symptoms of postharvest 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 most affected. Greater injury affects the entire head, including interveinal areas. The symptoms develop beginning four days after exposure to excessive ethylene levels of 20–35 ppm at 35–60°F (2–15°C). It may be more severe on overmature lettuce or lettuce produced in hot, dry areas. To reduce incidence of this disorder, maintain storage temperature just above freezing and ventilate properly. Sources of ethylene include ripening fruits and gasoline engines.

Soft rot

Bacterial soft rot (*Erwinia carotovora* subsp. *carotovora*) is the major disease of head lettuce in Hawaii. Yield losses may be 10–15 percent during summer and up to 75 percent during cool-wet winter and spring months. The disease penetrates the plant through wounds caused by mechanical means or previous pest attack. Soft rot spreads rapidly in the field during warm weather. Disease control is difficult once it has become 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 greenish. Extensive stem rotting causes the head to wilt. The symptom of collapse is similar to that observed on plants affected by lettuce drop. Several lettuce cultivars have been shown to be tolerant of soft rot. These cultivars include 'Ithaca', 'Minetto', 'Empire', 'Fulton',



Soft rot, caused by bacteria, is the major disease of head lettuce in Hawaii

'Vangard', 'Vanmey', and 'Salinas'. 'Calmar' is very susceptible to this disease, and 'Sa659' is moderately susceptible. Protective copper-based bactericides are recommended for soft rot control. The critical period for control is from 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 that fail to head and then rot. Symptoms also include bronzing, downward leaf curling, and extensive tissue necrosis. It takes one to two weeks from the time initial symptoms are detected to final plant collapse. Initial symptoms are often evident soon after transplanting, and up to 100 percent of the plants may succumb by harvest time.

The virus is transmitted by thrips in a persistent manner; that is, the thrips remain infective for long periods of time after feeding on a diseased plant. More than six different strains of TSWV have been identified on more than 46 plant families and 200 plant species.

Symptoms of tomato spotted wilt virus in semi-head lettuce

Important alternate hosts of this virus include solanaceous crops, jimsonweed, physalis, petunia, pigweed, bidens, purslane, nasturium, dahlia, flora's paintbrush, and many other ornamentals. Typical controls, such as a regular spray program and rogueing, have not been found very effective for spotted wilt control due to high thrips populations in the field, often exceeding more than one-half million per acre. Suggested alternative practices are to plant in isolated fields and to leave fields fallow for at least three weeks before planting a new crop to allow thrips pupae in the soil to hatch and disperse or die. No resistance to TWSV has yet been identified or bred into commercial lettuce cultivars.

Tip burn

Tip burn, a physiological disorder caused by localized calcium deficiency in the foliage, develops under hot weather and rapid growing conditions. Greater incidence has been found on Maui when the maximum monthly temperature rose above 85°F (29°C) and the minimum monthly temperature rose above 55°F (13°C).

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, the leaf margin tissues die, and the affected tissues provide openings for secondary bacterial pathogens. Tip burn can be controlled by planting tolerant cultivars, increasing soil calcium supply prior to planting, liming highly acid soils, spraying foliar calcium fertilizer on leafy types (see section on fertilizer placement), slowing growth through lighter fertilizer application (particularly N), and maintaining an ample and uniform supply of soil moisture.

Tip burn symptoms initiated in the field progress during storage, but healthy heads will not develop tip burn after harvest. Other vegetables affected by tip burn include cabbage, brussel sprouts, cauliflower, and endive. Head lettuce types are generally more susceptible to tip burn than leafy types. Initial research on tip burn management identified chemicals that reduced tip burn incidence but also reduced lettuce growth rates. Calcium sprays are often ineffective, especially on head lettuce, because calcium is inefficiently translocated to the leaf tissues that are deficient in calcium. In research with hydroponic butterhead lettuce, reducing nutrient concentration levels at night or circulating a 100-ppm calcium nitrate solution at night reduced incidence of tip burn compared to plants receiving a constant complete nutrient solution. Also, shading with shade cloth (up to 35 percent) can reduce tip burn during hot summer months.

Table 5. Growth period (days) for lettuce.

Type	Planting method: Direct seeding	Transplanting
Head	70–100	45–65
Manoa	50–60	
Romaine	80–85	55–65

Table 6. Average yields of lettuce in Hawaii.

Type	Yield (lb/acre/crop)*
Head	19,000
Romaine	15,000
Semi-head	17,000
Leaf	12,000
Endive (escarole)	10,000

*lb/acre x 1.12 = kg/hectare

Weeds

Integrated pest management (IPM) can be used to manage weed competition in lettuce production. Like an IPM program for insects, an IPM program for weed control uses identification, monitoring, sanitation, alternative cultural practices, and timely pesticide (herbicide) applications. Making a weed map for each field helps in the design of weed control measures and provides a record of weed problems in the field. Cultural control practices for weeds 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. Proper field preparation cannot be overemphasized as a recommendation to benefit lettuce growth and minimize weed problems during the crop growth cycle. Herbicide injury to lettuce seedlings can be reduced by applications of activated charcoal as a 1–5 percent slurry with water at a rate of 1 lb per 2000 linear feet of row. The slurry is sprayed in a 2-inch wide band over the planting row before planting or applying herbicide.

Young lettuce seedlings compete poorly against weeds. Adequate preemergence weed control requires proper preparation of the planting beds before the herbicide application. Two or three weedings may be required for a lettuce crop. Shallow cultivation assists weed control and helps prevent soil surface crusting after heavy rain. 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

Harvest 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. The period from planting to harvest varies with lettuce type and planting method (Table 5).

The growth period is at least one week longer in winter than in summer. Head lettuce fields may be 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 percent of the crop may be removed in one harvest.

Production yields

Over the year, 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 spring in Kula were 25,000 lb/acre. On the Big Island, the maximum experimental yield for drip irrigated head lettuce was 44,375 lb/acre (49,700 kg/ha), with an average of 2.2 lb (1 kg) per head, but average commercial yield statewide is lower (Table 6). In Florida, commercial yields of head lettuce averaged 21,600 lb/acre in 1989–1990. In the United States in general, a good commercial yield of head lettuce is 30,000 lb/acre with 1.9 lb/head at a plant population of 31,000 plants/acre, and a good endive yield is 16,000 lb/acre with 0.5 lb/head at 31,000 plants/acre. The goal of hydroponic lettuce production is to produce nine crops per year with an average yield of 10.6 oz (300 g) per square foot per crop.

Figure 1. Relationship between mean monthly head lettuce yield and rainfall at Volcano Experiment Station, Hawaii (4000 ft elevation). Data are from 25 experiments conducted over a period of eight years (Hartmann et al. 1981).

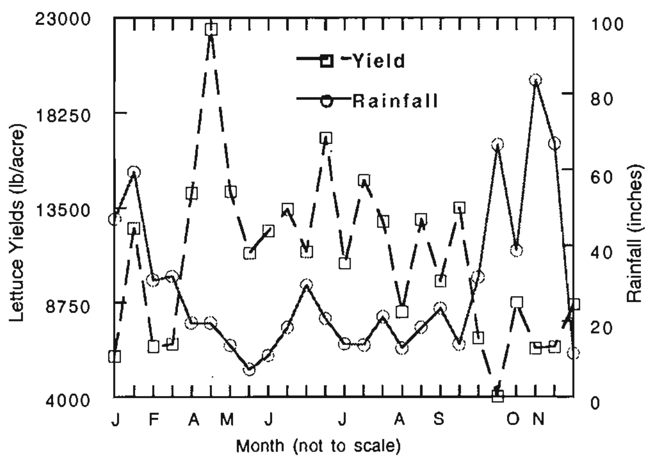
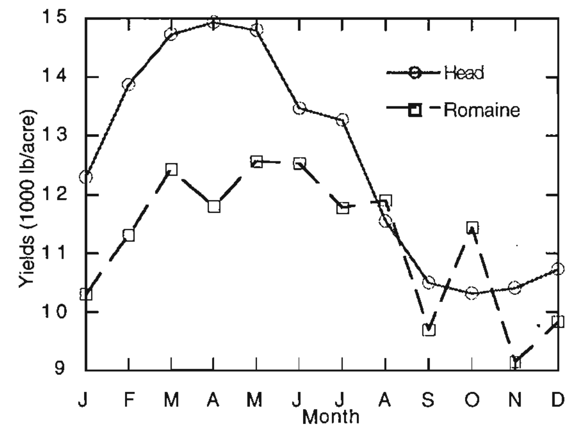


Figure 2. Monthly state-wide commercial yields of head/semi-head and romain lettuces as reported by the Hawaii Department of Agriculture for 1986–1992.



Harvesting

Labor is the largest cost in harvesting lettuce. In California, the time required to harvest a carton was reduced from 12.7 minutes in the early 1960s to 3.6 minutes in the early 1970s due to increased efficiencies in harvesting, trimming, and packing. Film-wrapping lettuce heads increases the time to 11.2 min/carton in 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 damage to wrapper leaves, a crop should not be cut when the heads are wet. Soiled and spoiled leaves on the base of the head are removed before packing. Heads showing traces of disease infection are discarded. Leaf and Bibb lettuces should be harvested early in the morning or in the late afternoon, or wilting will occur. In operations where quality control and handling practices are carefully tuned, it is more cost-effective to pick "firm" rather than "hard" heads, which results in savings of up to 7–11 lb per carton.

In California, picking crews are normally grouped in trios consisting of two cutters and one packer. 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 weighing a minimum of 50 lb. To prevent latex from dripping on the foliage, heads are placed butt-down in the bottom layer and butt-up in the top layer. Endive and semi-head and leaf lettuces are usually packed based on weight rather than count. About 5 lb is added to a 50-lb carton for each additional two wrapper leaves left on the heads at harvest.

Handling practices

Lettuce is a perishable commodity and should be handled accordingly. The key to successful delivery of fresh lettuce to markets is the immediate removal of field heat and subsequent maintenance of proper temperature and humidity. For shipment to Honolulu markets, growers on the Neighbor Islands usually vacuum cool harvested lettuce for 15–20 minutes, which brings temperature down to about 32°F (0°C) and results in a weight loss of about 2.5 percent. If foliage is dry it should be sprinkled before vacuum cooling. Bibb lettuces are especially fragile and should not be directly exposed to ice water for long periods of time.

Shipping and storage

The recommended shipping and storage environment for all lettuces and endive is 32°F (0°C) and 95% RH. The expected storage life is 2–3 weeks for head lettuce and 1–2 weeks for leafy types. Permeability films

Figure 3. Monthly price and production volume of head and semi-head lettuces in Hawaii were clearly correlated during the period 1986–1994.

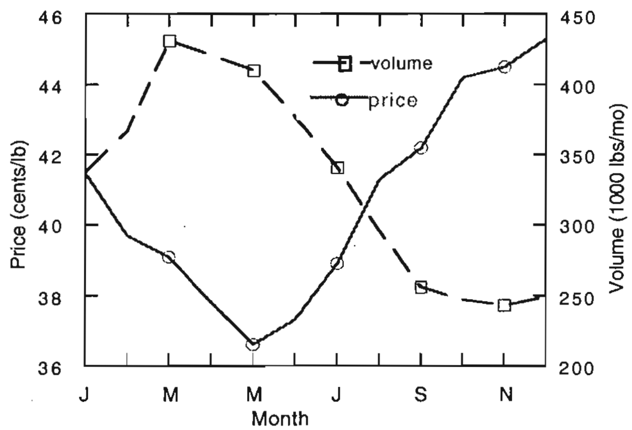
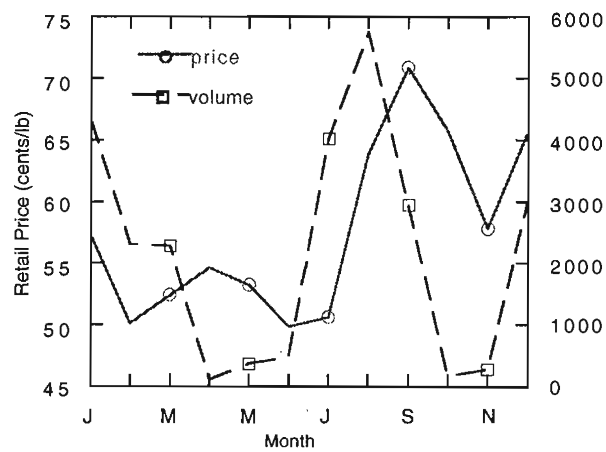


Figure 4. In general, the retail price of lettuce followed the volume of U.S. lettuce imports in 1992.



have been developed to extend the shelf life and postharvest quality of pre-packed chopped and shredded lettuce, which is popular in restaurants, institutions, salad bars, and home consumer packages. The gaseous concentration within film packs is important, because off flavors may develop at O_2 levels below 1 percent and CO_2 levels above 10 percent. Desired concentrations in modified-atmosphere packages are 1–3 percent O_2 and 5 percent CO_2 at 41°F (5°C).

Market information

In 1994 Hawaii imported about 23 million pounds of lettuce. Local production represented 8 percent of the head and semi-head lettuce and 27 percent of the romaine lettuce consumed in the state. The industry has the potential to produce 60–80 percent of the local demand year-round. If the industry produced 70 percent of the local demand, the 1994 farm-gate value would have been about $9.7 million, based on an average price of 53 cents/lb for head lettuce and 38.5 cents/lb for romaine.

California and Arizona produce more than 80 percent of the lettuce consumed in the United States and are also the major competitors in the Hawaii lettuce market. Cost of production for winter head and leaf lettuce in the Imperial Valley, California, in 1992 was more than $3200 per acre, with harvesting cost accounting for over half of the total cost and pest control accounting for about 10 percent of the total cost. In Monterey County, California, head lettuce harvested from April to October 1992 cost about $4200 per acre ($5.62 per carton) to produce, with contract harvesting accounting for 62 percent of the total production cost. Cost of production for head lettuce in South Florida in 1992 was more than $3500/acre, with fixed costs (land rent, machinery, management, and overhead) accounting for 20 percent of the total cost.

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

A clear and up-to-date understanding of the farm's financial situation during the annual production cycle is essential to sound marketing. Updated farm financial records and the use of computer programs will help cut overhead and increase production efficiency. Updated financial information and well organized farm records are also helpful in applying for loans, assessing crop losses due to unexpected pest outbreaks, and making timely production and financial decisions to take advantage of potential investment opportunities or unexpected market windows.

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

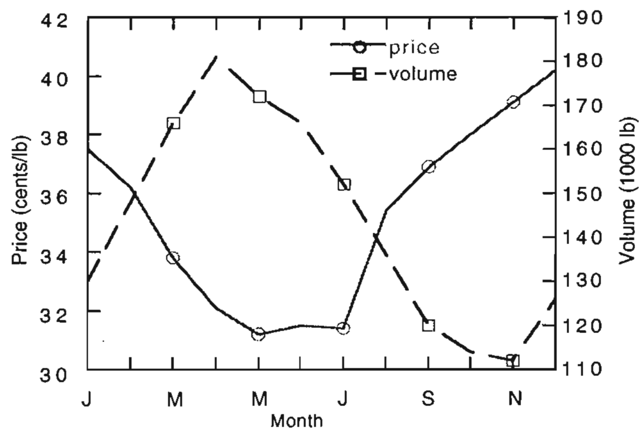
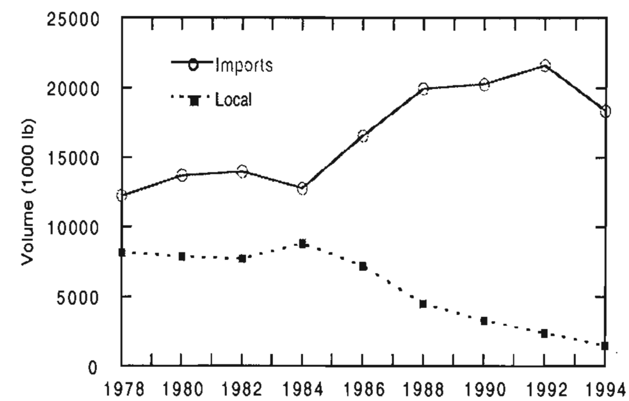


Figure 6. Head and semi-head lettuce imports to Hawaii mirrored local production between 1978 and 1994.



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