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# *“Low Mosaic” Lettuce Seed Production*

By R. D. WATSON



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## SUMMARY

Lettuce seed produced in Idaho was found to be of the highest quality. The virus content of the seed even without any control program was surprisingly low. The seed from more than half of the fields examined and indexed was below the rigorous standards of one-tenth of one percent required by the seed trade for "low mosaic content" label.

Recent research indicates that "virus-free" or "low-mosaic-content" seed production on a commercial scale is practical in Idaho.

Although aphids were always present in the Idaho lettuce fields from the time the plants came up, the major population build-up was late in the season. The lettuce mosaic virus is not seed-transmitted in plants that are infected after the lettuce plant blooms. The vectors appear virtually incapable of spreading the virus over any distance.

The amount of lettuce mosaic was reduced or remained low with successive years of production in Idaho. Early roguing and inspection greatly reduced the amount of lettuce mosaic found in the seed.

Symptom expression of lettuce mosaic varied with the age of the plant, season of the year, variety of lettuce, strain of the virus, and with culture practices.

# "Low Mosaic"

## Lettuce Seed Production

BY R. D. WATSON\*

Lettuce mosaic occurs wherever lettuce is grown and now has a worldwide distribution. The virus is carried in the seed from infected plants. This infected seed serves as the primary source of inoculum in new areas. The importance of the seed-borne nature of the virus has been emphasized by recent advances in control of the disease by the use of "virus-free" or "low-mosaic-content" seed.

In Idaho this virus disease causes relatively small losses in the production of commercial lettuce. Its importance to Idaho remains chiefly in its effect on the quality of the lettuce seed produced.

This study shows virtually no over-wintering of lettuce mosaic virus in Idaho except in the seed.

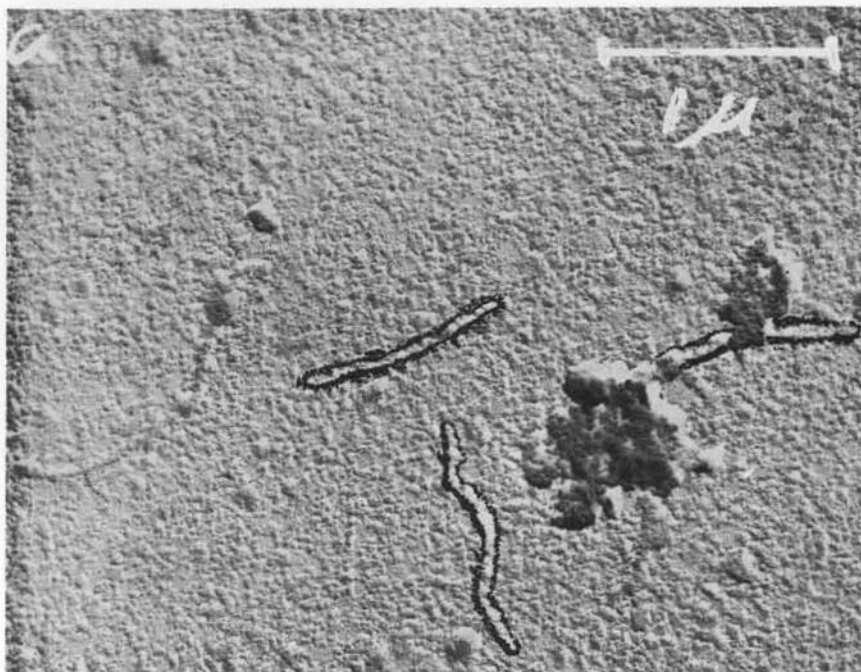
Cooperation of several Idaho lettuce-seed-producing companies and the Idaho Crop Improvement Association, Inc., is gratefully recognized.

### CAUSE OF LETTUCE MOSAIC

Lettuce mosaic is caused by a virus. Virus particles are generally very small as compared to other disease-producing agents such as bacteria or fungi. Lettuce mosaic virus, however, is one of the larger viruses infecting plants and is a rod-shaped molecule about 1 micron (0.000039 inches) in length (figure 1). The molecule is a very narrow, somewhat flexible, stringlike particle.

These virus particles are spread from plant to plant chiefly by insect vectors. Several different species of aphids are known to transmit the virus particle, including the green peach aphid, *Myzus persicae* Sulz.; *Macrosiphum gei* Koch; the potato aphid, *M. euphorbiae* Thomas; the cotton aphid, *Aphis gossypii* Glov. (2, 3) and *Macrosiphum barri* Essig. (8). Since these aphids lose their ability

\*Associate Professor and Associate Plant Pathologist, University of Idaho.



**Figure 1.** Electron microscope photograph of the lettuce mosaic virus rod-like particle, about 1 micron (0.000039 inches) long. Photo was re-touched to add contrast for printing.

to transmit the virus in a few minutes, the virus is classed as non-persistent in the insect vector.

Symptoms develop in the host plant about two weeks after the aphid has transmitted the virus. The amount of virus spread within the field depends more on the rapid movement of the aphids from plant to plant than upon the number of insects present in the field.

### **SYMPTOMS**

The symptoms of lettuce mosaic vary with the variety infected (figures 2-7B and table 1), stage of growth or development of the plants, weather conditions and strain of the mosaic virus (7, 8). Lettuce mosaic is most evident on the "young plant" as a vein clearing and mottling of light and dark green areas on an inwardly rolled leaf. The infected plants of most varieties have an overall yellowish color as compared to the healthy ones (figures 3, 5, 6). Leaf distortion and stunting are common to all varieties. Leaf necrosis (small dead area on leaf blade) is the most conspicuous symptom on certain varieties (table 1). The leaf mottling can be seen best by holding the leaf up to transmitted light or by shading it. On older plants the mottling becomes less distinct, while the general yellow color and stunting become the more predominant

Figure 2. Mosaic infected leaf of lettuce, variety Red Cos (transmitted light).

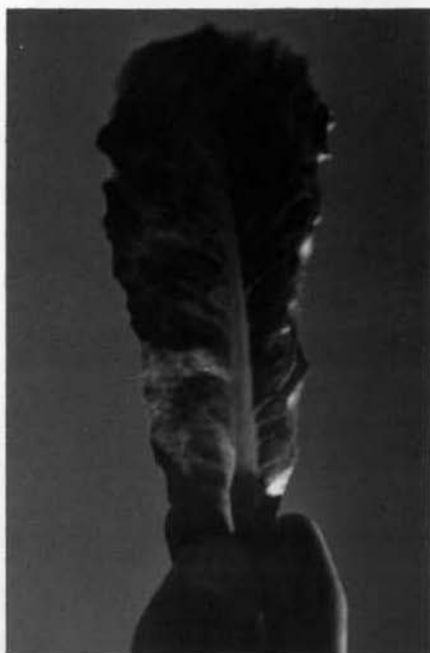
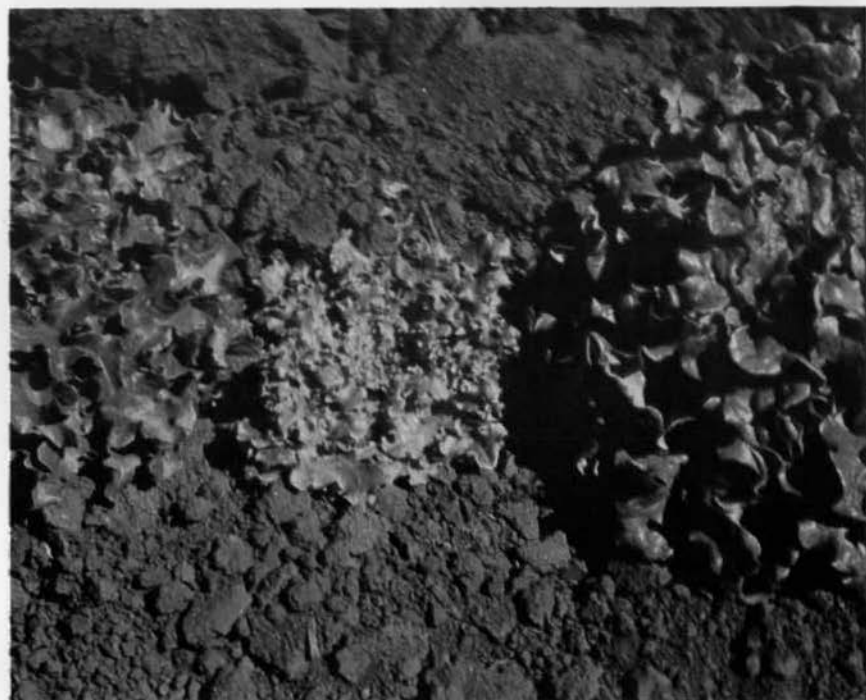


Figure 3. Mosaic infected plant of the Salad Bowl variety of lettuce in a row of healthy plants for comparison.





symptoms. Plants of certain varieties tend to have a wilted appearance.

Symptoms expressed by different varieties make identification of lettuce mosaic quite difficult and confusing for the untrained eye since the most prominent symptoms of lettuce mosaic in one variety, such as a puckered and rough-surfaced leaf, are found on the "normal" uninfected plants of other varieties of lettuce (figures 5-7). More than 40 distinctly different varieties of lettuce are commonly grown for seed in Idaho. In the world-wide collection of lettuce varieties studied at Wageningen, Holland, 138 varieties were recognized as being distinctly different (9). To add to the confusion the same variety of lettuce will be called by a different varietal name in different countries or by various seed companies. One older butterhead variety commonly called White Boston in the U.S.A. has a total of 72 different synonyms. Almost all of these varieties can be divided into the four distinct classes of lettuce, the cos or romaine varieties, the loose-leafed varieties, the butterhead varieties and the crisphead varieties (table 1).

Since the differences in symptom expression between varieties are confusing, a varietal rating system from 1 to 5 has been devised for each variety with a summary of its symptoms. Under this rating system, such varieties as Red Cos, Matchless, and Iceberg that develop easily identifiable symptoms have been given a rating of 1. Simpson, Prize Head, and Mignonette (Bronze), in which lettuce mosaic is most difficult to recognize, have been given a rating of 5 (table 1). Some experience is required in roguing field lettuce but the symptoms-rating system will be helpful.



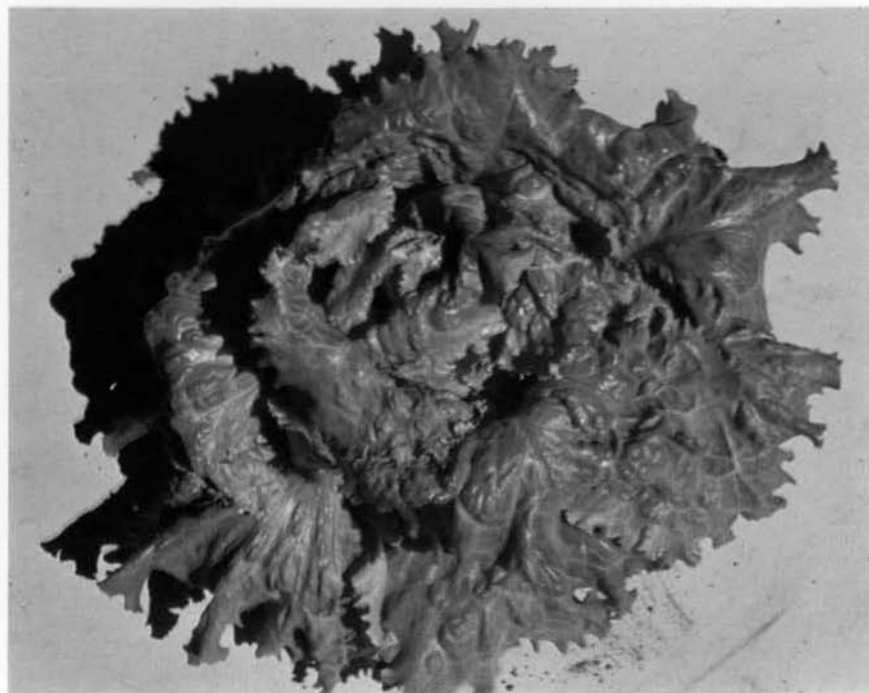
Figure 4. Healthy and mosaic infected plants of the Red Cos variety of lettuce.



**Figure 5.** Healthy and mosaic infected plants of the Paris White Cos variety of lettuce.



**Figure 6.** Mosaic infected plant of lettuce, variety (red) Salad Trim.



**Figure 7A. Healthy plant of the Iceberg variety of head lettuce.**



**Figure 7B. Mosaic infected plant of the Iceberg variety of head lettuce.**



Other virus or virus-like diseases can affect lettuce. Two viruses, not known to occur in Idaho, produce a yellow rather than a green mottle on lettuce and neither are seed-borne. The simple root fungus, *Olpidium brassica* Wor. Dang. (1, 4) which does occur in Idaho and transmits a virus commonly known as "Big Vein," produces virus-like mottle symptoms on lettuce and a clearing and enlargement of the veins (figure 8). All other diseases of lettuce that might be encountered in Idaho are rare in occurrence and produce symptoms in lettuce that are distinctly different and should not be confused with lettuce mosaic.

Natural infection of lettuce mosaic has been reported in most species of wild lettuce; on groundsel, *Senecio vulgaris* L.; cnicus, *S. cruentus* Dc; prickly sow-thistle, *Sonchus asper* Hoffm.; aster, *Callistephus chinensis* Nees.; and marigold, *Calendula officinalis* L. It also can be inoculated into endive, *Cichorium endivia* L.; spinach, *Spinacia oleracea* L.; and sweet pea, *Lathyrus odoratus* L.

The numbers of seed that carry the virus produced from the infected plant depends largely on the stage of the plant's development when infection occurs. Lettuce plants inoculated just before flowering produce fewer virus infected seeds than those inoculated soon after emerging. Plants that are infected after flowering has started do not transmit the virus through the seed (2).

Lettuce mosaic virus was found to be present in Idaho in nearly all seed fields examined. The number of infected plants varied from a trace to a maximum of about 1 percent in the seed fields (table 2). These mosaic-plant counts in Idaho were much lower than in other seed-producing areas where field readings up to 100 percent infection have been reported (5). These low field readings were validated by seed-indexing procedures which revealed Idaho-grown seed to contain an average of 0.3 percent infected seed as compared with an average of 3 percent in commercial seed lots from other areas. The temperature at which the plants are grown appears to influence the percentage of seed infected with mosaic. The average percentage of mosaic-infected seed produced from plants infected in the seedling stage has been higher when these plants were grown in the greenhouse than in the field, e.g. 6.2 percent in greenhouse and an average of 2.1 percent for field (table 3). Temperature may account in part for the higher percentages observed in California of 6 to 12 percent (2, 5).

## SOURCES OF PRIMARY INOCULUM

Lettuce-mosaic virus, in Idaho, overwinters in the seed from infected plants.

During 3 years of intensive observation of wild lettuce and other weed hosts, no case of lettuce mosaic was found on a wild plant. In records of many years of observation of these wild plants, there has been only one case of mosaic-infected wild lettuce near an old lettuce field.

Mosaic-free lettuce seed was planted each year from 1957 through 1960 in Moscow, Lewiston, Parma and Twin Falls. No infected plants were found in these fields. Lettuce-mosaic infected plants were interplanted systematically among the healthy plants on one of the plots located on the Branch Experiment Station at Parma. Spread occurred only rarely and then only to those plants adjoining the diseased ones. Likewise the degree of mosaic spread within lettuce seed fields appears to be relatively low.

The reduction of yield and quality of the commercial lettuce crop due to lettuce-mosaic infection is well known. The amount of injury decreases as the time of infection is delayed. Ninety-six percent of infected plants failed to produce heads when infected as seedlings, 74 percent when infected 20 days after emergence and about 50 percent when plants were infected at 40 days of age (3, 5, 6).

The primary, mosaic-infected plants produced much less seed than the healthy plants even when both were harvested at their own maturity date. The diseased plants of the leaf and cos varieties produced, on the average, less than one-half the quantity of seed produced by healthy plants. Heading varieties, such as Iceberg, produced less than one-tenth as much seed as the comparable healthy plants. Seed germination varied somewhat with the variety of lettuce, but the percentage of seed germination from mosaic-infected plants was seldom more than one-half that of seed from healthy plants.

There are probably several other factors that account for reduction in the quantity of mosaic observed when seed crops of lettuce are grown in Idaho in successive years. In most varieties of lettuce observed, the mosaic disease delayed seed-stalk formation and seed maturity. In Idaho, the lettuce seed must be harvested when the majority of the plants are ready, as the delay will cause heavy seed losses due to shattering. Hence, in commercial production the growers harvest the seed crop before the seed of the mosaic-infected plants is mature or ripe.

## CONTROL

As is often the case with disease control in plants, the pathologist has no practical cure once the plant has become infected with lettuce-mosaic virus. The control program must be one of disease prevention. The production of "virus-free" or "low-mosaic-content" seed is the most successful and economic control of lettuce-mosaic virus yet developed. The use of "low-mosaic-content" seed can pay its own way and can prevent crop failure as an additional benefit.

The direct loss from infected plants that develop from seed would, in itself, more than pay the commercial producers of lettuce for the added cost of good-quality, "low-mosaic-content" seed as is shown in the following example (11).

	Ordinary Seed 3 percent mosaic	Low-mosaic seed, less than 0.1 percent mosaic
1. Cost of seed per acre 25,000 plants per acre	\$ 7.00	\$14.00
2. Loss of plants due to mosaic- infected seed assuming no spread:		
.03 × 25,000 = 750 plants <sup>1</sup>	30.00	
.001 × 25,000 = 25 plants		1.00
Total cost of seed and loss of plants	\$37.00	\$15.00
Gain from use of "low-mosaic-content" seed		\$22.00

The use of ordinary seed in commercial lettuce fields could result in a total crop loss due to mosaic spread by aphid activity; whereas the use of low-mosaic seed, less than 0.1 percent, has proved to be good insurance to produce a marketable crop even under most severe conditions (3, 5, 10, 11). Aphid spread of the virus in intensive lettuce production areas will increase from 1 percent mosaic virus in the seed up to 100 percent at maturity of the crop as reported from parts of California, New York, England, Australia and New Zealand (3, 5, 10, 11).

Once the "low-mosaic-content" seed has been produced, there is good evidence that this seed could be increased in Idaho at little added expense. In nearly all cases, once a variety or seedlot was found to be nearly free of lettuce mosaic, it could be increased in Idaho without any evident increase in lettuce mosaic (table 4). In 1957 a new variety of lettuce, Ruby, was grown by several seed companies in widely separated locations in Idaho. Because of a limited quantity of seed available, the fields were quite small and were nearly always grown near or as a part of other lettuce fields. The original introduction seemed to be nearly free from mosaic. This variety was increased for 3 years by the several companies and the seed observed for 3 successive years has remained comparably free from lettuce mosaic. In no field was the proportion of mosaic as high as one plant per 10,000. This seems to be a general trend, in that seedlots low in mosaic can be increased in Idaho with little or no increase in the disease (table 2).

Nearly half the seed produced in Idaho (table 2) 1957-1958 could meet the requirements for "low-mosaic-content" seed having less than one mosaic-infected seed per 1,000 or less than 0.1 percent mosaic. Because of the low inoculum potential in both wild and cultivated hosts, it would seem that a little effort in roguing and seed selection would still further reduce the mosaic content of the seed produced until all of the seed would meet the rigid requirements of "low-mosaic-content" seed at little added production cost.

A cooperative program between the lettuce-seed-producing companies, the Idaho Crop Improvement Association, Inc. and the University of Idaho was started in 1957 to determine the value of

<sup>1</sup>Cost based on \$1 per carton of 25 plants.

inspection and roguing to reduce seed-borne lettuce mosaic in field-grown lettuce seed.

The progress can be followed by comparing the inspection reports for years 1957 and 1958 (table 2), and of 1963 (table 6). In 1963 a greater number of plants were sampled to determine the percentages of mosaic with more accuracy than was done in previous years. Percentages were calculated on a basis of at least 10,000 plants in 1963 and more than 50,000 plants were examined before a field was given a zero rating.

The number of field inspections that contained less than 0.1 percent mosaic has increased over the years from 40 percent in 1957 to 65 percent in 1959 and 84.3 percent in 1963. The number of fields that were recorded as free of lettuce mosaic increased from 6 percent in 1957 to 23 percent in 1963.

If the market requires further assurance of the "low-mosaic-content" of the seed produced, the seed might have to be indexed before sale to assure the buyer that each lot meets the requirements. A greenhouse indexing program may be too expensive for the varieties of lettuce grown in Idaho because of the relatively small volume of seed produced of each variety. A field indexing program appears to be a practical way in which the seed samples could be indexed either in the fall following seed harvest or the next spring. Large samples can be field planted and examined economically. The same sampling procedure and statistical treatment can be used with field indexing as with greenhouse indexing and because of larger samples observed in the field, greater accuracy can be obtained.

A field indexing program for the leaf, cos and head lettuce varieties grown in small lots has been under test for three years. It seems entirely feasible to develop a relatively low cost indexing program. By indexing plants in the field, samples in excess of 10,000 plants can be grown and inspected easily for seed-borne mosaic. Symptom expression has been good and even the most difficult varieties can be indexed with relative ease (tables 1, 2, 3 and 4). Some of these same varieties would cause considerably more difficulty in greenhouse indexing and require greater skill for identifying the disease than do the head-lettuce varieties now indexed in greenhouses (table 1).

The size of seed sample required has been calculated (11) on the basis of the degree of precision of results desired. Mosaic content of larger seed samples (providing they adequately represent the seedlot) can be estimated more accurately than can smaller seed samples. Where the percentage of mosaic in the seedlot is either quite high or quite low, smaller samples will give an accurate enough picture to accept or reject the lot. However, where the small sample is nearly at the "accept-reject" point, larger samples are required.

An adequate sample, for greenhouse-indexing of lettuce mosaic, should consist of 10,000-12,000 plants. Then, if upon examination of 3,000-4,000 plants, the indicated "accept" level of infected individuals has not been exceeded, the sample may be judged acceptable

without planting the remaining seeds and examination of the remaining plants (table 5). Likewise, if the "reject" number has been clearly exceeded, the sample can be rejected without further test of the population. Thus, in greenhouse indexing only those borderline cases need to be tested further. For example, if the test is set up with a total sample of 12,000 seed divided into three, 4,000-seed samples, the maximum number of infected individual plants in the 12,000-seed samples would be 6 or 8 infected plants depending on the degree of confidence desired (table 5). If, in testing the first of the 3 sub-samples, the number of mosaic-infected seedlings was high, e.g., above 4, the lot would be rejected with no further test. Likewise, if the number was less than 2, the lot could be accepted with confidence of 99:1 odds. Samples of fewer than 3,000 plants tested cannot be viewed with much confidence. Field indexing samples in excess of 12,000 plants could be examined economically and the resulting accuracy increased.

A foundation-seed program is not a required starting point to develop the "low-mosaic-content" seed program. The results of roguing indicate that if the fields are rogued early and adequately, the seed lots may be freed from mosaic. (See fields 1, 2, 3 and 5 in table 2, compare tables 2 and 6). Examination of these fields on May 27, 1957 showed that they contained 0.4, 0.2, 1.2, and 5.6 percent mosaic infected plants. Following this examination all four fields were rogued and examined in June and were found to contain a trace or less than 0.1 percent mosaic. The seed from these fields was indexed the next year and indicated the virus content to be very low (table 2).



Figure 8. Big Vein disease of lettuce (transmitted light).

Table 1. Lettuce varieties grown in Idaho rated according to the relative ease of field determination of lettuce mosaic symptoms.

Variety	Mosaic identification rating*	General notes on variety mosaic symptoms
Cos or Romaine varieties		
1. Red Cos (new) bs <sup>1</sup> , strong <sup>2</sup> Leaf red	(1)	mosaic plant clearly mottled and stunted, mottled areas light green on a smooth leaf in sharp contrast to the dark red of the normal plant. Probably the variety easiest to identify mosaic.
2. Dark Green Cos (old) 1856 ws <sup>1</sup> , none <sup>2</sup> Leaf dark green	(3)	mosaic plant yellow with mild mottle. Pale green open plant.
3. White Paris Cos (old) (Trianon) 1856 ws <sup>1</sup> , none <sup>2</sup> Leaf yellowish green	(2)	mosaic plant open head rosette, light yellow, stunted and clearly mottled.
4. Parris Island Cos (new) ws <sup>1</sup> , none <sup>2</sup> Leaf dark green	(2)	mosaic plant stunted, yellow with clear mottle. (Mosaic tolerant plant)
5. Eiffel Tower Cos (old) 1883 bs <sup>1</sup> , none <sup>2</sup> Leaf yellow green	(2)	mosaic plant stunted, yellow with clear mottle.
6. Mild Sucrine (old) 1880 ("Latin" type) ws <sup>1</sup> , none <sup>2</sup> Leaf light green	(3)	mosaic plant light yellow, mild light yellow-green mottle, stunted open plant.
Butterheading varieties		
1. Big Boston (old) 1775 (Trocadero) ws <sup>1</sup> , little <sup>2</sup> Leaf light greyish green	(2)	mosaic plants light green mottle, yellow-red, stunted and clearly evident in the field.
2. White Boston (old) Unrivalled or Green Trocadero ws <sup>1</sup> , none <sup>2</sup> Leaf light greyish green	(3)	mosaic plant yellow with light colored faint mottle. Open head rosette.

<sup>1</sup>Seed color, ws=white seed, bs=black seed.

<sup>2</sup>anthocyanin—strong, considerable, little, none.

\*Varieties with easy-to-identify symptoms, rated 1 graduating to 5, the most difficult to identify.



Table 1 — (Continued)

Variety	Mosaic identification rating*	General notes on variety mosaic symptoms
3. Bibb (new) bs <sup>1</sup> , little <sup>2</sup> Leaf very dark green	(3)	mosaic plant finely mottled, light colored, with the red color peppered or in a pinto pattern.
4. Bibb 41 (new) bs <sup>1</sup> , none <sup>2</sup> Leaf light green	(2)	mild mottle, light yellow open plant.
5. Tom Thumb (old) 1860 bs <sup>1</sup> , none <sup>2</sup> Leaf dark green	(3)	mosaic plant stunted. Yellow with a mottle which contrasts against the green of the normal plant.
6. Midas (new) 1950 ws <sup>1</sup> , none <sup>2</sup> Leaf yellowish green	(2)	mosaic plant light green mottled, yellow and stunted. Clearly evident in field.
7. Salamander (old) 1856 bs <sup>1</sup> , none <sup>2</sup> Leaf yellowish green	(3)	mosaic plant yellow mottled and somewhat stunted.
8. Continuity (new) (Crisp as Ice) bs <sup>1</sup> , considerable <sup>2</sup> Leaf brownish red	(3)	mosaic plant yellow, mottled; somewhat difficult to recognize because of bleaching of normal leaves.
9. Mignonette (old) 1895 bs <sup>1</sup> , considerable <sup>2</sup> Leaf reddish brown	(3)	mosaic plant yellow, stunted, and the mottle fairly clear.
10. Mignonette Dark Green bs <sup>1</sup> , little <sup>2</sup> Leaf dark green	(3)	mosaic plant yellow, mottled, mottle fairly clear.
11. Mignonette Bronze bs <sup>1</sup> , strong <sup>2</sup> Leaf reddish	(5)	mosaic plant yellow, mottled, fairly clear but difficult to see because of the bronze color of the normal plant.
12. Sweetheart ws <sup>1</sup>	(3)	mosaic plant yellow, mottled, with evident vein clearing.

<sup>1</sup>Seed color, ws=white seed, bs=black seed.

<sup>2</sup>anthocyanin—strong, considerable, little, none.

\*Varieties with easy-to-identify symptoms, rated 1 graduating to 5, the most difficult to identify.

Table 1 — (Continued)

Variety	Mosaic identification rating*	General notes on variety mosaic symptoms
13. Hubbards Market (old) 1875 ws <sup>1</sup> , none <sup>2</sup> Leaf light green	(3)	mosaic plant open rosette, yellow mottled with evident vein clearing.
14. May King ws <sup>1</sup> , little <sup>2</sup> Leaf light green	(5)	mild faint mottle, some necrotic spots circled with red.
15. Wayahead ws <sup>1</sup> , none <sup>2</sup> Leaf light yellowish green	(2)	mosaic plant yellow, mild mottle, mild necrosis on outer leaves.
16. All Year Round bs <sup>1</sup> , none <sup>2</sup> Leaf light yellowish green	(2)	yellow mild mottle, mild necrosis on outer leaves.
Loose-leaf varieties		
1. Ruby (new) ws <sup>1</sup> , strong <sup>2</sup> Leaf red	(3)	mottled areas fairly clear, red color less intense over the mottle.
2. Salad Trim (new) 1949 bs <sup>1</sup> , strong <sup>2</sup> Leaf dark red	(2)	mottled areas puckered and clear on smooth leaf. Red color less intense over mottled area.
3. Salad Bowl (new) bs <sup>1</sup> , none <sup>2</sup> Leaf yellow	(2)	mosaic plant light yellow, severely stunted and somewhat mottled.
4. Matchless (old) 1856 bs <sup>1</sup> , none <sup>2</sup> Leaf yellowish green	(1)	mosaic plant yellow, stunted, clearly mottled in excellent contrast to the dark green smooth pointed leaves of the normal plant.
5. Oakleaf (new) ws <sup>1</sup> , none <sup>2</sup> Leaf yellowish green	(3)	mottled areas fairly evident. Vein clearing and mottle on the smooth leaf. Mosaic plant yellow and stunted.
6. Grand Rapids (new) bs <sup>1</sup> , none <sup>2</sup> Leaf yellow	(4)	mosaic plant yellow, stunted, deep yellow on edges of leaves and a good mottle on larger plants.

<sup>1</sup>Seed color, ws = white seed, bs = black seed.

<sup>2</sup>anthocyanin—strong, considerable, little, none.

\*Varieties with easy-to-identify symptoms, rated 1 graduating to 5, the most difficult to identify.

Table 1—(Continued)

Variety	Mosaic identification rating*	General notes on variety mosaic symptoms
7. Slobolt (new) bs <sup>1</sup> , none <sup>2</sup> Leaf yellowish green	(4)	mosaic plant yellow, stunted, deep yellow on edges of leaves and a good mottle on larger plants.
8. Black Seeded Simpson 1856 bs <sup>1</sup> , none <sup>2</sup> Leaf yellowish green	(5) (old)	mosaic plant fairly evidently mottled. Stunted yellow outer leaves but confusing because of the blanching yellow leaves and frilled puckering of leaves on healthy plants.
9. Early Curled Simpson ws <sup>1</sup> , none <sup>2</sup>	(5) (old)	About the same symptoms as Black Seeded Simpson.
10. Prize head (old) 1879 ws <sup>1</sup> , strong <sup>2</sup> Leaf red brown	(5)	mosaic plant small, necrotic and mottled leaves shortened due to necrosis. Mosaic symptoms fairly easy to identify, but confusing because of the normal frilled and crumpled outside leaves. Leaves are ringed red and interior leaves are green.
Crisp-heading varieties		
1. Iceberg (very old) 1771 ws <sup>1</sup> , little <sup>2</sup> Leaf light green	(1)	mosaic plant lighter color with strong bright yellow green mottle, dwarf open head.
2. Hanson (new) 1922 (nonpareil) ws <sup>1</sup> , none <sup>2</sup> Leaf yellow	(3)	mosaic plant produces a yellow-green mottle, some necrosis on young leaves, stunted, failure to head normally.
3. Denver Market ws <sup>1</sup> , none <sup>2</sup> Leaf light yellowish green	(2)	mosaic plant very yellow, some necrosis of young leaves and stunted and failure to head normally.
4. Jade (new) bs <sup>1</sup> Leaf dark green	(2)	mosaic plant yellow, stunted, and fails to head normally. Light yellow stunted plant contrasts against the very dark green leaf of normal plant.

<sup>1</sup>Seed color, ws=white seed, bs=black seed.

<sup>2</sup>anthocyanin—strong, considerable, little, none.

\*Varieties with easy-to-identify symptoms, rated 1 graduating to 5, the most difficult to identify.

Table 1—(Continued)

Variety	Mosaic identification rating*	General notes on variety mosaic symptoms
5. Valverde (new) ws <sup>1</sup>	(3)	mosaic plant yellow, leaf stunted, and fails to produce a normal plant.
6. New York 12 (new) 1944 ws <sup>1</sup> , none <sup>2</sup> Leaf dark green	(2)	mosaic plant produces a yellow-green mottle with some necrosis on young leaves, stunted, and failure to head normally.
7. New York 515 (new) 1944 ws <sup>1</sup> , none <sup>2</sup> Leaf dark green	(1)	very clear mottle, stunting, and the light-green mosaic plant contrasts against dark green of normal plant.
8. Imperial 847 (new) 1936 bs <sup>1</sup> , none <sup>2</sup> Leaf dark green	(2)	mosaic plant yellow, stunted, and fails to produce a normal head.
9. Imperial 101 (new) 1936 ws <sup>1</sup> , none <sup>2</sup> Leaf dark green	(2)	mosaic plant yellow, stunted, and fails to produce a normal head.
10. Progress (new) (U. S. 2428) ws <sup>1</sup> , none <sup>2</sup> Leaf yellow green	(3)	mosaic plant yellow, stunted, and fails to produce a normal head.
11. Alaska (new) bs <sup>1</sup> , none <sup>2</sup> Leaf grey green	(2)	mosaic plant yellow, stunted, and fails to produce a normal head.
12. Great Lakes (new) 1941 ws <sup>1</sup> , none <sup>2</sup> Leaf dark green	(2)	mosaic plant yellow, stunted, and fails to produce a normal head.

<sup>1</sup>Seed color, ws=white seed, bs=black seed.

<sup>2</sup>anthocyanin—strong, considerable, little, none.

\*Varieties with easy-to-identify symptoms, rated 1 graduating to 5, the most difficult to identify.

Table 2. Lettuce mosaic in 1957 production fields and index of mosaic content in seed produced from these plants.

Field No.	Variety	FIELD MOSAIC READING				
		1957		1958		Field Index
		May 27	Inspection June & July	Plants	Moscow Indexed	
		%	%	No.	%	%
1.	New York 12	0.4 R	T	452	0	
2.	Hanson Head	0.2 R	T	262	0	
3.	New York 12	1.2 R	T	232	0.4	
4.	Salad Bowl		1.0	399	2.2	0.6
5.	Progress	5.6 R	T	398	0	
6.	Hubbards Market		0.5	336	0	0.00
7.	Mignonette		T			0.1
8.	Prize Head	T	0.2			Trace*
9.	Parris Island Cos		T			Trace*
10.	Oakleaf		T			
11.	Black Seeded Simpson	0.4	0.5	445	0.4	
12.	Big Boston	0.8	1.0	420	0.0	
13.	Grand Rapids	T	T			Trace*
14.	Grand Rapids		T			0.00
15.	Grand Rapids	1.0	0.3	509	0.2	
16.	Slobolt		T			
17.	New York 515		0.5	692	1.2	1.00
18.	New York 12		0.3	985	1.0	
19.	Early Curled Simpson		T	282	0.0	
20.	Salamander		0.5	474	0.2	
21.	Hanson		0.5			
22.	Grand Rapids		T			
23.	Iceberg		0.5	549	1.0	
24.	Ruby		0	480	0.0	Trace*
25.	Imperial 101		T	150	0.6	Trace*
26.	Denver Market		T			1.0
27.	Black Seeded Simpson		0.4			
28.	Continuity		0	123	0.0	0.0
29.	Prize Head		0.5	636	0.0	
30.	Salad Trim		0.1			
31.	Mignonette D. Green		T	481	0.2	
32.	Dark Green Cos		0.7	496	0.2	
33.	Red Cos		1.1	424	1.3	
34.	Paris White Cos		0.5			
35.	White Boston		T	596	0.3	
36.	Great Lakes		0			
Average Mosaic per Field						0.34

\*Trace= (in 1958 column) less than 1 plant in 10,000 but at least one mosaic plant per field.

T=Trace—1957 less than 0.1%. R=Rogued May 27.

Table 3. Mosaic content of seed produced from individual infected plants.

Variety	Seed produced at	Total number of plants indexed	Individual plants	Variety average
			%	%
Bibb	Notus	223	0.4	
Unknown	Notus	361	1.1	
Salad Bowl	Notus	167	1.2	
White Cos	Notus	91	3.3	
Red Cos	Greenhouse	330	8.5	
Red Cos	Greenhouse	376	5.1	
Red Cos	Greenhouse	475	5.7	6.2
Prize Head	Notus	297	3.4	
Prize Head	Notus	185	3.2	3.3
Iceberg	Boise	372	2.4	
Average of Red Cos greenhouse grown seed			6.2% mosaic	
Average of field grown seed			2.1% mosaic	
Average of all plants			3.7% mosaic	

Table 4. Comparison between the amount of seed-borne mosaic present in seed produced from fields low in mosaic and those high in mosaic count in 1957.

Fields having more than 0.1% mosaic—1957				Fields having less than 0.1% mosaic—1957			
Field No.	Mosaic 1957	Plants Indexed	Mosaic 1958	Field No.	Mosaic 1957	Plants Indexed	Mosaic 1958
	%	No.	%		%	No.	%
4	1.0	399	2.26	1	0.4 R	452	0
11	0.5	445	0.45	2	0.2 R	262	0
12	1.0	420	0.00	5	5.6 R	398	0
15	1.0	509	0.20	7	Trace	2,000*	0.15
17	0.5	692	1.16	9	Trace	10,000*	T
18	0.3	985	1.01	13	Trace	10,000*	T
20	0.5	474	0.21	14	Trace	10,000*	0
23	0.5	549	1.09	19	Trace	282	0
29	0.5	636	0.00	24	0.0	10,000*	T
32	0.7	496	0.20	25	Trace	10,000*	T
33	1.1	424	1.27	26	Trace	1,000*	0.1
				28	0.0	10,000*	0
				31	Trace	481	0.21
				35	Trace	596	0.33

Average mosaic 0.73% in 1958.

Average mosaic less than 0.013% in 1958 seed

Trace in 1957 was less than 0.1%

\*Counts made on field plantings. T=less than 1 mosaic plant in 10,000 count but at least one observed in field—1958. R=Rogued to trace.



Table 5. Statistical technique in indexing lettuce seed for mosaic content\*

Size of sample to be examined	Reject any sample containing the following numbers of mosaic plants	
	Degree of confidence	
	99:1	19:1
3,000	1	2
4,000	2	3
5,000	3	3
6,000	3	4
7,000	3	5
8,000	4	5
9,000	5	6
10,000	6	7
12,000	6	8
14,000	8	10
16,000	10	12
18,000	11	13
20,000	13	15

\*Table adapted from Tucher and Foster (8).

Table 6. Lettuce mosaic field readings 1963.

Field No.	Variety	Percent*
1.	Paris White Cos	0.118
2.	Mild Sucre	0.040
3.	Dark Green Cos	0.038
4.	Valmaine Cos	0.000
5.	Parris Island Cos	0.044
6.	Parris Island Cos	0.000
7.	Late Blonde Romaine	0.000
8.	Iceberg	0.030
9.	Iceberg	0.046
10.	Iceberg	0.012
11.	Iceberg	0.077
12.	Iceberg	0.153
13.	Hanson Head	0.025
14.	Hanson Head	0.064
15.	New York 12	0.050
16.	New York 12	0.337
17.	New York 12	0.204
18.	White Boston	0.214
19.	White Boston	0.102
20.	White Boston	0.013
21.	White Boston	0.044
22.	White Boston	0.004
23.	White Boston	0.055
24.	Mignonette	0.000

\*Percentages were calculated on field counts of 10,000 to 50,000 or more lettuce plants in the fields containing few to no mosaic infected plants.

Table 6 - (Continued)

Field No.	Variety	Percent*
25.	Bibb	0.072
26.	Bibb	0.000
27.	Bibb 41	0.079
28.	Hubbards Market	0.029
29.	Hubbards Market	0.011
30.	Tom Thumb	0.075
31.	Big Boston	0.044
32.	Big Boston	0.086
33.	Big Boston	0.038
34.	Big Boston	3.000
35.	Butter Crunch	0.222
36.	Wayahead	0.036
37.	All Year Round	0.000
38.	All Year Round	0.048
39.	All Year Round	0.000
40.	Oak Leaf	0.038
41.	Oak Leaf	0.237
42.	Oak Leaf	0.040
43.	Oak Leaf	0.055
44.	Black Seeded Market	0.000
45.	Black Seeded Simpson	0.053
46.	Black Seeded Simpson	0.035
47.	Black Seeded Simpson	0.000
48.	Black Seeded Simpson	0.119
49.	Black Seeded Simpson	0.119
50.	Black Seeded Simpson	0.059
51.	Black Seeded Simpson	0.081
52.	Early Curled Simpson	0.086
53.	Early Curled Simpson	0.018
54.	Early Curled Simpson	0.015
55.	Early Curled Simpson	0.000
56.	Prize Head	0.036
57.	Salad Bowl	0.025
58.	Salad Bowl	0.037
59.	Grand Rapids	0.040
60.	Grand Rapids	0.008
61.	Grand Rapids	0.042
62.	Grand Rapids	0.000
63.	Grand Rapids	0.005
64.	May King	0.000
65.	May King	0.017
66.	Ruby	0.025
67.	Spring Glory	0.000
68.	Deep Green	0.000
69.	White Bataviau	0.000
70.	Green Summer	0.000

Average Mosaic per field = 0.094%

\*Percentages were calculated on field counts of 10,000 to 50,000 or more lettuce plants in the fields containing few to no mosaic infected plants.

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