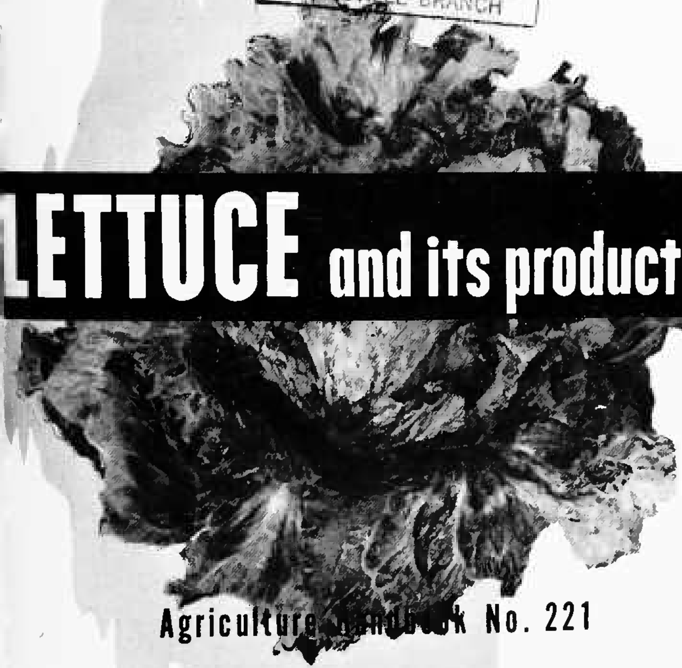
LETTUCE and its production



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CONTENTS

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Lettuce and Its Production[1]

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Lettuce (*Lactuca sativa* L.) is an important vegetable crop in this country; it exceeds in farm value all fresh vegetable crops except potato and tomato. During the 1950's the acreage for harvest fluctuated between 204,000 and 233,000 acres. The farm value of the crop fluctuated between $96 million in 1950 and about $142 million in 1957 (*33*).[2] These figures do not include the collectively huge amount of lettuce grown in home gardens, for roadside stands, and for local markets.

One can find at least three, and frequently four, types of lettuce in most of the large markets and many of the smaller ones in nearly every city of the country. There is always a variety of the crisphead type, commonly a variety of butterhead, often a variety of cos, and sometimes a looseleaf variety. Moreover, lettuce is offered to the consumer in all seasons.

The ancient Greeks and Romans had lettuce, but most of the evidence, as De Candolle shows, indicates that lettuce is a comparative newcomer to our assemblage of cultivated plants. For instance, there is no Sanskrit or Hebrew name for the plant. Likewise, Bretschneider, an authority on the cultivated plants of China, states that lettuce was introduced from the West into China, but not until 600 to 900 A.D. Herodotus records that lettuce was cultivated by the Persians as early as the sixth century B.C. Several writers report that it was grown by the Greeks in the fifth and fourth centuries B.C. Reasoning from this scattered information it seems highly probable that lettuce was domesticated within historic time, and certainly did not become a widespread cultivated plant until the beginning of the Christian era.

The food value of lettuce is confined mostly to minerals and vitamins. Compared with other vegetables it is a good source of calcium, iron, and vitamin A; it is low in energy, protein, ascorbic acid (vitamin C), thiamine (vitamin B_1), riboflavin (vitamin B_2), and niacin. In comparing the food value of 32 vegetables on a pound, acre, and man-hour basis, MacGillivray and others (*20*) placed these crops in 4 groups, in descending order, based upon their efficiency in producing 9 nutrients. Lettuce falls in the third group with such crops as celery, asparagus, and snap beans.

Lettuce has taste appeal for most people, and it is easily prepared for the table. Since it is consumed

[1] The authors are much indebted to R. Bardin, G. W. Bohn, V. R. Boswell, W. H. Gabelman, R. G. Grogan, J. F. Harrington, J. M. Jenkins, Jr., D. G. A. Kelbert, J. McCabe, L. L. Morris, W. D. Pew, G. J. Raleigh, J. E. Welch, and F. W. Zink, Jr., for their help in the preparation of this handbook.

[2] Italic numbers in parentheses refer to Literature Cited, p. 48.

raw, none of the nutrients are lost in cooking or in preparing it for table use. Vitamin C, however, is lost if the leaves are not kept cool and moist. Because the calorie content is low, it has become a common ingredient of most low-calorie diets.

In the United States most of the commercial crop of lettuce is produced in several areas in each of three regions (fig. 1):

1. The western region, which includes Washington, Oregon, California, Arizona, New Mexico, Colorado, and Texas.

2. The northern region, which includes Maine, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Ohio, Michigan, and Wisconsin.

3. The southeastern region, which includes Virginia, North Carolina, South Carolina, Georgia, and Florida.

Since 1949 approximately 90 percent of the acreage harvested for market has been grown in the western region. About 87 percent of the lettuce produced in the western region comes from Arizona and California.

BOTANY AND GENETICS

All domesticated varieties of lettuce belong to the species *Lactuca sativa* L. The genus *Lactuca* is a member of the very large sunflower, or thistle, family, the Compositae, which also includes: *Helianthus*, sunflower; *Sonchus*, sowthistle; *Taraxacum*, dandelion; *Cichorium*, endive; *Tragopogon*, salsify; and *Cynara*, artichoke.

Species of *Lactuca* occur all over the world. The basic chromosome numbers are n=8 and 9, but there are several species, mostly in the New World, that have a basic number of 17. These probably arose as natural amphidiploids from crosses between 8 and 9 chromosome species. Cytogenetic studies support this hypothesis.

Cultivated lettuce is an annual plant with panicled heads of yellow flowers. The flower is composed of many florets surrounded by several series of bracts, called, as a group, an involucre. Each floret has a strap-shaped corolla. The anthers are fused and form a tube that surrounds the style. The style is cleft into two branches at its apex. The single-celled ovary contains a single ovule that matures into a dry fruit called an achene. The achene is flattened and beaked and crowned with a pappus. Although commonly referred to as a seed, as in this handbook, the achene is botanically a fruit.

Cultivated lettuce was probably derived from the so-called wild, or prickly, lettuce, *L. serriola* L. Wild lettuce and cultivated varieties hybridize readily without any decrease in the fertility of the progeny in the F_1 or ensuing generations; this indicates a close genetic affinity. Furthermore, both *L. serriola* and *L. sativa* have nine pairs of chromosomes. There is much evidence for a continuous flow of genes between them. Although the F_1 hybrids between the two forms are so conspicuous in cultivated seed fields that they are immediately seen when the fields are rogued, an inspection of individual plants of wild lettuce adjacent to abandoned fields of market lettuce or seed fields often indicates that introgression has occurred. Broad basal leaves, few spines along the midrib of the leaf, and the general conformation of the plants suggest that such individuals are recent derivatives of hybridization between cultivated varieties and wild lettuce.

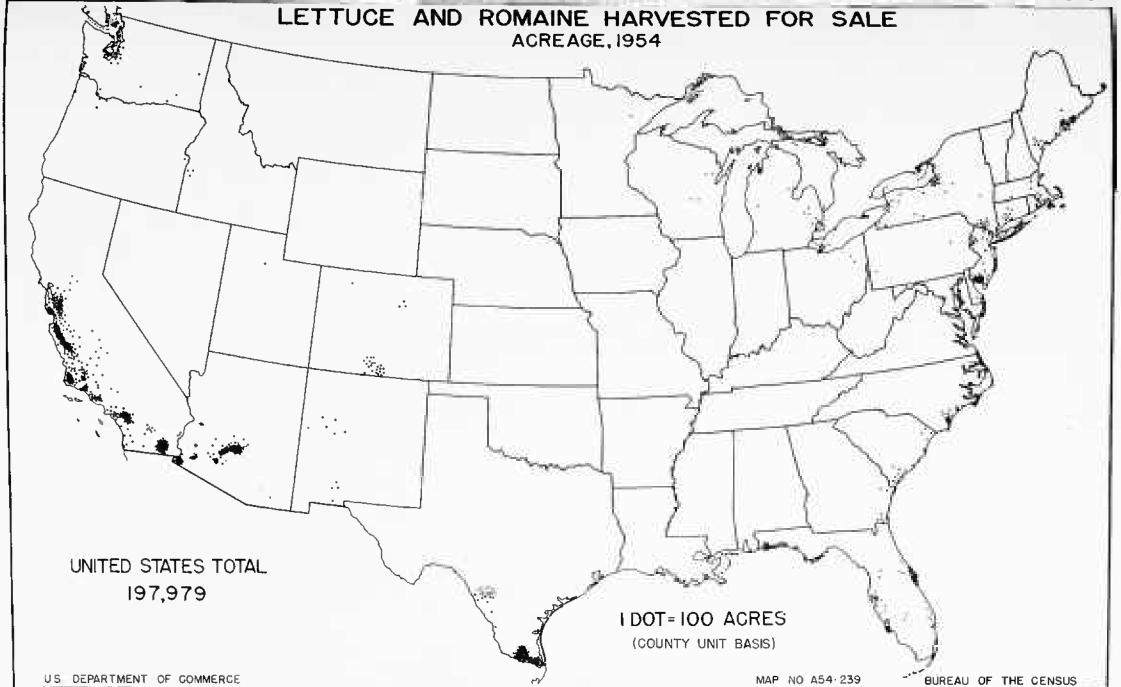

FIGURE 1.—Map of the United States, showing the important lettuce-production areas and the approximate acreage planted to the crop in each area.

According to Vavilov (*35*), *L. serriola* is indigenous to the huge area encompassed by inner Asia Minor, Transcaucasia, Iran, and Turkestan. We can therefore assume that cultivated lettuce was domesticated in this general area.

Genetic information about lettuce is relatively sparse. Data on a few genes have been reported in the literature, however, and they are listed with their authorities in table 1.

In addition, several crosses between *L. serriola* and varieties of *L. sativa* have been studied. The gene *B*, *b* for shattering vs. nonshattering seed heads was described by Whitaker and McCollum in 1954 (*41*) and by Lindqvist in 1956 (*17*). Durst (*7*, pp. 329–341) studied spininess and described the gene *S*, *s* for spines vs. no spines, in 1930. For both characters, the wild parent carried the dominant allele.

Other genetic studies have been extremely limited. Thompson (*28*) found the *C* and *R* loci linked with a recombination value of 36 percent. No other linkages have yet been fully demonstrated. In quantitative inheritance investigations, Durst (*7*) analyzed several size characters and concluded only that many genes were responsible for each trait.

Research on chromosome structure, fertility in interspecific crosses, and polyploidy has produced some significant information. These studies indicate the close genetic relationship of *L. sativa*, *L. serriola*, *L. saligna* L., *L. virosa* L., and *L. altaica* Fisch. & Mey. These species form a single compatibility group. There are at least two other compatibility groups in the genus, but they are not cross fertile with the *L. sativa* group.

TABLE 1.—*Genes of lettuce (L. sativa)*

Symbol [1]	Description of trait	Authority
W, *w*	Black vs. white seed color [2]	Durst (*7*, pp. *329–341*). Thompson (*28*).
Y, *y*	Yellow vs. white seed color [2]	Thompson (*29*).
G, *g*	Dark-green vs. yellow-green leaf color	Thomspon (*28*).
C, *c*	Anthocyanin present vs. absent in leaves [3]	Thompson (*28*).
T, *t*	Anthocyanin present vs. absent in leaves [3]	Thompson (*28*).
R, *r′*, *r*	Intense-red vs. spotted-red vs. tinged-red leaves.[3]	Thompson (*28*).
(Unnamed)	Normal-green vs. chlorophyll-deficient leaves	Whitaker (*38*).
St, *st*	Netted-vein vs. striate-vein leaves	Whitaker and Bohn (*40*).
U, *u*	Lobed vs. unlobed leaves [4]	Whitaker (*39*). Lindqvist (*18*).
K, *k*	Nonheader vs. header	Pearson (*23*).
(Unnamed)	Downy mildew resistance (race 5) vs. susceptibility.	Jagger and Whitaker (*13*).

[1] A capital letter denotes dominant allele.
[2] *Y*, *y* is epistatic to *W*, *w*, giving 9 black, 3 yellow, 4 white in F_2.
[3] *C*, *c* and *T*, *t* are complementary. Effects of *R*, *r′*, *r* appear only in *C-T-* genotype. Order of dominance is $R > r' > r$.
[4] Studies of crosses between *L. sativa* and *L. serriola* indicate that the inheritance of lobing may be more complex.

LETTUCE BREEDING

Lettuce flowers are normally self-pollinated. The structure of the flower facilitates self-fertilization but makes difficult the manipulation of the flowers for crossing. Normally, the flowers open in early morning, remain open for a short time, and then wither. Pollination occurs during this short period. The style is enclosed in a tube formed by fusion of the anthers (fig. 2). It grows up through this tube, and the anthers dehisce as it pushes up through the tube. When the stigmas emerge from the tube, they are covered with pollen grains. It is always necessary to wash the grains off before applying pollen from another source to make a hybrid (fig. 3).

Some of the pollen grains, however, will have already germinated, and complete elimination of selfing in a flower head that is cross-pollinated is therefore virtually impossible. It is usually necessary to carry a dominant marker gene in the pollen parent in order to distinguish the crosses from the selfs. The highest proportion of crosses is obtained if the self pollen is removed and foreign pollen applied when the stigma lobes have just started to separate. Cross-pollinating before or after this stage will result in a very low proportion of crosses.

At least one form of male sterility has been found in lettuce. This may be useful to prevent selfing, since a male sterile plant forms no viable pollen. When a plant of this type is used as a female parent, pollen from the male parent alone will function and only crosses will be obtained.

Little is known about the development of the old standard varieties

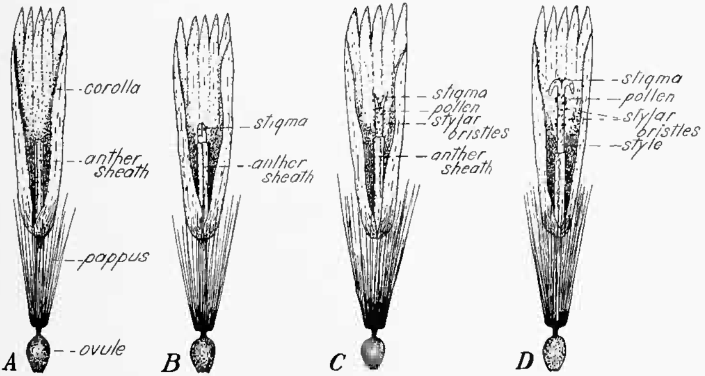

FIGURE 2.—An individual lettuce floret: *A*, At an early stage of anthesis, just before the stigma emerges from the anther sheath; *B*, with the stigma emerging from the apex of the sheath; *C*, at the stage satisfactory for pollen removal; *D*, at a late stage of development. A flower at this last stage is too far advanced for successful removal of pollen and cross-fertilization. (From (28).)

FIGURE 3.—The operator is washing the pollen from the styles and stigmas of the composite lettuce flower: it will then be ready for application of foreign pollen.

of lettuce before the introduction of the Imperial varieties. Most of them were listed as introductions by various seedsmen and farmers in the United States, as foreign introductions, or as selections from other varieties.

The first major completely documented breeding of lettuce was initiated by I. C. Jagger of the U.S. Department of Agriculture in 1922. Brown blight, a disease whose cause is still unknown, threatened the existence of the western lettuce industry in the 1920's. The main variety at that time, New York, was severely damaged by the disorder. Resistant plants were selected within the variety New York, and crosses between New York and White Chavigne, a resistant French variety, were made in an effort to obtain additional adapted, resistant strains. Crosses were made between New York and Blonde Lenté a Monter to obtain resistance to downy mildew, also a serious disease in the West. Starting with Imperial F in 1930, a large group of varieties with the name Imperial and a letter or number were released and soon became the major group of crisphead varieties grown in the United States. They were resistant to brown blight and to the known strains of downy mildew.

A variety released by the U.S. Department of Agriculture and the Michigan Agricultural Experiment Station in 1941 was a different horticultural type named Great Lakes. Further selection within the type have resulted in numerous varieties and strains, which make the Great Lakes type the most widely adapted crisphead lettuce in the United States. Because of this wide adaptation, its extreme solidity and weight, and its favorable shipping qualities, it became the most extensively grown lettuce type in the United States and largely replaced varieties of the Imperial type. Its eating quality, however, is only fair to poor.

Horticultural improvement continues as an important lettuce-breeding goal. Introductions of new varieties by the U.S. Department of Agriculture and the California Agricultural Experiment Station have been made with this in mind. Climax, Vanguard, and the four Golden State varieties (see p. 13) are examples.

Problems of disease resistance, however, are of major importance. Since the introduction of the Imperial varieties, another race of the fungus causing downy mildew appeared. None of the commercial varieties except Imperial 410 was resistant to this race. Much of the lettuce research of the U.S. Department of Agriculture, the California Agricultural Experiment Station, and the Texas Agricultural Experiment Station has been to obtain resistance to this new race and to breed resistant varieties. Two varieties have been introduced so far: Valverde, by the Texas Agricultural Experiment Station and the U.S. Department of Agriculture in 1959, and Calmar, by the California Agricultural Experiment Station and the U.S. Department of Agriculture in 1960.

Another lettuce disease of tremendous economic importance in the West is mosaic. An extensive search for varieties resistant to this disease has been made, but up to 1962 no satisfactory source of resistance has been found.

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CLASSIFICATION AND ADAPTATION OF LETTUCE VARIETIES

Thompson (*30*) suggested a division of lettuce varieties into five classes, as follows: (*a*) Crisphead varieties; (*b*) butterhead varieties; (*c*) cos, or romaine, varieties; (*d*) looseleaf, or bunching, varieties; and (*e*) stem lettuce.

Thompson's classification is a simple and practical means of segregating the vast number of lettuce varieties (an estimated 150 or more) into easily identifiable groups. It has been accepted by most horticulturists in this country and will be followed in this handbook.

Crisphead Varieties

The crisphead varieties are distinguished by their firm heads and brittle texture. The leaves form a head by overlapping one another in a smooth, regular manner. The veins are coarse and the ribs are prominent. The head is usually 6 or more inches in diameter.

Crisphead is the most important commercial type of lettuce in this country. There are numerous crisphead varieties, each with some specific character or set of characters that make it desirable for culture in a particular region. Their firm, compact, solid heads make them popular. Such heads withstand long-distance transportation and the stresses and shocks associated with harvesting and marketing practices. Since the crisphead varieties can be delivered to the consumer in good condition even after long-distance transportation, they can be produced in areas best adapted to lettuce culture. Nearly all the lettuce harvested for market in the western region is of the crisphead type, and probably one-half or more of that produced in the other regions is of this type.

Some common varieties of crisphead lettuce are Great Lakes Regular, Premier Great Lakes, Imperial 101, and Imperial 615. Most of the modern crisphead varieties have been derived by selection in progenies evolved from the old variety New York (synonyms—Los Angeles Market and Wonderful) crossed with various other varieties, both foreign and domestic.

Butterhead Varieties

The butterhead varieties are distinguished by their soft pliable leaves and delicate buttery flavor. The leaves form a head by overlapping one another in a smooth regular manner. The veins are finer and the ribs are less prominent than those of the crisphead varieties. The head is less firm and somewhat smaller than that of the crisphead type.

Because of the soft, pliable texture of the leaves of the butterhead varieties, they bruise and tear easily. The damaged tissues become discolored, often blackened and unsightly, before the lettuce arrives in the retail markets. Consequently, butterhead varieties are not adapted to long-distance transportation. Even for local markets, the produce must be handled with great care to place it before the consumer in good condition.

The butterhead varieties are traditionally grown near the centers of population in the East, along the east coast of New York, New Jersey, Virginia, and North Carolina, and in the Middle West. Prior to the development and expansion of the lettuce industry in the western region during the first and second decades of this century, the butterhead varieties were predominant in eastern markets. They rapidly lost favor, however, to the crisphead varieties, until it became imperative to develop crisphead varieties adapted to eastern conditions.

During the 1950's, because of consumer dissatisfaction with the quality of some of the crisphead varieties, production of the butterhead varieties revived, especially for local and nearby markets. Principal varieties of butterhead lettuce are Big Boston, White Boston, Bibb, and May King.

Cos, or Romaine, Varieties

The cos, or romaine, varieties are easily recognized by the upright character of the plant, the long, loaf-shaped head, and the long, narrow leaves. The varieties of cos are divided into self-closing and loose-closing types. The leaves of the self-closing varieties curve inward at the tips and form a well-blanched, closed head. The loose-closing varieties will not form a closed head. The leaves appear coarse, but they are tender, sweet, and tasty and have less bitterness than other varieties. The table quality of the cos varieties is excellent.

The growing popularity of the tossed salad has increased the demand for cos varieties. The dark-green outer leaves and the golden-yellow inner ones are attractive and flavorsome ingredients of such salads.

However, the cos varieties, like the butterhead varieties, are ill adapted to long-distance transportation. The elongated heads with spatulate leaves are difficult to fit into conventional packages. The stiff, but tender, leaves are easily torn, punctured, and crushed. Therefore, the cos varieties are grown mostly for local and nearby markets, but there has also been a small but steady demand for these varieties in the winter-production areas of the western region for more distant shipping. From these areas cos lettuce is shipped mainly in cars with other vegetables. Common varieties of cos lettuce are Dark Green and White Paris.

Looseleaf, or Bunching, Varieties

The looseleaf, or bunching, varieties do not form heads. The leaves are clustered or pressed together, but only the young ones at the center of the plant overlap to any extent. The older leaves are arranged loosely around the stem.

Looseleaf varieties are popular for the home garden and are the principal varieties grown in greenhouses. They are not adapted to long-distance transportation and have a short market life. Their soil, water, and temperature requirements are not so exacting as those of the three preceding classes; therefore, they are better adapted to the needs of the home gardener. Common varieties of looseleaf lettuce are Black-Seeded Simpson, Prize Head, Grand Rapids, and Salad Bowl.

Stem Varieties

The edible part of stem lettuce is the enlarged stem, or seedstalk. It may be peeled and eaten raw or it may be boiled, stewed, or creamed. Stem lettuce is an ingredient of many Chinese dishes. It is little used in this country except by people of Chinese extraction. Celtuce is the only variety offered for sale in the United States.

DESCRIPTION OF THE IMPORTANT VARIETIES OF LETTUCE

Crisphead Varieties

The crisphead varieties of lettuce can be separated into two distinct types: (a) Imperial and (b) Great Lakes.

Varieties of the Imperial type are mostly large and normally medium green. The leaves are thin, entire margined, savoyed, and crumpled. They form symmetrical, partly exposed heads, with many wrapper leaves. The quality is good to excellent.

Great Lakes types are generally characterized by dark-green, thick, crisp, tough, serrate leaves. They form extremely firm, heavy, mostly exposed heads. They are moderately slow bolting and resistant to tipburn. The quality is only fair to poor; the texture is generally coarse and tough.

Varieties of the Great Lakes type were derived from crosses between varieties of the Imperial type and the little-known variety Brittle Ice. Unfortunately, during World War II stock seed of Brittle Ice was allowed to deteriorate; as a result this variety ceased to exist. Lack of seed of the Brittle Ice parent has frustrated efforts of plant breeders to produce new varieties of Great Lakes type with superior quality. Except for poor eating quality and inability to make adequate size under moderately low temperatures, the Great Lakes varieties are ideal for the grower who must depend upon surface transportation to send his produce long distances to market.

Varieties of Imperial Type

New York.—Large; late maturing; mature plant spreading; leaves broad, slightly savoyed, crumpled, stiff, coarse, with heavy veins and protruding midribs; a slow bolter; quality good; seeds whitish. This variety was named and introduced by Peter Henderson and Co. in 1896. It was grown almost exclusively during the development of the lettuce industry in the western region. Since about 1926, New York has been replaced with disease-resistant and better adapted varieties. Nearly all the commercially important varieties of the Imperial type have descended from New York through a combination of hybridization with other varieties, backcrossing, and selection. New York was first shipped to eastern markets as "Iceberg" or "Western Iceberg." This was a misuse of the name, as the Iceberg variety is altogether different from New York. There are several seedsman's strains of New York. One of them, New York 515, is supposedly much more resistant to tipburn than other New York strains.

Imperial 44.—Medium size; for summer or fall maturity; medium green; leaves broad, long, much savoyed, crumpled, with smooth margins; heads symmetrical, spherical, nearly always covered with wrapper leaves; a slow bolter; not so susceptible to tipburn as other varieties of this type; quality excellent—crisp and tasty; seeds whitish. This variety was developed by the U.S. Department of Agriculture and the New York (Cornell) Agricultural Experiment Station and released in 1938. Imperial 44 was originally selected for culture on the muck lands of northern New York, but it has been replaced by varieties of the Great Lakes type, which are less susceptible to tipburn. It is grown mostly in the western region, but there also it is gradually losing favor to varieties of the Great Lakes type.

Imperial 615.—Large, vigorous; for late-fall or winter harvest; plant spreading at maturity; dark green; leaves broad, slightly savoyed, crumpled; heads well formed, solid, almost spherical, covered with wrapper leaves except for the apex; bolts quickly and tipburns badly if exposed to high temperatures; quality excellent; seeds whitish. This variety was developed by the U.S. Department of Agriculture and the California Agricultural Experiment Station, and released in 1934. Imperial 615 will produce good-sized heads under fairly low temperatures. Until the late 1950's it was essentially the only variety grown for midwinter harvest in the western region. It has been almost entirely replaced with Imperial 101.

Imperial 101.—This variety closely resembles Imperial 615, except that the plants are slightly larger and more vigorous (fig. 4). It requires slightly longer to mature than Imperial 615. Most strains of this variety are less smooth and less uniform than those of Imperial 615. Like Imperial 615, it is adapted for late-fall and midwinter harvest in the western region. The history of this variety is obscure. It is obviously a selection from Imperial 615, but the person or firm responsible for the selection is not known with certainty. There are reports that a Japanese grower near Hollister, Calif., made the original selection and increased the seed. In some seed catalogs the Hollister Seed Co. of Hollister, Calif., is listed as the originator.

Varieties of Great Lakes Type

Varieties and strains of the Great Lakes type are similar in appearance and so numerous that some system of classification is needed for clarifying the differences among them. They differ in size, color, season of maturity, tipburn resistance, and other characters. Zink and Welch (*43*) studied 25 varieties and strains of Great Lakes type during one harvest season. As a result of their studies they proposed a division into four subtypes. The Golden State varieties (introduced in the late 1950's) appear to be different enough, especially in quality,

FIGURE 4.—Mature head of Imperial 101.

to warrant the addition of a fifth subtype. The subtype groupings used by Zink and Welch may not be the best nor final answer to classification of the Great Lakes varieties, but their system brings some order out of what otherwise would be chaos. The similarities and differences are much easier to comprehend when they are arrayed in groups similar in appearance and environmental response.

Subtype 1 (subtype variety Premier Great Lakes).—Characterized by few wrapper leaves, exposed heads, color similar to subtype 5 but lighter green than other subtypes, smooth leaf surface and margin, early maturity, whitish seeds. Principal varieties are Imperial 456, Pennlake, and Premier Great Lakes.

Subtype 2 (subtype variety Great Lakes 428).—Characterized by few wrapper leaves, exposed heads, darker green color than subtype 1, smooth leaf surface and margin, larger heads and later maturity than subtype 1, whitish seeds. Principal varieties are Great Lakes 428, Great Lakes 59, and Emerald.

Subtype 3 (subtype variety Great Lakes Regular).—Characterized by adequate wrapper leaves, good cover, slightly savoyed leaf surface, dentate ruffled leaf margins, darker green color than subtypes 1 and 2, late maturity, whitish seeds (fig. 5). Varieties in this subtype are the most widely grown of the Great Lakes type. Principal varieties are Great Lakes Regular, Great Lakes 118, Great Lakes 66, Great Lakes 366, Great Lakes A–36, Great Lakes

FIGURE 5.—Mature head of Great Lakes Regular.

407, Great Lakes R–200, Oroverde, and Grandeverde.

Subtype 4 (subtype variety Great Lakes 659).—Characterized by abundant wrapper leaves, excellent cover, markedly dentate frilled or ruffled leaf margins, darker green color and later maturity than other subtypes, slow bolting, heat resistance, whitish seeds. Principal varieties are Great Lakes 659, Wespak, Primaverde, and Gem.

Subtype 5 (subtype variety Golden State A).—Characterized by adequate wrapper leaves, good cover, about the same color as subtype 1, late maturity, good quality, black seeds except Golden State D—which has white. Principal varieties are Golden State A, Golden State B, Golden State C, Golden State D, and Climax.

Other Crisphead Varieties

Two new distinctive crisphead varieties, Vanguard and Valverde, do not fit into either the Great Lakes or Imperial category.

Vanguard.—Large, vigorous; adequate wrapper leaves; fair cover; leaves grayish green, smooth, with regular margins, thick, good texture; interior leaves yellowish; quality good; seeds black (fig. 6). Vanguard is different in origin from other lettuce varieties. R. C. Thompson, who developed Vanguard, combined a wild species of lettuce, *Lactuca virosa*, with cultivated lettuce. Like the *L. virosa* parent, Vanguard has smooth, grayish-green leaves. The basal ones are retained throughout the life of the plants.

Valverde.—Intermediate in appearance between Great Lakes and Imperial types. Few wrapper leaves; partially exposed heads; leaves dark green, somewhat blistered and savoyed; heads firm but not hard; quality good; seeds white

FIGURE 6.—Mature head of Vanguard.

(fig. 7). It is resistant to the physiological races of downy mildew occurring in the lettuce-growing areas of Texas, Arizona, and California.

Butterhead Varieties

Bibb.—Small; early to midseason; plant loose and spreading when young, compact when mature; leaves short, spatulate, closely clustered to form a compact globular head, not overlapping, dark green with some dark-red pigment, thick, smooth, brittle; a rapid bolter; quality excellent—delicate buttery flavor, sweet, tender; seeds black. It is a good variety for the home garden, greenhouse, and local market. It was introduced into this country about 1890 as Half Century. It disappeared for a time from trade channels; later it returned under the names Bibb and, erroneously, Limestone.

Big Boston.—Medium large; intermediate in season; young plant with upright twisted leaves; mature plant compact, with firm, well-defined, broad, slightly pointed head; leaves broad, smooth, slightly savoyed, somewhat twisted, thick, stiff, hard, dull light green except for the borders of the outer leaves—which are tinged reddish brown; quality fair—not so sweet and tender as other butterhead varieties; bolts easily and is very susceptible to tipburn damage; seeds whitish (fig. 8). It is widely adapted, but grown mostly for local markets and short-distance shipping in the East and Southeast.

White Boston.—Except that it is light green and lacks any trace of red pigment in the leaves, this variety is almost identical with Big Boston. It has the same range of adaptation, and is preferred to Big Boston when an all-green head is desired. It is known in Europe as Unrivalled and appears to be the same as the French variety Sans Rival.

Continuity (Crisp as Ice).—Large; late; spreading; forms loose, well-blanched heads; leaves loosely overlapping, broad, cup shaped, savoyed, twisted, thin, soft, limp, with entire margins, deep green overlaid with brown; a slow bolter; quality good—soft texture, sweet; seeds black. A good summer variety in some localities, but used more as a novelty. It was introduced into this country about 1878.

May King.—Small; very early; light green with slight red tinge when grown outdoors; leaves spatulate, thin, brittle, clustered into small, round heads; inside leaves creamy yellow; quality good—buttery flavor, sweet, tender; seeds whitish. It can be used for forcing and is a good, early variety for home gardens. It bolts easily and scorches readily at high temperatures.

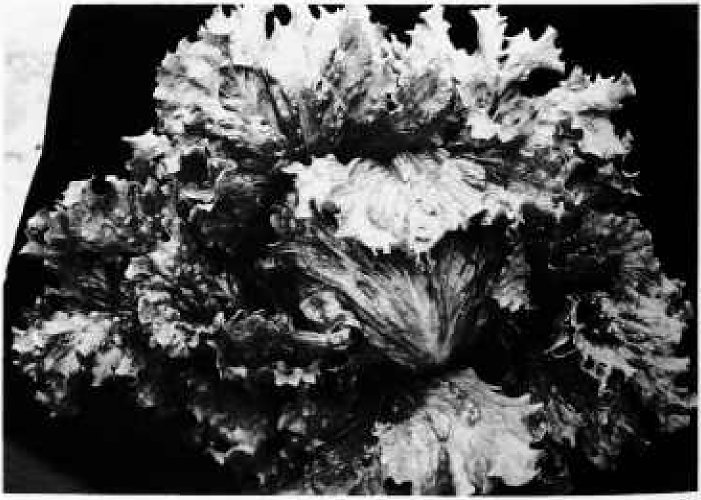

FIGURE 7.—Mature head of Valverde.

Midas.—Large; intermediate in season; leaves light green, slightly savoyed; a slow bolter; quality good; seeds whitish. Similar to Big Boston except that it has no red pigment in the leaves, bolts slowly, and matures later, and the heads are not so firm. A good variety for the home and market garden. It was developed by the U.S. Department of Agriculture and released in 1954.

Salamander.—Medium large; early to intermediate in season; compact or slightly spreading; leaves broad, savoyed, crumpled, thin, limp, soft, with entire margins, light green; heads globular, fairly firm; quality excellent—delicate buttery flavor, sweet; a medium bolter; seeds brownish black. A popular variety for the home garden and local market. It withstands high temperatures better than most butterhead varieties. Salamander was introduced into this country from Europe about 1854. It is sold under more names than any other variety; Tracy (*32*) listed 38 synonyms.

Cos, or Romaine, Varieties

White Paris.—Large; self-closing; intermediate or late in season; leaves oval to spatulate or slightly spatulate, curving inward at the ends and overlapping to form a loaf-shaped, rather loose head; a slow bolter; quality excellent—firm, crisp, sweet; seeds whitish. It is an old variety of European origin; it has been listed by American seedsmen since 1860. This is one of the best varieties for the home garden.

Dark Green.—Similar to White Paris, except perhaps a little darker green, slightly shorter, and more open at the top; seeds whitish (fig. 9). The origin of this variety is unknown.

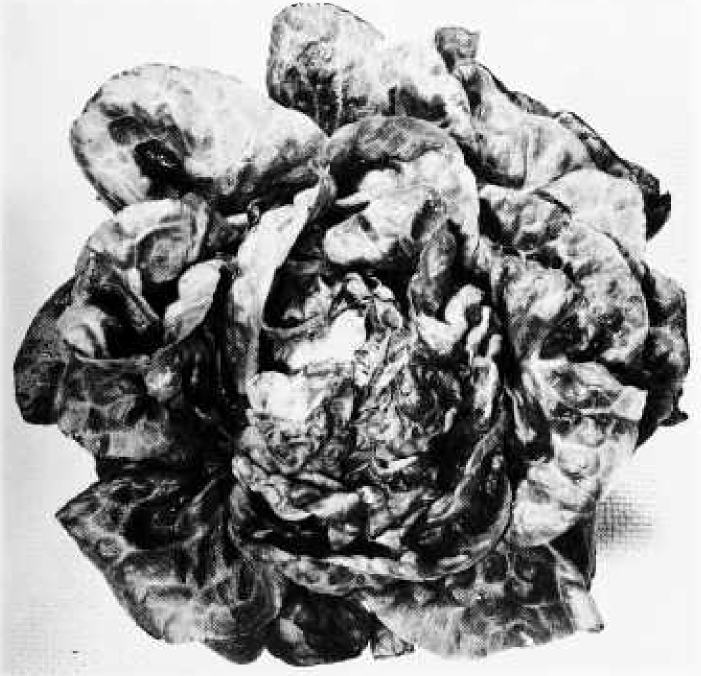

FIGURE 8.—Mature head of Big Boston.

Parris Island.—Medium size; not completely self-closing, often tied close with a string in retail markets; 1 week to 10 days later to mature than White Paris or Dark Green; leaves more coarse and tough than either of those varieties, dark green; quality medium; seeds whitish (fig. 10). This variety was introduced by the South Carolina Agricultural Experiment Station in 1951. In many districts it is replacing the older varieties because it manifests some tolerance to the virus causing lettuce mosaic. Plants usually will produce marketable heads even though infected with mosaic; whereas other varieties fail to mature a crop.

Looseleaf, or Bunching, Varieties

Black-Seeded Simpson.—Large; midseason; compact plant; leaves broad, savoyed, crumpled, twisted, thick, stiff, coarse, with serrate margins and prominent midribs, light green; easily grown, tolerant of high temperatures; a slow bolter; quality only fair; seeds black. It is adapted to home gardens. This variety was first listed in this country by Peter Henderson & Co. about 1880.

Early Curled Simpson.—Medium size; early to midseason; leaves short-spatulate to broad, savoyed, crumpled, thick, stiff, with serrate or frilly margins, light green; quality only fair; seeds whitish. It is well adapted to the home garden but bolts readily. According to Tracy (*32*), it has been known in this country since about 1860.

Grand Rapids.—Large; early to midseason; plant spreading when young, fairly compact when mature; leaves long, somewhat spatulate, crumpled, blistered, thick, with heavy midribs and frilled margins, light or yellowish green; bolts easily; quality poor outdoors, but very good when grown under glass; seeds black. It is adapted to greenhouse culture (*31*) and is used more extensively for this purpose than any other variety. It is a very satisfactory variety for spring sowing in the Northwestern States. It bolts easily and the quality is poor farther south. This variety was first listed

FIGURE 9.—Mature head of Dark Green cos lettuce.

by seedsmen in 1890, but it is said to have been developed by Eugene Davis of Grand Rapids, Mich., at a much earlier date. It is reported to have been obtained after 15 years of selection within the variety Black-Seeded Simpson.

Prize Head.—Large; early; plant spreading; leaves thin, short, spatulate, savoyed, crumpled, with serrate margins, frilled at borders, tinged red but bright green where not exposed; wilts easily; a slow bolter; quality good—sweet, tender, crisp; seeds whitish. It is a good variety for home gardens (fig. 11). The origin of this variety is unknown; it was named and introduced by D. M. Ferry & Co. of Detroit, Mich., about 1868.

Salad Bowl.—Large; medium early; leaves much divided and lobed, medium green; very attractive; tolerant of high temperature; a slow bolter; quality fair; seeds black (fig. 12). It was developed by the U.S. Department of Agriculture and released in 1950.

SEEDBED PREPARATION, PLANTING, AND THINNING

Where the crop is grown under furrow irrigation, the land should be properly leveled to permit accurate control of water (*15*). If the land is not leveled the beds will be variable in height; uneven areas are difficult or impossible to irrigate properly. The soil will be too dry in some areas and too wet in others and the crop will germinate and develop irregularly. These conditions often lead to disease infection, a prolonged harvest period, and a product of variable quality.

FIGURE 10.—Mature head of Parris Island cos lettuce.

The usual routine in preparing the seedbed is to plow, disk, and float. This sequence of tillage operations should leave the soil in a soft, mellow condition and free from large clods and trashy organic material. If the sequence is ineffective, it may be necessary to repeat one or all of these operations or to vary the sequence. The character of the soil and the preceding crop determine the tillage sequence required.

In the northern region and coldest parts of the Southeast, the land is often plowed in the fall and left rough until spring when the seedbed is prepared. Thus, the soil is exposed to alternate freezing and thawing during the winter, which makes it in a fine, mellow condition in the spring, excellent for further tillage operations.

Most of the lettuce crop in the West is planted on raised two-row beds. The beds are furrowed with a lister, usually with two or three 14-inch bottoms, to depths of 4 to 8 inches. The beds commonly are 40 or 42 inches from center to center. The seedbed is 18 to 22 inches wide; the furrow 20 to 22 inches wide. The seed is ordinarily sown in rows 3 to 4 inches from the edge of the bed, which leaves 14 to 16 inches between the rows (fig. 13). The beds are ordinarily shaped, smoothed, and planted in one operation.

FIGURE 11.—Mature plant of Prize Head.

FIGURE 12.—Mature plant of Salad Bowl.

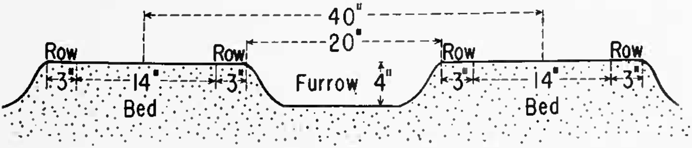

FIGURE 13.—Diagrammatic sketch of the double-row planting system on slightly raised beds. The dimensions may vary slightly with local conditions. If soluble salts are troublesome, peaked beds can be used.

If good, viable seed of over 90 percent germination is used, the rate of seeding depends primarily upon climatic factors. Lettuce seed is very sensitive to high temperatures during germination and emergence. Soil temperatures higher than 75° to 80° F. for prolonged periods greatly reduce emergence.

For early-fall planting in the desert areas of the western region when temperatures are high, 2½ to 3½ pounds of seed per acre is necessary. Heavy seeding at this time is insurance against poor stands. Later in the season as the weather becomes cooler, 1½ to 2 pounds of seed per acre is sufficient. In cool weather cover the seed to a depth of one-fourth to one-half inch. In hot weather, barely cover the seed. The action of irrigation water will help to settle the soil enough to cover the seed.

When the young seedlings have reached the two- to three-leaf stage, thin and space them 12 to 16 inches apart in the row. The spacing between plants in the row will vary with the variety, soil fertility, and climatic factors. Complete thinning the plants before they are affected by competition for space or nutrients. The time from germination to thinning varies from 3 to 8 weeks; the time depends mostly upon temperature.

Thinning is an expensive hand-labor task, usually done with short-handled hoes. The plants may be blocked out mechanically in clusters to appropriate distances and then further thinned by hand to a single plant at each point. Care must be taken not to leave two plants side by side, as such plants develop asymmetrically and almost never make marketable heads. Some growers draw a heavy (about 1,000-pound) roller, approximately 10 feet long and spanning three beds, parallel with the beds over the young plants immediately before thinning. This operation firms and smooths the space between the seed rows, which makes thinning easier. Whether rolling is harmful to the plants has not been determined.

SOIL MANAGEMENT AND FERTILIZATION

Lettuce is very sensitive to the acid-alkaline balance in the soil. The soil reaction should be nearly neutral (about pH 6). Lettuce is intolerant of acid soils, but it has a fairly high salt tolerance; for this reason it does well on the alkaline soils of the West. In many parts of the East the soils are too acid for maximum growth. Apply lime to correct the acid reaction before planting such soils to lettuce.

Lettuce is surprisingly modest in its nutrient uptake. Lorenz and Minges (*19*) estimated that a summer crop of lettuce in the Salinas Valley of California will contain 47 pounds of nitrogen, 7 pounds of phosphorus, 117 pounds of potash, and 30 pounds of lime per acre. The relatively low mineral nutrient content of lettuce does not mean that it can be grown successfully on soils of poor fertility. In fact the opposite is true; the best crops of lettuce are produced on soils of high fertility.

Among the methods of increasing and maintaining the fertility and good physical structure of the soil are the use of proper tillage, green-manure crops, animal manures, and commercial fertilizers including synthetic ones. Usually an appropriate combination of two or more of these methods produce the desired result most efficiently and economically. Specific rates and kinds of fertilizer to be applied cannot be given here because the needs can vary from farm to farm and even from field to field on the same farm. However, general principles of fertilizer practice for lettuce on individual farms and fields follow.

Green Manures

Green-manure crops, when properly grown, can furnish an abundance of organic matter. In regions of heavy rainfall, green-manure crops aid in preventing erosion and in conserving the soluble nutrients in the soil. At the time these crops are turned under, additional nitrogen may be needed to aid in decomposing the organic material. Furthermore, in the western region, green-manure crops are usually watered by the flood method of irrigation, which tends to leach out the soluble salts from the zone that will later be occupied by the roots of the lettuce plants. Grasses and leguminous crops such as alfalfa, clover, cowpeas, soybeans, and vetch are good sources of organic matter. In the western region, sesbania and papago peas are often used. Legumes add nitrogen to the soil, but some grasses produce more organic matter than legumes in a short time and may be preferable. Grasses require the addition of more commercial nitrogen than do legumes; but, because of the higher tonnage produced, grass plus nitrogen is more efficient than legumes alone in many situations.

Animal Manures

Lettuce shows a marked response to animal manure. Pew and coworkers (*24*) found that lettuce grown on manured soil matures earlier, is of better quality, and yields more than lettuce grown on comparable nonmanured soils. Use manure with caution on lettuce grown for summer or fall harvest in the hot areas of the western region. Excessive manure and high temperatures may result in plants with loose heads or premature seedstalk formation.

Well-decomposed barnyard manure, free from weed seeds, is a most desirable source of organic material. In applying manure, spread it evenly over the field and plow it under or disk it in promptly. Even with generous applications of animal manures, some nitrogen is usually necessary to produce the most profitable crop. The nitrogen is commonly added as a side dressing shortly after thinning.

Commercial Fertilizers

Of the three elements—nitrogen, phosphorus, and potassium—applied as commercial fertilizers, nitrogen is the one likely to be deficient in most soils. This is especially true in soils of the western region where there is usually sufficient native phosphorus and potassium in the soil for the crop. Nitrogen can be applied in several ways and in many forms. Method and rate of application are generally more important than the source of the commercial forms of nitrogen commonly used.

For Arizona, Pew and coworkers (*25*) suggest applying about one-half to two-thirds of the total nitrogen before planting. This may be broadcast in granular or fine crystalline form, injected into the soil as a gas or solution, or applied in the irrigation water. The rest of the nitrogen is applied in solid form as a side dressing or in irrigation water immediately after thinning and later as the needs of the plants dictate. This method is probably applicable for most soils in the western region.

During cool weather, organic nitrogen, except synthetic urea, is available to the plants very slowly, if at all. Therefore, some source of synthetic or natural inorganic nitrogen is essential to maintain good growth during cool weather. The common forms of inorganic nitrogen are nitrate of soda, sulfate of ammonia, ammonium nitrate, and agricultural ammonia. Urea, a synthetic organic form, is sometimes used. In the western region, do not use nitrate of soda because its sodium ion tends to make the soils too alkaline. Where the pH of the soil is near, or above, neutral, sulfate of ammonia is beneficial; on acid soils do not use it or use it sparingly. In the western region, anhydrous ammonia is frequently applied in the irrigation water. The ammonia gas is metered into the water. Careful control of the dispensing apparatus is necessary; the companies that furnish the material usually supervise its application.

On some soils in the western region lettuce responds to added phosphorus. Responses to phosphorus are especially marked when the plants are in the seedling stage. When adequate phosphorus is available, the seedlings become established more quickly and grow faster than they do on soils low in this element or on soils in which much phosphorus is present but fixed in unavailable form. For soils that are deficient in available phosphorus, supply this element before planting the seed or in the first side dressing. Phosphorus may be applied in several forms, such as phosphate, superphosphate, treble superphosphate, and liquid phosphoric acid.

Most soils adapted to lettuce culture have enough potassium for lettuce production. Evidence is lacking that applications of fertilizer potassium improves yield or quality of lettuce. But there is evidence that excess potassium may be toxic within the plant and thus be harmful to its growth.

Correct fertilizer placement is important. The movement of phosphorus in the soil is extremely limited; therefore, place phosphorus fertilizers where the roots will grow quickly into the fertilized zone. In contrast, inorganic nitrogen fertilizers, especially the nitrate form, move freely in the soil solution. Consequently, place such nitrogen material at a level in the soil at which leaching below the root zone will be minimized. For the preplanting application, place the fertilizer no deeper than 6 to 8 inches. In sidedressing young plants, place the fertilizer 1½ to 2 inches below the seed level and cultivate about 2 inches into the furrow. In sidedressing large plants, place the fertilizer 1½ inches deep and 4 to 6 inches to the furrow side of plants.

ROTATIONS

In selecting crops for a lettuce rotation, keep in mind the purposes of a rotation. In general they are: (1) To reduce or eliminate soilborne diseases; (2) to maintain or increase soil fertility; (3) to improve the physical structure of the soil; and (4) to control weeds and insect pests.

Deep-rooted leguminous crops, such as alfalfa and clover, are valuable as alternate crops with shallow-rooted crops, such as lettuce, for they tend to open up the soil to greater depths. Furthermore, the zone of nutrient absorption for these roots is deeper than for shallow-rooted crops. They also add nitrogen to the soil. Small grains and many leguminous forage crops are well adapted and valuable for use in a lettuce rotation as they are not subject to the same root diseases that attack lettuce. Of the vegetable crops, cucurbits, beets, spinach, tomatoes, onions, and sweet corn are usually not subject to diseases that affect lettuce.

Soil on which lettuce is produced inevitably receives much compaction from heavy equipment in tillage and harvesting operations. Many times compaction is aggravated by the necessity to have heavy equipment on the soil when it is so moist that it compacts badly. To counteract these harmful effects, select a crop for the rotation that requires less heavy equipment for culture and that requires the equipment to be used only when the soil is in a more nearly ideal condition.

IRRIGATION

Regulating and maintaining favorable soil moisture is necessary to produce a successful crop of lettuce. For optimum growth, lettuce requires a constant and relatively abundant supply of soil moisture throughout the growing period. Sharp fluctuations in soil moisture, especially in the later stages of development, are severely detrimental to normal growth.

In the western region where the crop is raised almost entirely without rainfall, the grower has close control over soil moisture. In the eastern and southern regions this is not true. Some control can be exercised over drought, however, by supplemental irrigation. Whenever rainfall is inadequate in these areas, irrigation water will be needed to produce a satisfactory crop. Thompson (*30*) estimates that in the East and South 5 to 8 inches of rainfall or the equivalent in irrigation water is necessary during the growing period of the spring crop. The amount required depends upon such factors as character of the soil, the amount of cloudy weather, and the prevalence of winds. Supplemental irrigation water, usually applied through a sprinkler system, can insure adequate moisture for the crop. Considerable skill and experience are necessary to integrate rainfall and irrigation so that soil moisture is maintained at favorable levels throughout the growing season. Unpredictable rains following soon after irrigation may result in a serious excess of water.

In the western region, lettuce is irrigated by open furrows. The water is taken from the head ditch into the individual furrows by means of metal tubes used as siphons, short pieces of rubber tubing, or wooden conduits made from lath. With each of these methods the flow of water from the head ditch into the furrow can be regulated easily.

Under some circumstances an irrigation before furrowing is justified; it germinates weed seeds that are later destroyed by light disking and it leaches the soluble salts out of the surface layers of the soil where they might interfere with seedling emergence.

Usually start irrigating immediately after planting; however, if a delay in germination is desired start irrigating later. For the initial irrigation, apply enough water to moisten the entire soil mass of the beds. Do not permit the surface soil to dry until the young seedlings have emerged. Some growers believe that running water has a cooling effect upon the soil, so in warm weather they allow the water to flow long after the soil is saturated. This is a questionable practice because it tends to waterlog the

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soil, which reduces the air content and prevents good germination. The result may be a spotty, uneven stand. Often the crop must be disked up and the field reseeded.

The fall crop in the western region may need an irrigation prior to thinning to soften the soil as an aid in thinning. Immediately after thinning an irrigation is beneficial; it firms and moistens the soil around the plants, which aids them in making a quick recovery from the thinning operation.

The frequency of irrigation after thinning depends on the character of the soil and climatic factors. In parts of the Monterey Bay area of California where the climate is cool and rate of evaporation moderate to low, Veihmeyer and Holland (*36*) found that irrigation need not be more frequent than once every 30 days after thinning to produce a summer or fall crop of lettuce. In Arizona where the climate is hot and evaporation is high, Pew and coworkers (*25*) state that intervals of 10 to 14 days in the early stages of development and 7 to 10 days as the heads mature are about the proper frequencies for the fall crop. They state, however, that the spring crop may go as long as 30 days without irrigation in the early stages of development but that it requires irrigation every 20 to 23 days in the later stages.

After the first harvest, it is customary to give the remaining plants a light irrigation to insure enough moisture for continued normal growth. Excessive irrigations or rain just before or during the harvest season, especially if temperatures are high, may result in loose, puffy heads. Excessive moisture when heads are approaching market maturity or are overmature also may cause bursting of the heads.

CULTIVATION AND WEED CONTROL

The primary purpose of cultivation after the lettuce crop has been planted is weed control. In fact, Veihmeyer and Holland (*36*), on the basis of several experiments in the Salinas Valley of California, suggest that this is the only reason for cultivation. But most horticulturists insist that there are other valid reasons for cultivating the crop. These are: (a) To replace the soil around the young seedlings after thinning; (b) to open the furrow and loosen the soil surface for improved penetration of irrigation water; (c) to dust mulch the bottom and sides of the furrow to facilitate the application of fertilizers; and (d), in nonirrigated areas, to break up the surface crust after rains. Horticulturists are generally agreed however, that these are far less important than weed control. Many growers undoubtedly have cultivated lettuce excessively.

Weed control is necessary throughout the growing season. Weeds compete with lettuce plants for nutrients and water and are hosts for disease-producing viruses, which can be transmitted to lettuce plants by insects. Weeds are best controlled when young. If the field has been properly prepared and cultivated, normally only one hoeing is necessary to control weeds after thinning.

Lettuce is shallow rooted; therefore, cultivate, as nearly as possible, only the surface layers of the soil (2 to 3 inches deep when grown on irrigated beds; 1½ to 2 inches when grown "flat.") Deep cultivation tends to root-prune the plants; this mechanically restricts the area from which the roots may obtain nutrients and water.

HARVESTING AND MARKETING

In 1948 a method of dry packing and vacuum cooling was developed in the Salinas-Watsonville district. It is now the standard method in the West and is often used in most major production areas of the Midwest, East, and Southeast.

This new method had extensive effects on nearly all phases of harvesting and marketing. Until that time head lettuce was cut in the field and hauled in bulk to packing sheds where it was trimmed and packed with crushed ice in wooden crates, usually 4 or 5 dozen heads to a crate. Crates were then loaded into railway refrigerator cars, and more crushed ice was blown on top of the load before shipment.

With the new method, the lettuce is cut and packed in the field (fig. 14). The first cutting, or topping out, is made when the earliest maturing heads are hard. Usually three or four cuttings are made, but sometimes only one or two are made if the market is slow or if quality is poor. Cutting is ordinarily done late in the morning and during the afternoon when the plants are less turgid than in early morning and the leaves are less likely to break.

Labor crews in the West are usually supplied by a labor contractor. The crews are divided into groups, each with a specific job. The harvesting-packing method varies with the packing company, area, and potential yield. Many companies use the following method.

The first group consists of the cutters, who select mature heads, cut them off close to the ground, trim to six wrapper leaves, and set them upside down on a bed. Each cutter usually covers two beds.

Cartons are prepared by men on a specially designed, slow-moving

FIGURE 14.—A lettuce-harvesting crew at work in the field.

truck with wide-track wheels, spaced 80 inches to span two double-row beds. These men fold and staple cartons by machine and toss them to the ground where other men distribute them over the area to be harvested.

Usually packers, pushing light wheelbarrows carrying cardboard cartons, follow the cutters. A packer places a layer, usually of 12 heads, top up in the carton and another layer of 12 top down (fig. 15). He places the full, open carton in the furrow and sprays water on the exposed butts. A closer with a portable tool closes and staples the carton. Sometimes, a sheet of paper is placed over the exposed butts before the carton is closed.

FIGURE 15.—A lettuce carton packed with 2 dozen heads, just before the carton is closed and stapled.

When packed the cartons are placed in two long rows, separated so that another wide-track truck can be driven between them; this permits simultaneous loading from both sides of the truck. Two men load the cartons onto pallets that cover the truck bed. Two other men on the truck arrange the cartons on the pallets. The load is then tied down with rope and taken to the cooler.

Some companies use a packing machine carried on a truck. With this, the cartons never touch the ground. As the truck is driven along the rows, the workers place the lettuce heads on conveyor belts, extending laterally from the moving truck, that carry the heads onto the truck. There they are packed into cartons. The packed cartons are conveyed to the closing machine and then to a second truck that takes them to the cooling plant. In some areas, tractor-pulled, wide-track trailers rather than trucks are used for hauling the packed cartons to the cooler.

Crew sizes vary from 50 men to as many as 300 men. The standard 50- to 60-man crew in the Salinas-Watsonville district covers 14 beds in a sweep. Larger crews fill up to four or five truckloads at a time. For light cuttings, fewer than 50 men are used.

In the West, the standard-size, corrugated paperboard carton is 9¾ x 14 x 21 inches. It is designed to hold 2 dozen heads, but it may be packed with 1½ dozen larger heads or 2½ dozen smaller heads. Cartons are printed, usually in two or three colors, with a shipper's label. This gives a brand name, the name and location of the shipper, the number of heads, and the product. Most shippers have two to four different labels, with a favored label used for the highest quality lettuce packed as 2 dozens, or "2's." Other labels are used for lower quality lettuce, or lettuce packed as "2½'s" or "1½'s." Some head lettuce is still packed in wooden crates, either in sheds with icing in some parts of the East or dry-packed in the field in many parts of the country for local shipment. To accommodate larger heads, cartons used in the East and Midwest are slightly larger than those used in the West.

At the cooling plant the pallets carrying the lettuce are removed from the truck by enormous truck-lifts and loaded side by side on long, flat, low-wheeled dollies. These are pushed into the vacuum cooler, which is a large steel tube (fig. 16). It may have doors at both ends or a single door with the other end permanently closed. When loaded, the tube is tightly sealed and air is removed rapidly from the chamber by a powerful vacuum pump or steam jet. Evaporation of the surface and tissue water of the leaves occurs in the lowered pressure of the chamber. This causes a cooling of the entire head. The vacuum is maintained until the temperature is lowered to about 33° F. The time required depends upon the initial temperature of the load; it usually takes 15 to 30 minutes. After the cartons are removed from the tube, they are placed on a conveyor belt that carries them to precooled railroad cars, which contain only bunker ice and fans or a diesel-powered cooler, or to refrigerated trucks for shipment.

There are several sizes of cooling tubes. The standard size holds 320 cartons, or one-half of the normal capacity of a railroad car. Some tubes are half this size, and portable tubes are one-fourth this size. Others will hold as much as one or two railroad cars or truck trailers.

Vacuum cooling of lettuce is more economical than the old shed-packing method; i.e., cardboard cartons are cheaper than wooden crates, the cost of crate ice and load ice is eliminated, and labor costs are lower.

Also, ice in the crate kept the lettuce wet and dripping, which made the crate heavier and more difficult to handle. The jagged edges of the ice caused some damage to the leaves. The water also facilitated the growth and movement of various organisms causing breakdown. In the dry pack, these factors are eliminated, although the load occasionally warms up enough to cause some wilting and breakdown.

In 1961, a new packing method was developed in the Salinas-Watsonville district of California. Its impact on the industry has yet to be fully determined. The process consists of shrink-wrapping lettuce heads in plastic film before cooling. This is done either in the field or in a shed.

In the field, lettuce heads are cut, stripped to a single wrapper leaf and conveyed to a group of workers in a truck-type vehicle driven through the field. There each head is wrapped in a thin plastic film either by hand or by an automatic or a semiautomatic wrapping device. The wrapped heads are conveyed through a heat tunnel, where, at a temperature of about 300° F., the film shrinks and hardens around each head, which gives a tight clear wrapping. The heads are then packed in cartons, 20 or 24 per carton, and vacuum cooled.

The essential difference between the field and shed methods is that in the latter the lettuce is cut in the field and hauled into a shed where the heads are trimmed to one wrapper leaf and then fed into a stationary machine that wraps and heat shrinks the wrapper automatically. They are then packed in cartons and vacuum cooled as in the field method.

The future importance of shrink-wrapping in lettuce marketing

FIGURE 16.—A vacuum cooler for lettuce being filled with lettuce cartons. After the produce is brought to the desired temperatures, the cartons are loaded directly onto refrigerated railway cars or trucks from the tubes.

probably will depend upon two factors:

The economic factor.—A greater proportion of workers at higher wage levels is needed either in the shed or on the truck than for the standard field packing operation. It will, however, be possible to reduce the size of the crew. In addition, it is expected that shipping costs will be lower with the reduced weight of the lettuce. It has been estimated that the removal of all but one wrapper leaf will reduce the weight per carton by 10 to 15 pounds. Other factors include the cost of the equipment and materials and the possible savings in reduced deterioration of the lettucc.

Consumer appeal.—A serious problem is the red discoloration of the butt. This can be trimmed off with unwrapped lettuce but not with wrapped lettuce. Another concern is whether there will be an increase or decrease in the amount of russet spotting, pink rib, and other types of breakdown in transit. These and other problems must be solved satisfactorily before shrink-wrapping becomes a successful marketing practice.

Butterhead, cos, and looseleaf lettuce are grown almost entirely for local or relatively nearby markets. Far less attention is given to harvesting and packing of these types than to crisphead lettuce because of their relatively low volume and short distance to market. Nevertheless, they are even more exacting in the care needed to keep them in first-class market condition. In the West, these varieties are dry packed in western crates in the field and shipped by refrigerated truck to local outlets. In the East, they are packed in wooden crates or bushel baskets and shipped in refrigerated trucks.

SEED PRODUCTION

Most lettuce seed produced in the United States is grown in California. Arizona, Idaho, Utah, and Oregon are also producing areas. According to the Agricultural Marketing Service (*33*), 660,000 pounds of seed of heading varieties, 158,000 pounds of seed of looseleaf varieties, and 25,000 pounds of cos seed were produced in 1958.

Two unusual features make the production and harvesting of lettuce seed different from the procedures with most other annual plants. First, most of the seed must be indexed for mosaic virus. Second, the head lettuce plant matures in two stages: From seed to market maturity, and from market maturity to flowering. The transition from market maturity to flowering necessitates cutting open the heads or otherwise removing the tight leaf covering to allow the flower stem to break through readily.

For head lettuce, seed-to-seed production usually requires 6 to 8 months but sometimes as long as 10 months. Good weather, high soil fertility, freedom from disease and insect damage, and sufficient water, as required for a head lettuce crop, are also necessary for growing seed. In addition, temperatures too warm for normal head formation are needed to encourage bolting. During the maturing of the seed, calm, dry weather is important. High winds or heavy rains will result in the loss of much seed. Seed plants of lettuce are shown in figure 17.

At market maturity, bolting is facilitated by one of several methods of removing the tight covering of leaves. The usual method is to make two slashes at right angles across the top of the head, not deep enough to cut the growing point. Another method is to slice off the top of the head but not deep enough to harm the growing point. A third method is to press down firmly on the top of the head, breaking the leaf ribs near the stem, and pull off the entire mass of head leaves without damaging the stem. If the crop is grown for market lettuce before harvesting seed, cut the heads fairly high on the stalk; this will leave enough productive lateral buds to form seedstalks and a crop of seed.

With the recognition of the economic seriousness of lettuce mosaic since 1950, with its seedborne characteristic, modification of seed-production procedures has become necessary (*9*).

Zink, Grogan, and Bardin (*42*) showed that planting of seed containing a maximum of 0.1 percent seedborne infection of the virus offers the only feasible control of mosaic. The following procedure has been developed for producing seed of low mosaic content.

For a seed crop, plant the seed at about the same rate as for a market crop or a little heavier (see Seedbed Preparation, Planting, and Thinning). Rogue offtypes, diseased plants, weaklings, and other undesirable plants before blooming. Two roguings are the minimum requirement; one about 2 weeks before market maturity and one at seed maturity. More extensive roguing is required for growing mosaic-indexed seed (see p. 31).

A most important first step in producing mosaic-indexed seed is the use of stock seed free of infection. This seed is usually obtained from plants grown in a greenhouse where infected plants can be removed and spread of virus can

FIGURE 17.—Lettuce plants maturing seed in the greenhouse. To produce stock seed free from lettuce mosaic it is usually necessary to grow the plants in a greenhouse in order to assure close control of the insect vector of the disease.

be almost completely prevented. Clean stock seed insures against infection starting in the field; thus control measures are reduced to those directed against outside sources.

More roguings are necessary for growing low-mosaic seed than for regular seed. Since every infected plant is a source of virus for infecting virus-free plants, remove each as soon as possible after it is recognized. Plants may show symptoms at any time; therefore, examine all plants in the field frequently and remove infected plants as they appear. After thinning, rogue twice a week for 3 or 4 weeks. After that, rogue once a week until bolting. Rogue again before harvest, since a new set of symptoms appears in the seed-head stage.

Control of weeds (p. 24) and insects (p. 43) is highly important in seed production. Many common weeds (p. 34) are hosts of the lettuce mosaic virus and can act as sources of infection. Eliminating these weeds, both within the field and around the edges, will reduce the possible infection centers. Insect carriers, especially the green peach aphid, are responsible for spread of the virus.

In order to be labeled as mosaic-indexed seed, the percentage of seedborne infection should not exceed 0.1 percent. This is determined by a seedling indexing procedure after the harvested seed has been cleaned and packaged. Lots of seedlings raised in flats are inspected for mosaic symptoms, and the number of infected plants is determined. No fewer than 3,000 plants per lot of seed should be indexed in this way, and more than 10,000 need to be indexed in doubtful cases. California allows the same tolerance as for weed seeds, that is, as high as 0.3 percent infection may appear and the lot may still be legally labeled as mosaic-indexed. Seed that does not fall within the tolerance level of 0.3 percent must be sold as regular seed.

Through the 1950's progressively more mosaic-indexed seed was produced each year. In the Salinas-Watsonville district of California, a county ordinance was passed in 1958 making it illegal to plant nonindexed seed of any variety of head lettuce. The use of mosaic-indexed seed will necessarily continue to expand unless resistant varieties can be developed.

Since greater care is taken with all production practices and disease control throughout the growing of mosaic-indexed plants, seed yields have increased markedly. Yields of nonindexed seed usually range from 200 to 400 pounds per acre; whereas, indexed seed may yield as high as 600 to 800 pounds per acre.

Isolation is important in successful seed production. Lettuce is naturally self-pollinated, but some crossing can occur. Contamination, after several generations, can lead to loss of varietal integrity. As high as 17 percent crossing can occur between plants standing next to each other. The average is about 3 to 3.5 percent. This is sufficient to cause considerable loss of uniformity in a variety. To prevent crossing, plant different varieties at least 10 feet apart, with several rows of a taller crop, such as corn or sunflowers, between them. If possible, grow a white-seeded variety next to a black-seeded one, to enable detection of seed mixtures.

The growth regulator gibberellic acid may shorten the seed-production period and perhaps increase seed yields. Several experiments in the greenhouse and a few in the field have indicated that seed may be harvested up to a month earlier and that yields may be somewhat higher than normal (*12*).

Until the 1950's, lettuce seed was harvested entirely by hand. The tops of the standing plants were bent over the mouth of a canvas sack and the seed shaken into it. This was usually done two or three times at intervals of about 7 to 10 days since the seed heads mature progressively. Some lettuce-seed fields are now being harvested by machine; a faster and more efficient process because less hand labor is needed. The plants are cut, elevated to a side belt, and delivered to a wagon. They are spread out on a canvas on the ground to dry. Later, the seed is removed with a stationary thresher. Some seedsmen still prefer to harvest by the "shake" method. Small lots are always harvested by this method. After harvest, the seed is cleaned with standard equipment to remove chaff and unfilled seed.

DISEASES OF LETTUCE AND THEIR CONTROL

Mosaic is the major lettuce disease in the United States. The nature and seriousness of diseases differ widely among the growing areas. In the West, mosaic causes by far the most damage. Downy mildew is also important in some areas, and big vein may have serious economic effects during a poor market when only high-quality lettuce is salable. In the Midwest, Northeast, and Southeast, aster yellows, damping-off, and mosaic are of major importance. Tipburn and rib blight sometimes may be very severe in any area. Other diseases of occasional importance in specific areas are damping-off, spotted wilt, stemphyllium, anthracnose, powdery mildew, bottom rot, sclerotinia, and botrytis. Brown blight was once serious in the West (*1*).

Damping-Off

Diseases that affect young seedlings before and shortly after emergence are designated by the collective term "damping-off." The causal agents of damping-off are species of *Pellicularia* and *Pythium*, usually *Pythium filamentosa* (Pat.) Rogers and *P. ultimum* Trow. These fungi destroy the stem tissue at the soil line, girdling the stem and causing the collapse and death of the seedling. Damping-off may cause serious reduction in plant stands during cool, wet weather, especially in localized areas where the soil is poorly drained and poorly aerated. Where young seedlings are grown in plantbeds for transplanting to the field, damping-off can be a serious problem. Crowding and lack of proper ventilation in the beds are ideal conditions for the growth of damping-off organisms.

In the field, good soil and water management practices and the use of seed disinfectants will control damping-off. In plantbeds, water control, proper ventilation, evenly spaced plants, and the use of soil fumigants will all be beneficial in reducing losses from damping-off organisms.

Mosaic

Common lettuce mosaic is caused by the virus *Marmor lactucae* H. It was first recognized and described as a virus disease in Florida in 1921. Since then, it has often caused serious loss in many lettuce areas in the world.

The symptomatology of mosaic is known in some detail, although some aspects of it are not fully understood. Differences in symptom expression are caused in part by differences in stage of plant growth at which infection occurs; it is this relationship that still needs exploration.

On a plant carrying seedborne virus, the first true leaf is usually mottled (fig. 18) with two shades of green, normal and yellowish, and is irregularly shaped. Sometimes this symptom may not appear until the second or third leaf or possibly even later. As the plant develops, the leaf edges show excessive frilling and the leaf tips roll back. In the early-rosette stage, vein clearing occurs. Later the entire plant will be stunted and yellowish and may fail to head (fig. 19).

Plants infected after emergence may or may not show the same sequence of symptoms; this probably depends on the stage of growth at which they are infected. If infection occurs late, the head may form and mature without any symptoms showing. If the plant bolts, however, symptoms appear on the seedstalk. The stem leaves become mottled and frilled. The seedstalk is stunted, with its branches shortened and yellowed. The involucres are distorted and show necrotic spots, particularly on the tips of the bracts. Necrotic girdling of the pedicels is common.

FIGURE 18.—Leaf from mosaic-infected lettuce plant, showing the typical mottling caused by the disease.

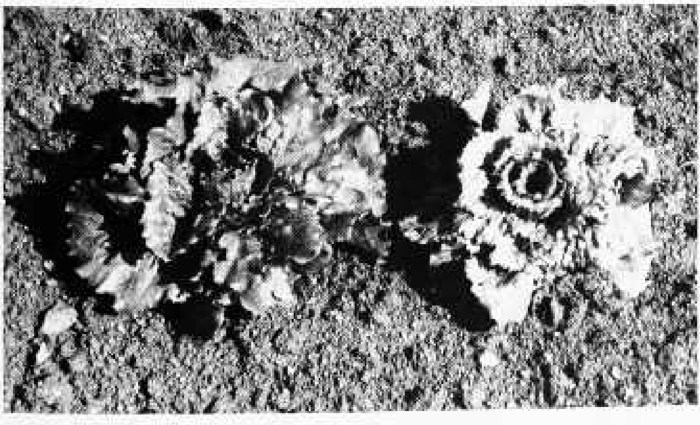

FIGURE 19.—Healthy lettuce plant on the left; mosaic-infected plant on the right. The light color, misshapen leaves, and small size of plant are typical symptoms of this disease.

Some varieties of lettuce (Jade, Imperial D, and Chesthunt Early Giant) are hypersensitive to mosaic and show necrotic flecks on the head leaves when infected. They also have necrotic lesions on the flower stalks in addition to the involucre spotting.

In general, symptoms are most pronounced during periods of rapid growth when the plants have ample nitrogen and the leaf tissue is dark green. It is difficult to detect symptoms on slow-growing, light-green plants.

Plants infected relatively early in the life cycle are sparingly or completely sterile. Seed yields are often extremely low; severely infected plants may yield nothing.

Mosaic virus may be spread as a seedborne infection or from plant to plant by insect vectors.

In nonindexed commercial lots of seed, seedborne infection commonly ranges from 1 to 3 percent. In some it may be as high as 14 percent; in a few strains, however, it may be at or near zero. Indexed seed must carry no higher than 0.1 percent infection (0.3 percent in California).

An example of the importance of the percentage of seedborne infection: A 1-percent infection in the seed planted at the rate of 1 pound per acre would mean on the average 4,000 infected seeds per acre, or 1 infected seedling per 6 feet of bed.

Mosaic is carried from plant to plant by several species of aphids. Dickson and Laird (*5*) have shown that the most important of these is the green peach aphid (*Myzus persicae* Sulz.). The percentage of infection that appears in a field is related to the seed infection and the size and movement of the aphid population. One-hundred percent infection may be reached when the aphid population is large and active. Aphids may pick up the virus from seedborne infected lettuce plants in the field or from infected weeds. The number of weed hosts is not known nor is their individual importance as sources of inoculum completely understood. Several of the known weed hosts are common, however, in lettuce-growing areas and may be major sources of inoculum. Thirty-five species of plants besides common lettuce are reported as hosts of the virus. Some of these may be at most only token hosts. Others, such as groundsel and prickly lettuce, may be significant sources of the virus (see following tabulation).

Reported weed hosts of lettuce mosaic virus: [2]

Scientific name	*Common name*
Anagallis arvensis L.	Scarlet pimpernel.
Aster spp.	Common aster.
Capsella bursa-pastoris (L.) Medic.	Shepherds-purse.
Chenopodium album L.	Lambsquarters.
Chenopodium murale L.	Sowbane.
Cichorium spp.	Chickory, endive.
Erodium cicutarium (L.) L'Her.	Filaree.
Lactuca serriola L.	Prickley lettuce.
Lamium amplexicaule L.	Henbit, deadnettle.
Lathyrus odoratus L.	Sweetpea.
Malva parviflora L.	Cheeseweed.
Picris echioides L.	Oxtongue.
Pisum sativum L.	Garden pea.
Senecio vulgaris L.	Groundsel.
Silybum marianum (L.) Gaertn.	Milkthistle.
Sonchus asper L.	Sowthistle.
Spinacia oleracea L.	Spinach.
Stellaria media (L.) Cyrill.	Chickweed.
Tagetes erecta L.	African marigold.
Tetragonia expansa Murr.	New Zealand spinach.
Zinnia elegans Jacq.	Zinnia.

[2] From Keener and Foster (*14*).

There are several possibilities for control of lettuce mosaic. However, only the planting of mosaic-free or mosaic-controlled seed is feasible at the present. While this does not eliminate the disease, it retards extensive infection long enough that much lettuce can be harvested from fields that would otherwise yield no marketable heads. By using indexed seed, fields that are ordinarily severely damaged should have only light infection. Since mosaic has a cumulative effect in areas where lettuce follows lettuce and adjacent fields are planted almost in sequence, the effectiveness of the low-mosaic seed is eventually lost, particularly when many aphids are present. As the virus is carried from field to field, the inoculum level rises and infections get heavier and heavier and may reach 100 percent.

Spray programs to control the aphid population are more effective in restricting the number of aphids in the lettuce head than in preventing the spread of the virus from plant to plant. Ultimate, reliable control of the disease must come from genetic resistance. This is not known to exist at present, but research is being conducted to find or create it.

Spotted Wilt

Spotted wilt sometimes causes heavy damage in lettuce. This is a virus disease that is widely distributed. It is especially important on tomatoes and peppers, but it also infects celery, nasturtium, dahlia, and several other cultivated species; it also attacks some weeds.

Symptoms on lettuce are characteristic and usually fairly easy to distinguish from those of other diseases. Young plants that are infected turn yellow, wilt, and die, often within a week. Symptoms on older plants are marginal wilting, marked twisting, yellowing, and necrotic spotting of the leaves. The infection is often most serious on one side of the plant; this produces a typical lopsided appearance (fig. 20). The younger, heart leaves may have necrotic spots or turn completely black and die. Infected plants eventually die.

Several species of thrips, including *Frankliniella* spp. and *Thrips tabaci* Lind., are the vectors of the virus. The virus, once acquired by the thrips, persists during the lifetime of the insect.

No effective control of the disease is known. All commercial varieties of head lettuce are susceptible, although the variety Mignonette may have some resistance.

Aster Yellows

Aster yellows is also a virus disease. At least two strains of the virus are known; an eastern strain that causes severe losses in lettuce and a western strain that has not been serious on lettuce in the important market-lettuce districts but causes extensive damage to celery.

The first symptom of aster yellows on lettuce is a chlorosis, or loss of green color, in the young leaves. Center leaves develop abnormally as short, thickened stubs. The outer leaves are twisted and yellowed. Light-brown latex deposits form on the affected leaves. Late infections on lettuce may show only latex spots in the interior of the head. Infected plants that bolt have distorted, discolored flower buds and bushy outgrowths of axillary buds (fig. 21).

Aster yellows is not seedborne; it is transmitted in the field by leafhoppers: The six-spotted leafhopper, *Macrosteles fascifrons* (Stål.), in the East and several species in the West. No source of genetic resistance is known. Control of the leafhoppers will help prevent the disease.

June Yellows

June yellows is the name that has been given to a complex of lettuce diseases. Grogan, Snyder, and Bardin (*8*) stated that it was caused chiefly by mosaic but also by other infectious diseases, faulty nutrition, excessive salinity, poor root development, the use of unsuitable varieties, and unfavorable climatic and soil conditions. Costa, Duffus, and Bardin (*4*) and Duffus (*6*) stated that at least two viruses are responsible for part of the complex. One is the radish yellows virus, which affects radish, spinach, sugar beet, and other crop and weed species as well as lettuce. The other is the malva yellows virus, which also affects cheeseweed, sugar beet, and other species. Both are transmitted by the green peach aphid as is the lettuce mosaic virus, although they are not related to the latter.

Radish yellows virus and malva yellows virus cause similar symptoms in lettuce and may occur separately or together. Irregular chlorotic blotching appears on older leaves. These areas tend to coalesce and later produce severe interveinal yellowing, especially near the leat margins and base. Eventually the whole leaf, except for narrow bands along the main veins, turns yellow. Some varieties, notably Prize Head, show a reddening of tissue rather than yellowing.

Severe yellowing ruins the appearance and quality of a head of lettuce. Beyond this it is not known what economic damage may be done by the viruses. There is no known source of resistance to either virus, although the severity of symptoms among varieties differs markedly.

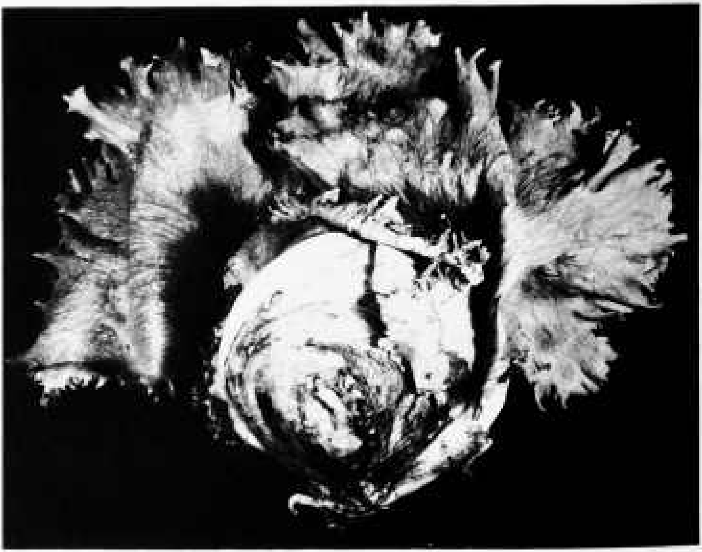

FIGURE 20.—A lettuce plant infected with the spotted wilt virus, showing the typical necrotic pitting of the midrib of the larger veins of the exterior leaves of the head and the lopsided appearance of the plant.

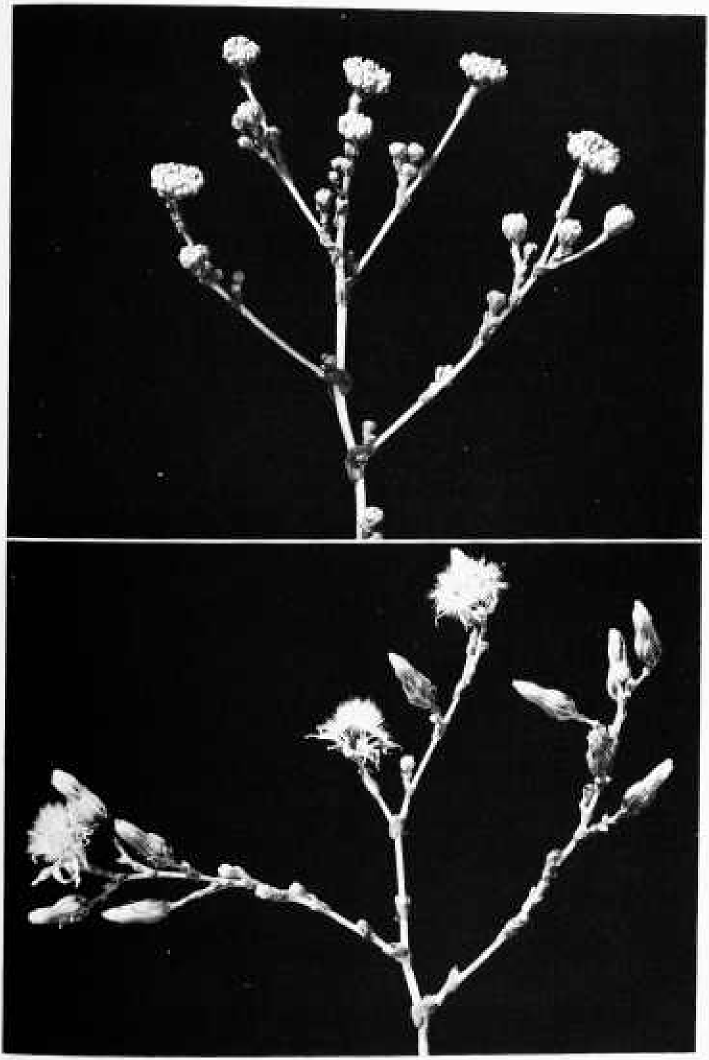

FIGURE 21.—Flowering shoot from a plant infected with aster yellows (upper); shoot from a comparable uninfected plant (lower).

Big Vein

The big vein disease of lettuce was first reported in 1934. Prior to 1958, the causal agent was assumed to be a soilborne virus; however, there was never convincing proof. In 1958, Grogan and coworkers (*10*) demonstrated a significant association between big vein disease and *Olpidium brassicae* (Wor.) Dang., a primitive fungus. Some recent work by Campbell and coworkers (*2*) suggests that *Olpidium* may be a vector of the virus that causes big vein.

The leaves of plants infected with the organism when small show a pale-yellow clearing along the veins. Such plants are apt to be stunted and never develop into marketable heads. Leaves of plants infected in later stages show severe vein clearing—actually a disappearance of chlorophyll adjacent to the major veins—and ruffling of the outer, more mature leaves (fig. 22). The infected plants have a peculiar upright position. The leaves fold in to form a head, but infected heads are never so large nor so solid as comparable uninfected heads. Such heads can be marketed, but they are light and loose and the quality is poor. Big vein is most likely to occur on heavy, wet soils, and symptoms develop most conspicuously when the air temperatures are between 42° and 60° F. The symptoms gradually fade out at higher temperatures.

No effective means of control are available. Avoid big vein infested soil if possible, but this is not very practical because the organism remains infective in the soil for at least 8 years. For small areas, steam sterilize the soil or treat it with certain chemicals. None of the common commercial varieties

FIGURE 22.—Lettuce leaves showing mild to severe vein clearing, a characteristic symptom of big vein.

are resistant to the disease. Now that the causal agent is known, a large-scale screening program to search for resistance is feasible.

Downy Mildew

After lettuce mosaic, downy mildew is probably the most destructive disease of lettuce in this country. It is reported to have damaged the crop at one time or another in all the chief producing areas in the western region, and it can be serious in greenhouses and plantbeds in the East and South. The disease is incited by the fungus *Bremia lactucae* Regel. This organism is favored by cool, moist weather, with humidity at or near the saturation point. It is spread by windblown spores. These spores require free water to germinate and become infective. Rain, fog, or dew will usually provide enough water for the spores to germinate.

At first pale-colored spots appear on the undersurface of the older leaves. These spots are irregular, sharply angled, and confined within the main veins. When conditions are favorable, the pale areas become covered with white, fluffy spore masses (fig. 23). These spores are spread from plant to plant by wind or by splashing rain. The infected areas become brown and necrotic, and eventually the entire leaf is destroyed. At harvest, damaged outer leaves have to be trimmed off before the head is placed in the carton. When most of the wrapper leaves are heavily damaged, the head is unmarketable. If weather conditions are conducive for rapid growth of the fungus and infection is widespread, entire fields can be destroyed within a week or less.

FIGURE 23.—Part of a lettuce leaf infected with downy mildew, showing the white powdery masses of spores. The mycelium of the fungus tends to be limited by the veins, hence the lesions are usually angular in outline.

The fungus frequently develops during transit; this provides an entry point for slime- or rot-producing organisms. As a result the produce may be decayed and unfit for market before it arrives at its destination, or shortly thereafter.

Chemical control of downy mildew through the use of sprays or dusts is ineffective and impractical because of poor coverage and excessive costs. The best means of control is through the use of disease-resistant varieties. At present (1961), disease-resistant varieties are available for only two producing areas and seasons: Valverde, adapted to winter culture in the Lower Rio Grande Valley of Texas, and Calmar, adapted to summer culture in the Salinas Valley of California. Plant breeders are developing resistant varieties for other areas and seasons.

Powdery Mildew

Powdery mildew (*Erysiphe cichoracearum* DC.) is not a serious disease of lettuce. It is reported to do sporadic damage to the crop in the Salinas-Watsonville district of California. The disease first appears as white, powdery masses on both surfaces of the older leaves. These white, fluffy masses consist of both spores and mycelium. The infected leaves later become brown and dry and have a scorched appearance. Infected plants are usually small, poor in quality, and unmarketable. Grogan and coworkers (*8*) have recommended dusting with sulfur to control the disease, if enough damage is occurring to warrant control.

Tipburn

Tipburn is one of the most common diseases of lettuce (*27*). It occurs in nearly all the lettuce-producing sections of the country in both field and greenhouse (*31*). Little has been learned about the environmental and genetic factors important in the etiology of the disease. Most of the information about the disease comes from scattered observations and impressions rather than from carefully controlled experimental work. However, investigators generally agree that: (a) The disease is nonparasitic, i.e. the causal agent is not an insect, fungus, bacterium, or virus; and (b) there are distinct genetic differences among varieties with respect to susceptibility to the disease. For example, varieties of the Great Lakes type are less susceptible to the disease than other varieties; some of the Imperial types are moderately resistant and a few are very susceptible; the butterhead and cos varieties are extremely susceptible. But, under favorable conditions for the development of the disease, even the most resistant varieties show tpical symptoms.

Initially dark-brown spots appear between the larger veins and along the margin of the leaves; at first these commonly occur on the outer leaves, but later they also develop on internal leaves (fig. 24). These spots usually coalesce, and the entire margin of the leaf becomes brown and necrotic. Ordinarily only a few leaves of the head are infected. The necrotic areas are ideal places for the invasion of rot- and slime-producing micro-organisms that cause secondary decay. Tipburn seldom occurs in young plants, and it rarely occurs in the young leaves of older plants. The disease tends to appear just before the plants reach market maturity.

The following environmental conditions are reported to favor the development of tipburn:

1. Conditions that support rapid, succulent growth, such as an abundant supply of nutrients and excessive water.
2. High relative humidity and

high temperatures, particularly night temperatures that exceed 65° F.

3. Fluctuating soil-moisture content.

4. Low temperatures during early development followed by relatively high temperatures at maturity. (These conditions frequently prevail at the time late-spring lettuce is grown in the western region.

If these environmental conditions are important in the etiology of the disease, it is clear that most of them cannot be controlled by the grower. Therefore, about the only effective means of control is to plant varieties known to have some resistance to the disease.

Sclerotinia

Sclerotinia, or drop, is a fungus disease caused principally by *Sclerotinia sclerotiorum* (Lib.) DBy. It occurs during cool, moist parts of the growing season in most lettuce-growing districts.

In late stages of the disease, a soft, watery, brown rot that severs the stem is produced. In damp conditions, a white mycelium appears on the underside of the leaves. Finally, the hard black resting bodies, or sclerotia, are formed. These average about one-fourth inch in diameter. They persist in the soil for several years. Cup-shaped fruiting bodies arise from the sclerotia. Although these produce spores, it is the growth of mycelium from sclerotia lying near lettuce plants that is responsible for most of the spread of the disease.

Eliminating sclerotia from the soil is extremely difficult. Nonsusceptible crops may prevent increase of the sclerotia in the soil, but use

FIGURE 24.—Part of a lettuce plant showing marginal tipburn. The dark, necrotic, fragmented area extends from the margin into the leaf tissue as much as one-quarter inch or more.

of these in a short rotation is ineffective as a control. Application of calcium cyanamid to the soil or flooding for long periods will eliminate some of them. No resistant varieties are known. Lettuce grown on raised beds and not overwatered is less likely to be infected than that grown on muck, subjected to heavy watering, or both.

Anthracnose

Anthracnose, sometimes called shot hole or ring spot, is caused by the fungus *Marssonina panattoniana* (Berl.) Magn. It is not a major lettuce disease, but it occasionally causes serious damage in cool, damp seasons.

At first, small, brownish, water-soaked spots appear on the lower leaves. These enlarge and become straw colored. The centers later fall out, forming the characteristic shot holes. Similar small, sunken, water-soaked spots appear on the underside of the midrib. Affected leaves eventually shrivel and die.

Moisture is required for the spread of the fungus spores. Splashing rain, sprinkler water, or water from dew-covered plants carried by cultivation practices will spread the spores. Their germination is favored by cool temperatures, around 60° to 65° F., as well as moist conditions.

In California, wild lettuce, *Lactuca serriola*, is the main source of inoculum. It usually becomes infected with anthracnose in the early spring. For preventing anthracnose, keep the areas around lettuce fields free of wild lettuce and rotate lettuce with nonsusceptible crops, since the fungus can live only about a year in dead material. In addition, do not cultivate when fields are wet, since the spores can be spread by the tools. No source of resistance to anthracnose is known.

Bottom Rot

Bottom rot is a disease of maturing lettuce plants that is caused by *Pellicularia filamentosa* (formerly *Rhizoctonia solani*), one of the organisms responsible for damping-off of seedlings. It may be destructive on muck, especially on varieties that grow close to the ground.

Necrotic lesions first appear on the petioles and midrib of the lower leaves. These may spread over the entire petiole and cause the death of the leaf. Successive leaves may be infected until the head is a slimy mass; eventually this drys down to a blackened mummy.

The fungus lives in the soil and in plant remains. It develops rapidly during warm weather when there is much moisture under the plants.

To control bottom rot, rotate lettuce with nonsusceptible crops or dust the soil under the plants with a fungicide. In greenhouses, where the disease may be a major problem, sterilize the soil.

Botrytis

Botrytis, or gray mold, is a fungus disease especially important in the greenhouse, but it also appears in the field and in transit. It is caused by *Botrytis cinerea* Fr. Botrytis sometimes appears as a secondary infection in fields of lettuce infected with sclerotinia.

On older leaves, lesions appear as water-soaked areas, which turn yellow. Soon a gray mold appears. On the stem at the base of the leaves, a brown to black, dry, firm decay appears that may rot through the stem and cause the head eventually to break off.

In the greenhouse, soil sterilization, adequate ventilation, and cool temperatures will control the disease.

Rib Blight

Like tipburn, rib blight is a somewhat mysterious disease of lettuce. No organism has been associated with it, and the conditions that cause it are not understood.

Rib blight is also known as brown rib or rib discoloration. A dark-brown or black elongated spot appears in the midrib of the outer leaves as the head nears maturity. More severe symptoms include several spots along the midrib and a brownish discoloration extending through the smaller veins of the leaf blade. In transit, secondary infections may set in and cause the entire head to rot.

Rib blight seems to occur most frequently during periods of warm weather. It is not known whether its appearance coincides with that of tipburn and it is caused by the same environmental conditions. Some varieties are less severely damaged by rib blight than others, but no resistant varieties are known. Methods of control are unknown.

INSECT ENEMIES OF LETTUCE AND THEIR CONTROL

Lettuce may be attacked by several kinds of insects, but the principal ones are caterpillars of various kinds and leafhoppers. Other insects, such as crickets, grasshoppers, and wireworms, are sometimes destructive. Aphids are injurious to the crop not only directly because of their feeding but also because they spread virus diseases, especially lettuce mosaic. In the eastern part of the country leafhoppers are a problem because they transmit the virus disease aster yellows.

Suitable insecticides for the control of insects on lettuce, effective dosages, and appropriate precautions are published annually by the Entomology Research Division of the U.S. Department of Agriculture (*34*). In 1958 Harries and coworkers (*11*) published control methods for lettuce insects in Arizona.

Insects Affecting the Market-Lettuce Crop

Cutworms and Armyworms

The beet armyworm, *Spodoptera exigua* (Hbn.), the yellow-striped armyworm, *Prodenia ornithogalli* (Guen.), and various cutworms are often a serious menace to young lettuce seedlings. In the western region this is especially true of the crop planted in late summer or fall. If insecticides are not used to protect the young plants, the stands may be so reduced that it becomes necessary to disk up the field and reseed. Attack by these insects usually is from worms that hatch from eggs deposited by moths on young plants, but sometimes the worms move in from adjoining fields.

Moths of the beet armyworm are grayish brown with lighter gray markings on the wings. They have a wingspread of about 1 inch and when at rest are 5/8 to 3/4 inch long. Moths of the yellow-striped armyworm are somewhat darker and have distinctive markings on the forewings. They have a wingspread of about 1 1/4 to 1 1/2 inches and when at rest are 3/4 to 7/8 inch long. These moths deposit large masses of eggs on the small plants almost as soon as they emerge. The egg masses are covered with scales from the body of the moth; this distinguishes them from other moth eggs. The eggs hatch in a few days, and the young larvae devour the plants they are on and spread to other plants. Armyworm moths are nocturnal, but they may be active in daylight.

Cutworm moths are all nocturnal, dusty gray, and heavy bodied. They have a wingspread of 1¼ to 2 inches and are ¾ to 1 inch long when at rest. They deposit smaller masses of eggs on the plants than do the armyworm moths, and these egg masses are not covered with scales from the moth. The damage to the young plants by the small cutworms is similar to that of the small armyworms. Larger cutworms tend to cut off the plants at the soil surface, as the name implies.

In areas where these insects are a menace, carefully watch the fields; damage to stands can occur very rapidly. If small worms and eggs are present, dust or spray at once; if only eggs are present, prepare to dust or spray within 3 or 4 days.

Cabbage Looper

The cabbage looper, *Trichoplusia ni* (Hbn.), is a pest in all the principal lettuce-growing regions in the United States. In the western region it attacks primarily the fall crop. McKinney (*21*) has shown the importance of this insect to fall-grown lettuce in the Southwest. Infestations of this insect usually become critical near thinning time, and may be serious immediately after thinning.

The moths are grayish brown and approximately ¾ of an inch long and have a wingspread of 1¼ to 1½ inches. They have a characteristic silvery spot near the middle of each of the front wings that looks like a figure 8 (fig. 25). The moths ordinarily fly near the ground and are most active at night. The pearly white eggs are laid singly on the leaves and hatch within a few days. When first hatched, the caterpillars have dark heads and almost colorless bodies. They begin feeding almost at once and soon become pale green. When mature the caterpillars are about 1½ inches long. They crawl by doubling up, or forming a loop, then projecting the front part of the body forward. They get the name "looper" from this method of locomotion (fig. 26).

FIGURE 25.—Adult of the cabbage looper moth.

FIGURE 26.—Cabbage looper feeding on lettuce leaf.

If insecticides have been applied to control cutworms and armyworms, they will probably control loopers and there will be no need to make further applications for looper control until after thinning. However, closely examine the field for loopers before starting the thinning operation. If loopers are present, apply insecticides before thinning so that the worms will not concentrate on the remaining plants after thinning. Watch the plants closely after thinning and apply insecticides when necessary. Three or four well-timed applications of insecticides are usually sufficient. If a thorough application is made just before the plants commence forming heads, about 30 days before harvest, usually no further applications will be needed.

Corn Earworm

Harries and coworkers (*11*) reported in 1958 that the corn earworm, *Heliothis zea* (Boddie), causes considerable damage to lettuce some years in the Southwest. Damage consists of the feeding and presence of worms inside the lettuce heads (fig. 27). Severe infestations may make the crop unmarketable, since the infested heads cannot be determined by inspection and discarded.

The corn earworm moth (fig. 28) is about the same size as the cabbage looper moth, but it is light olive green to grayish or yellowish brown. Eggs are laid singly on the leaves; they are ribbed and shaped like a flattened ball. After the eggs hatch, the small larvae feed for a short time on the outer leaves before entering the head.

Control consists of applying insecticides to prevent the worms from entering the lettuce heads. Once they are inside the heads, the damage is done because they cannot be reached with insecticides.

FIGURE 27.—Corn earworm feeding in lettuce head.

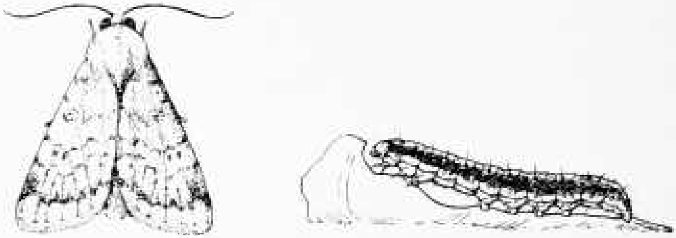

FIGURE 28.—Adult and larva of the corn earworm.

Aphids

Aphids, primarily the green peach aphid, *Myzus persicae* (Sulz.), (fig. 29) and the lettuce seed stem aphid, *Machrosiphum barri* Essig, may injure lettuce plants in several ways. Reid and Cuthbert (*26*) have pointed out that aphids cause heavy losses to growers of leafy vegetables by: (a) Reducing vigor and yield of plants, (b) contaminating edible plants, (c) transmitting destructive virus diseases of plants, and (d) killing plants, if infestation is heavy. Although mosaic is seedborne (p. 32), usually only a small percentage of the plants are infected. However, these plants serve as a source of infection from which the disease is spread to other plants by aphids. Control of aphids is therefore necessary to prevent the spread of disease as well as to prevent direct damage caused by the feeding and presence of the insects in the lettuce heads.

Leafhoppers

The six-spotted leafhopper, *Macrosteles fascifrons* (Stal.), is a major pest of lettuce in the eastern and north-central parts of the United States. This small, green, wedge-shaped insect is likely to be undetected until after the lettuce is injured. This leafhopper damages lettuce indirectly by spreading aster yellows. Because of the activity of the insect, small numbers are important in the spread of the disease. This makes control difficult. Wallis (*37*) in 1960 listed the host plants of aster yellows, as well as other leafhopper vectors of the virus.

Other Insects

Grasshoppers and field crickets sometimes infest young lettuce fields in sufficient numbers to threaten stands. Parker (*22*) has pointed out that grasshoppers are one of man's most ancient insect enemies. Control of these insects was once dependent upon poison baits, but these have now been replaced by more effective sprays or dusts.

In many areas of the Southwest, especially where lettuce is grown near cotton, the salt marsh caterpillar, *Estigmeme acrea* (Drury), is a problem. These insects breed in cotton and move to lettuce. Aluminum-foil barriers around the fields will prevent injury from these insects. Set a foil strip about 7

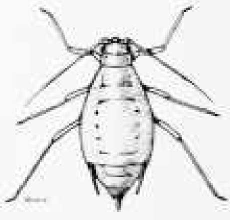

FIGURE 29.—Green peach aphid, wingless form.

inches wide upright in the ground; let about 5 inches protrude above the soil surface. Then dig post holes against the barrier about every 20 feet, to trap the caterpillars as they travel along the foil barrier.

Wireworms are immature forms of click beetles, family *Eliteridae.* They feed on the underground parts of plants, and can be recognized by their shiny, wirelike, yellow to orange bodies. Lane and Stone (*16*) list lettuce as one of the crops especially susceptible to attack. Damage to the roots may kill young plants or inhibit the development of older plants.

Insects and Mites [3] Affecting the Lettuce-Seed Crop

Aphids

Aphids are common pests of the lettuce-seed crop. Carlson (*3*) has shown that heavy losses in yield of lettuce seed may be attributed to the lettuce seed stem aphid, *Macrosiphum barri.* The green peach aphid, *Myzus persicae,* is also capable of damaging lettuce seed, but in the Southwest it does not usually occur in large numbers at the season of the year that the crop is maturing. In this region the primary damage to the seed crop by the green peach aphid is usually the spread of mosaic before seedstalk development.

Spider Mites

Spider mites, primarily the two-spotted spider mite, *Tetranychus telarius* (L.), (fig. 30) are sometimes serious pests of the lettuce-seed crop. They are very small: adult females average 0.42 mm. in length; males and immature forms are considerably smaller. They vary in color from pale yellow to orange red or greenish. Infested plants are heavily webbed, and leaves are yellowish in color. Feeding of these mites devitalizes the plants and reduces the yield of seed.

Hyaline Grass Bug

The hyaline grass bug, *Liorhyssus hyalinus* (Fab.), often causes considerable damage to the lettuce-seed crop. Carlson (*3a*) reported experiments by McKinney which showed that both adults and nymphs of this insect were capable of reducing yield and viability of lettuce seed. Adults of this insect resemble lygus bugs, and these two insects are often confused. They can, however, be easily identified by a close examination of the antennae. Those of lygus bugs are hairlike and tapered toward the end; whereas, those of the hyaline grass bug are slightly clubbed at the end. Lygus bugs may occur on the lettuce-seed heads in small numbers, but they are usually of little importance on this crop. Eggs of the hyaline grass bug are red and are laid in clusters usually on the flowerbuds or flower stems. The eggs hatch into reddish nymphs that feed directly on the flowerbuds and developing seed.

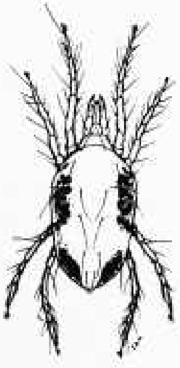

FIGURE 30.—Adult female of the two-spotted spider mite.

[3] Mites, although not true insects, are close relatives of them and, therefore, are discussed here.

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