Bulletin No. 386 - Production of Lettuce Seed as Affected by Soil Moisture and Fertility

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Production of Lettuce Seed

as affected by soil moisture and fertility

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UTAH STATE AGRICULTURAL COLLEGE
IN COOPERATION WITH THE
U. S. DEPARTMENT OF AGRICULTURE
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Some Practical Suggestions

A high soil moisture level combined with a good supply of nitrogen fertilizer are conditions favoring a high yield of lettuce seed in northern Utah. Either alone is effective to a measurable extent, but together the effect is often greater.

Although high soil moisture is desirable, too frequent irrigation should be avoided as it is associated with lower yields of seed than when lettuce is irrigated less frequently. Excessive irrigation causes loss of nitrate nitrogen by leaching and reduction in stand by rot.

One of the best ways to determine when to irrigate is to place gypsum blocks at a depth of 12 inches between two normally spaced plants in 4 to 6 scattered locations throughout the field. When a majority of these blocks give a reading of 5,000 ohms or more on an electrical resistance bridge the field should be irrigated. In northern Utah in a summer with little rain about 5 irrigations (or a total of about 12 acre-inches of water) will be required between mid-June and early September. Under other climatic or soil conditions the number of irrigations may be lower or higher depending on how quickly the soil dries out.

If there is a lack of irrigation water, a grower could place blocks at a depth of only 6 inches and irrigate whenever the majority give readings of 40,000 to 50,000 ohms. Under the Utah conditions described above this procedure would normally require about 2 irrigations, and result in a somewhat lower yield than could be expected under high soil moisture conditions.

An application of 40 to 80 pounds of nitrogen per acre (equivalent to 200 to 400 pounds of 20 percent ammonium sulfate), depending on the natural soil fertility, applied in the spring of the seed-producing year, is recommended. While there is no proof that the use of phosphate fertilizer will definitely increase seed yields, it is usually recommended unless the soil is extremely fertile.
Production of Lettuce Seed as Affected by Soil Moisture and Fertility Conditions

by

Leslie R. Hawthorn and Leonard H. Pollard

Introduction

Much of the lettuce seed produced in the United States is grown under irrigation in various western states. Few studies have been made to determine the extent to which yields of seed are influenced by soil moisture and other cultural conditions. Crops have been irrigated mostly on the basis of local practices and the general experience of the grower. Recent studies in Utah (Hawthorn 1951) showed rather conclusively that carrot and onion seed crops grown side by side under the same climatic conditions differ widely in their response to soil moisture. High seed yields were obtained from carrots grown under low soil moisture conditions. In contrast high yields of onion seed were obtained only when the soil moisture level was high. However, even with onions, surprisingly satisfactory yields were recorded under low soil moisture conditions. Such findings suggest that desirable and efficient cultural practices for other vegetable seed crops, including lettuce, can only be determined by field experiment.

Earlier Investigations

Soil moisture studies with lettuce seed crops have not been reported. Veihmeyer and Holland (1949) have worked with market lettuce in the Monterey area of California. There they found that three irrigations spaced about one month apart, or a total of 10 to 14 acre-inches, were sufficient to produce market lettuce during the summer or fall.

The effect of soil moisture on a few vegetable seed crops other than lettuce has been reported. MacGillivray (1948) and MacGillivray and Clemente (1949) working in California reported that high soil moisture was associated in their experiments with high yields of onions and carrots. In Utah, a series of experiments similar to those reported here were conducted with seed crops of both carrots and onions in the years 1947 to 1949, inclusive (Hawthorn 1951). Soil moisture tension was recorded at depths of 6 to 60 inches by determining the electrical resistance in calibrated gypsum (plaster of paris) blocks according to the method originally described by Bouyoucos and Mick (1940), and later improved by the same authors (1947). In these Utah experiments it was observed that low soil moisture was often associated with high carrot seed yields under northern Utah conditions. In contrast, seed yields were usually low when the soil was maintained at a high moisture level.

In the low soil moisture plots, where seed yields were often highest, the soil was allowed to dry out to a per-
manent wilting percentage at a depth of 2 feet before irrigation was applied. In 1951 in a later Utah study the same trend toward high carrot seed yields under low soil moisture conditions occurred again, even though the plants were growing in dense seed-to-seed plantings with rows only 9 inches apart (Hawthorn 1952).

Similar studies with onion (Hawthorn 1951), while showing that high seed yield is always associated with high soil moisture, nevertheless also showed that highly satisfactory seed yields can be obtained even though the onions in the second or seed-producing year are grown under low soil moisture conditions.

The importance of nitrogen in lettuce seed production was indicated as early as 1933 by Claypool (1934). He found high seed yields consistently associated with applications of nitrogen, either alone or in combination with other fertilizer materials. When the nitrogen was applied with phosphoric acid, seed yields were usually higher than when the nitrogen was applied alone.

In 1946 Griffiths, Jones, and Finch stated that lettuce seed yields in Arizona are often increased by a nitrogen side dressing at the time bolting begins. These same investigators reported that lettuce also responds markedly to phosphorus on all soils in Arizona, and they recommended the application of both nutrients to lettuce seed crops. Applications of fertilizer, particularly nitrogen, have been found profitable with other vegetable seed crops. Hawthorn (1952) found that 100 pounds of N (550 pounds of 20 percent ammonium sulfate) applied as a side dressing in the spring resulted in higher seed yields from seed-to-seed carrots, than from similar carrots receiving no nitrogen. Schudel (1952) working with seed crops of cabbage, turnip, mustard, onion, garden beet, spinach, radish, and cucumber, reported that most of them had higher seed yields when nitrogen was applied either alone or with other materials. He concluded that nitrogen “is the key to seed production in Oregon.”

Data on leaf analysis in relation to plant nutrition were presented by McCollum (1952) for a fairly large number of crop plants including lettuce. He suggested the midrib of a mature wrapper leaf as the most satisfactory part of a lettuce plant for such an analysis. He presented figures to indicate that when growing lettuce for market (seed production is not considered) an analysis showing 500 parts per million (ppm) or more of nitrate nitrogen indicates sufficient nitrogen, and when only 200 ppm or less are found, a deficiency exists. With phosphorus, McCollum stated that 1,000 ppm are sufficient, and that 500 ppm or less indicate deficiency.

**Materials and Methods**

In 1952 and 1953, experiments were conducted with a leaf variety, Black Seeded Simpson, sown as early in the spring as weather and soil conditions permitted. In 1954, a crisp-headed, slow-bolting variety, Great Lakes, was used as a seed-to-seed crop, by sowing the seed early in September 1953.

The experiments were conducted in a Sterling fine sandy loam during the first two years, and on a Salt Lake
silty clay loam in 1954. All fields were in the vicinity of Logan, Utah. Sterling fine sandy loam is a well drained lake terrace soil with moderate permeability. At depths of 6 feet or more it is often underlain by gravel. Salt Lake silty clay loam is developed from fine lake sediments, but in the field where the experiment was conducted, the drainage was good. The soil is slowly permeable and underlain by a strongly calcareous clay.

In all years, the yield data were collected from single-row plots 25 feet long. Rows were 30 inches apart. The record rows were bordered on each side by a guard row which received the same fertilizer treatment. Between the moisture plots there were extra guard rows, so that there was a distance of at least 12 feet between a record row at one moisture level and a similar row in an adjacent moisture level.

A field design based on the split-plot technique was used so that the effect of soil moisture and fertilizer applications could be studied both singly and in combination. Three soil moisture levels were split into 6 soil fertility levels in the first 2 years, and into 8 such levels in the third year. There were always 6 replications; thus in 1952 and 1953 there were 108 plots, but in 1954 there were 144 plots.

To obtain soil moisture records, gypsum blocks were placed at a series of depths ranging from 6 to 60 inches below the soil surface in two locations in all moisture plots in the first, third, and fifth replications. Placement at the lowest depth was suggested by the studies of Weaver and Bruner (1927) who determined that the roots of lettuce may penetrate to a depth of six feet by the time the plant is in flower.

Gypsum blocks were used in these experiments because in similar studies with other seed crops (Hawthorn 1951, 1952) they had been found to be a quick, convenient, relatively inexpensive way of determining when to irrigate, as well as a satisfactory means of keeping records on soil moisture tension at a series of predetermined depths. With such a system records can be taken as frequently as one wishes and in a fraction of the time required for determining moisture by soil samples. Certain precautions have to be observed in the use of gypsum blocks for, as indicated by Baver (1956), they can only be used in non-saline soils. When there is more than 0.2 percent salt in the soil, gypsum blocks and the electrical resistance method cannot be used. Taylor (1955) has reported however, that this method has many field uses in connection with irrigation and soil moisture research.

The three soil moisture treatments established were:

1. High. Plots were irrigated in 1952 when the majority of gypsum blocks at the 12-inch depth were beginning to rise above a 1,000-ohm resistance. In 1953 and 1954, irrigation was delayed until the resistance had reached 5,000 ohms.

2. Medium. Plots in this treatment received irrigation water when the majority of gypsum blocks at the 6-inch depth registered resistance above 75,000 ohms. According to Bouyoucos and Mick (1947), such a resistance characterizes the permanent wilting percentage of a fairly large number of widely different soils.

3. Low. Irrigation water was ap-
plied in this treatment when the ma-
jority of gypsum blocks at a depth of
24 inches gave a reading of more than
75,000 ohms. In actual practice no
irrigation water was added to any of
the low moisture plots in any of the
3 years after the soil moisture treat-
ments had been set up.

The soil moisture treatments were
not begun until the lettuce had
reached vegetative maturity. Prior to
that time the lettuce in all treatments
was irrigated alike. In 1952 and 1953
the Black Seeded Simpson lettuce at-
tained vegetative maturity in late
June, and in 1954 the overwintered
crop of Great Lakes was forming
heads in mid-June.

Superimposed on each moisture plot
were the following fertilizer treat-
ments:
1. No fertilizer
2. 215 pounds per acre of P2O5
3. 215 pounds per acre of P2O5
   plus 40 pounds of N
4. 215 pounds per acre of P2O5
   plus 80 pounds of N
5. 215 pounds per acre of P2O5
   plus 160 pounds of N in 1954
   only
6. 40 pounds per acre of N
7. 80 pounds per acre of N
8. 160 pound per acre of N in 1954
   only

The P2O5 (phosphoric acid) was
applied as concentrated superphos-
phate (42 percent) and the N as 20
percent ammonium sulfate. Both
materials were drilled in bands about
2 inches below the soil surface and
as close to the rows of lettuce as was
physically possible. These bands were
to one side of, rather than below, the
corrugation which was made later for
irrigation. The treatments, with one
exception, were made in the spring
prior to the time the lettuce was
blocked out regardless of whether it
had been sown in the spring, or over-
wintered as in 1953-54. The exception
involved the application of 160 pounds
of nitrogen per acre in 1954. To
avoid any possible injury to the young
lettuce from this treatment, half of
the amount was applied on April 3,
and the remainder on June 10, more
than three weeks before the lettuce
began to bolt.

Moisture treatments were random-
ized within blocks, and soil fertility
levels within each moisture plot. The
data were analyzed statistically.

When approximately 50 percent of
the plants showed full "feather" (the
white pappus), they were cut, wind-
rowed, and, when sufficiently cured,
threshed. The actual period of seed
harvest varied with the years as fol-
lows: In 1952, during the last week
of September; in 1953, in the first
week of September; and in 1954 in
the last week of August. The yields
reported in this publication are all
based on the weight of seed harvested
and processed in accordance with
good commercial practice. A sample
for germination test1 was taken from
each experimental lot of seed by the
use of a Boerner sampler.

To determine when and how the
lettuce plants used the nitrogen (N)
and the phosphorus (P) available to
them, and whether the amount present
in the midrib of mature leaves varied
with the moisture and fertility treat-
ments, chemical analyses of the 1953
and 1954 crops were made.1

1 All the germination tests were made by
official methods under the direction of E. H.
Toole, Horticultural Crops Research Branch,
Agricultural Service, United States Depart-
ment of Agriculture, Beltsville, Maryland.
The midrib was chosen for analysis because of the findings of McCollum (1952). However since he was dealing with lettuce harvested in the vegetative stage for market, and in this study the chief concern was seed production; the procedure for collecting samples was somewhat different from his. In the first of these two years, midrib samples were collected soon after bolting began, then about three weeks later, and again just prior to seed harvest. In 1954 samples were collected four times as follows: first at the time when the lettuce was at market maturity and then at the three times approximating those observed in 1953.

Each sample consisted of a collection of healthy, mature midribs located as near the base of the plants as feasible—one from each of approximately 50 plants. The midrib was immediately torn from the leaf blade, and each sample was placed in a drying oven for 36 hours at 70°F. Following this the samples were ground in a Wiley mill to pass a 40-mesh screen, bottled, and stored for chemical analyses. In these the amounts of nitrate-nitrogen and soluble phosphorus were determined. 2

Experimental Results

The change in variety from Black Seeded Simpson grown in 1952 and 1953 to the Great Lakes variety in 1954 apparently had no effect on the general results attributable to soil moisture and fertilizer treatments. Neither did the fact that the Black Seeded Simpson was sown in the spring, while the Great Lakes was grown as an overwintered crop started in the fall of 1953 seem to make any difference to the results obtained.

Irrigations required

The number of irrigations required to maintain each of the three soil moisture levels arbitrarily set up in these experiments is given in table 1. Although the quantity of water applied was never measured, a fairly accurate estimate of the acre-inches taken up by the soil in 1954 was obtained by calibrating the soil-moisture-retention curves against the moisture-tension readings. In the 5 irrigations applied in the high moisture treatment of that year, 10.24 acre-inches of water were retained by the soil, and in the 2 irrigations of the medium soil moisture treatment just over 10 inches were retained. Naturally greater soil moisture deficits occurred between the infrequent irrigations of the medium moisture treatment than occurred between the more frequent irrigations of the high moisture treatment. The lettuce in the low moisture treatment was not irrigated after reaching vegetative maturity in any of the three years. Soil moisture tension in this treatment either never reached 75,000 ohms at a depth of 24 inches—in general equivalent to a permanent wilting percentage—or this resistance was reached such a short time before seed harvest, that no irrigation was given.

The size of stream, the length of run, and the number of hours of irrigation at each application were ap-

2The detailed chemical procedures can be obtained on request from the Utah Agricultural Experiment Station.
Table 1. Modal heights of lettuce* plants and yields of processed seed per acre as influenced by soil-moisture levels, 1952-54

<table>
<thead>
<tr>
<th>Soil-moisture level</th>
<th>Irrigations</th>
<th>Height†</th>
<th>Yield†</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>9</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Medium</td>
<td>2</td>
<td>2</td>
<td>42.3</td>
</tr>
<tr>
<td>Low</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

L. S. D.: 19:1 1.1 1.0 0.9 73 62 41
99:1 1.6 1.4 1.3 104 90 58

*The Black Seeded Simpson variety in 1952 and 1953; the Great Lakes variety in 1954.
†Average of all plots in a given soil-moisture treatment regardless of fertilizer treatment.

Approximately the same every year. More water actually was applied than is indicated by the estimated acre-inches for 1954, because of runoff. It was impossible to avoid having some waste water, but this was always held to a minimum.

Undoubtedly more water was applied in the high soil moisture treatment in 1952 than in either 1953 or 1954, because 9 irrigations were given that year in comparison to only 5 in each of the following two years. Frequent irrigation is not necessarily associated with a large total application of water, as indicated by the figures above for 1954. Where the soil is maintained at a high moisture level, the amount of water taken up at each irrigation is considerably less than is absorbed where irrigation is infrequent.

**Soil moisture records**

In these studies more attention was given to soil moisture tension than to numbers of irrigations and the amount of water applied. It was important to know how dry the soil at various depths in the different treatments actually became. Some typical soil tension curves obtained in this study are presented in fig. 1, in which a log reading of 3.0 is equivalent to a resistance of 1,000 ohms, and 5.0 equivalent to 100,000 ohms. The curves shown are only a few of the many recorded every year.

The higher the resistance in ohms the greater the soil moisture tension and the drier the soil. To absorb water a plant has to exert a greater tension than that of the soil. It is obvious from graph A in fig. 1 that the moisture tension at a depth of 18 inches in the high moisture treatment remained relatively low during the entire season, indicating that the soil never became dry. Even at a depth of only 6 inches, the tension never exceeded a log reading of 4.0 until just prior to harvest. In contrast, in the low moisture treatment (C) the soil moisture tension at a depth of 18 inches gave a reading by the end of season as high as 4.9 for the log of resistance. Such a reading is equivalent to 75,000 ohms, or approximately a permanent wilting percentage. In
the same treatment, moisture tension in the gypsum blocks at a 6-inch depth reached 144,000 ohms, and tension increased to progressively lower degrees as the season advanced at all depths down to and including 60 inches. In the medium moisture treatment (B) intermediate soil moisture conditions prevailed.

In these experiments there was little precipitation during those periods when the various soil moisture conditions were being maintained, and what little there was had no appreciable effect on the soil moisture tension.
able effect on the soil moisture tension. The heaviest rain was 0.45 inches on June 27, 1954. On June 28 soil moisture tension readings in all treatments were higher at the 6-inch depth than they had been on June 26, the day prior to the rain. At lower depths, tension had either increased or remained the same. Although the blocks at the 6-inch depth were unaffected by a precipitation of less than 0.5 inch, the work of Wyn (1954) would indicate such precipitation often is effective. Even though atmospheric humidity is increased by rain and transpiration from the plant is reduced, plants may go on absorbing water from the soil to an extent sufficient to increase the soil moisture tension. However had it not rained, the tension readings might have been higher. The precipitation, even though small, had a certain effectiveness.

Effect of soil moisture

Seed yield. High seed yield was clearly associated with high soil moisture in 1953 and 1954 (table 1). Even in 1952 when the association was not so evident, and the yield was highest under medium soil moisture conditions, the difference was not significant between the high and medium soil moisture treatments. In each of the three years seed yields in the low moisture plots were lower than those in either the medium or the

Fig. 2. Typical lettuce plants of the Black Seeded Simpson variety as affected by soil moisture just prior to harvest, Logan, Utah, 1953; left, plant from plot receiving no irrigation since late June; right, plant from plot receiving five irrigations in same period
Fig. 3. Mass effect of soil moisture on plant growth of Black Seeded Simpson lettuce, Logan, Utah, as seen about 10 days prior to harvest, 1953: upper, only one irrigation since late June; lower, five irrigations during same period. Note how plants fill space between rows in lower picture. Instrument in foreground is one type of electrical bridge used in connection with the gypsum blocks buried in the soil.
high by margins exceeding those required for significance at odds of 99:1.

The seed yield in the high soil moisture plots in 1952 was probably caused by a depletion of nitrogen in the soil. The high frequency of irrigation that year undoubtedly reduced the available nitrogen by excessive leaching. The relation of nitrogen to the 1952 results will become more apparent with the presentation of the yield data and midrib analyses as related to the application of nitrogen fertilizer.

**Plant height.** Plants grown under high soil moisture conditions were tallest in all three years and those grown under conditions of low soil moisture were shortest (table 1). Although no measurements were recorded, the size of inflorescence in terms of numbers of branches and numbers of flowers was in general greatest on the tallest plants and least on the shortest ones (fig. 2). In the wet plots just prior to harvest the inflorescences of adjacent 30-inch rows were often almost touching, while in dry and even some medium moisture plots the space between rows was often great enough to allow a person to walk without brushing against the plants (fig. 3).

**Time of seed maturity and its viability.** The level of soil moisture at which the lettuce was grown had a noticeable effect on the time seed matured and was ready for harvest. During the three years of study, the lettuce grown under low moisture conditions was always ready to harvest 2 to 4 days earlier than lettuce in the medium moisture plots, and this in turn matured 3 to 4 days ahead of that grown in the high moisture plots. Time of maturity and harvest varied considerably in the three years however. In 1952, seed harvesting of Black Seeded Simpson began with the cutting of the seedstalks in the low moisture treatment on September 22 and ended with the crop in the high moisture plots a week later. The same variety was harvested from August 31 to September 5 in 1953, while the overwintered crop of Great Lakes was cut between August 23 and 30 in 1954. In any one year soil moisture conditions did not cause as great differences in time of maturity as were observed between years.

The percentage germination of the harvested seed was affected little if any by soil moisture conditions.

**Effect of nitrogen**

**Seed yield.** The application of nitrogen in the form of ammonium sulfate had nearly as consistent an effect in increasing lettuce seed yield as did the maintenance of a high soil moisture level (table 2). In 1952 and 1954 this effect was distinctly measurable, but in 1953 it was not so apparent.

In 1954, when for the first time an application of 160 pounds per acre of nitrogen was made, there was no further measurable increase in seed yield above that obtained in the plots receiving 80 pounds per acre of nitrogen. Whether an increase in yield might have occurred in 1952, had 160 pounds of nitrogen been applied that year is not known. The evidence for its possible occurrence in 1953 is slim as nitrogen had no clear-cut effect even at lower rates that year.

Nitrogen was clearly the most effective in increasing lettuce seed yields
under high soil moisture conditions, and the least in the plots receiving a minimum of water. This effect will be discussed more fully in the discussion of interrelations on page 15.

**Plant height.** Plant height was increased consistently but not necessarily greatly in the lettuce experiments by applications of nitrogen fertilizer (table 2). The average differences in modal height between plants in the nitrogen treatment having the shortest plants and those in the treatment having the tallest plants were only 1.6, 1.0, and 2.0 inches for 1952, 1953, and 1954, respectively, but differences of as little as 0.6, 0.3, and 0.09 inch in the same three years were all that were required for significance at odds of 99:1. Such differences were not so obvious to the eye as those caused by the different soil moisture levels.

**Time of seed maturity and seed viability.** No measurable differences in time of seed maturity caused by the application of nitrogen fertilizer were recorded. The viability of the seed was also unaffected by nitrogen.

**Effect of phosphorus**

The effects of phosphorus when applied at a rate of 215 pounds per acre of phosphoric acid ($P_2O_5$) were decidedly less noticeable than those from either the different soil moisture levels or the various applications of nitrogen. In each year the trend seemed to be in the direction of slightly higher seed yields where phosphorus had been applied. In no year, however, were the differences between the mean yields of the two treatments (0 and 215 pounds of phosphoric acid) large enough to be statistically valid, although in 1952 the F value obtained in the analyses of variance did approach significance at the 5 percent level.

In all three years the differences, if any, in height of plants grown in plots receiving phosphorus and those without such applications were extremely
small. Even in 1953 when the average difference was valid, it was only 1.1 inches.

No measurable differences in the viability of the harvested seed as a result of the two levels of phosphorus fertility were observed.

**Interrelations**

There were not so many interactions among treatments as might be expected in an experiment of this type. Only in 1952 did the effect of fertilizer on seed yields and plant height vary distinctly with the moisture level. Of the interactions which occurred, only that between moisture level and nitrogen has much practical significance, and even then because of its failure to occur in 1953 and 1954, there is a question of how important it may be through the years. The interrelation of nitrogen and soil moisture level, however, is one that is more likely to occur than some others and thus warrants some attention.

**Moisture x nitrogen.** With each 40-pound increment of nitrogen from 0 to 80 pounds per acre the yield of lettuce was increased, regardless of the moisture level (table 3). The effect however was not the same. The effect was greatest in the high moisture, and least in the low moisture plots. This was true even though seed yields tended to be highest in the medium moisture treatment. The highest seed yields, each attributable to an application of nitrogen at the rate of 80 pounds per acre in the high, medium, and low soil moisture treatments, were 612, 660, and 342 pounds of seed per acre, respectively, and these in turn were 206, 172, and 22 pounds higher than where no nitrogen had been applied.

Further study of the data in table 3 shows that in a similar way the effect of soil moisture was dependent on the nitrogen level. Under high (80 pounds per acre) nitrogen conditions, the difference between the low and medium levels of soil moisture with 342 and 660 pounds of seed per acre, respectively, was 318 pounds. In contrast the difference between the same two moisture levels without the benefit of nitrogen was only 168 pounds.

**Table 3. Acre yield of Black Seeded Simpson lettuce seed as influenced by different levels of both soil moisture and nitrogen fertility, 1952**

<table>
<thead>
<tr>
<th>Nitrogen applied</th>
<th>Yield at indicated moisture level</th>
<th></th>
<th></th>
<th></th>
<th>Average yield†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pounds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>406</td>
<td>488</td>
<td>320</td>
<td>405</td>
</tr>
<tr>
<td>40 pounds</td>
<td></td>
<td>534</td>
<td>560</td>
<td>318</td>
<td>471</td>
</tr>
<tr>
<td>80 pounds</td>
<td></td>
<td>612</td>
<td>660</td>
<td>342</td>
<td>538</td>
</tr>
<tr>
<td>average‡</td>
<td></td>
<td>517</td>
<td>569</td>
<td>327</td>
<td>468</td>
</tr>
</tbody>
</table>

*The standard error for N within each or any moisture level is 16 pounds per acre, and the standard error for any horizontal or diagonal comparison is 35 pounds per acre.

†The standard error to be used in connection with average yields resulting from application of nitrogen is 30 pounds per acre.

‡The standard error to be used in connection with average yields resulting from different soil moisture conditions is 23 pounds per acre.
Midrib analysis as related to seed yield and fertilizer application

As indicated earlier, midrib samples from healthy basal leaves were collected periodically during the seasons of 1953 and 1954, and these were later analyzed for their nitrate nitrogen and phosphorus content. In considering the effect of soil moisture (fig. 4 and 5) it is apparent that the initial parts per million of both nitrogen and phosphorous as determined in 1954 on June 21 when the lettuce was mostly in head, but had not yet started to bolt, were both relatively high in comparison with analyses made in early and late August. The parts per million of nitrogen ranged from 4,400 to 4,700 on June 21, while those for phosphorus ranged from 1,380 to 1,410. These figures were considerably in excess of the parts per million indicated as sufficient for lettuce by McCollum (1952). If fertilizer treatment irrespective of soil moisture level is considered, then so far as the nitrogen was concerned the parts per million on June 21 ranged from 3,800 in midribs from no-nitrogen plots to 5,100 in midribs from lettuce benefiting from the highest application, 160 pounds per acre. Where phosphorus was included in the fertilizer the parts per million of phosphorus on June 21 was 1,510 and where phosphorus was omitted the amount was 1,280. Regardless of the amount on June 21 under any of the conditions just mentioned, the parts per million of both nitrogen and phosphorus were much less just before
harvest and usually differed considerably from each other on the basis of soil moisture levels as well as fertilizer treatment.

**Nitrate nitrogen and seed yield**

From the time of full vegetative maturity (heads formed on June 21) to the time when most of the lettuce was bolting on July 12, 1954, there was comparatively little difference in the nitrate nitrogen content of the midribs as affected by soil moisture, although under all soil moisture conditions the parts per million of nitrate nitrogen increased during this period of three weeks (fig. 4). After July 12 the nitrogen in the midribs was depleted most rapidly under the high soil moisture conditions and the least under low soil moisture. Presumably this nitrogen was being used in the development of the inflorescence and later the seed itself. These results would indicate that under high soil moisture conditions the transfer of

![Graph showing seasonal phosphorus content of lettuce midribs as affected by soil moisture in 1954](image)
nitrogen away from the midribs was occurring more rapidly than under low soil moisture conditions. In no instance did the nitrate nitrogen content drop to the rather low minimum requirements listed by McCollum (1952). However, in his report the vegetative growth rather than the reproductive development of lettuce was under consideration.

It has already been shown (tables 2 and 3) how seed yields in general tended to increase as the application of nitrogen fertilizer was increased. This fact plus the evidence that nitrogen content of the midribs decreased as the seed stalk and inflorescence developed, seems to indicate that nitrogen was used heavily in the seed production processes. Where soil moisture was high, the plant apparently was able to utilize to a greater extent the nitrogen stored in the midribs. The noticeable decrease in the nitrate nitrogen content of the midribs of the lettuce grown under high soil moisture conditions may also indicate that some leaching of nitrogen from the soil was possible, and that the plant was unable to obtain all it could use. It seems unlikely, however, that the nitrogen would have been leached to a depth below the entire root system, a part at least of which was extending to a depth of approximately 5 feet.

When the application of nitrogen fertilizer to the soil is studied in relation to the nitrate nitrogen content of the midribs (fig. 6), it is apparent

![Image](Image)

Fig. 6. Seasonal NO₃-N in lettuce midribs as affected by application of nitrogen fertilizer in 1954
the greater amount of nitrogen applied, the higher the nitrogen content of the midribs at practically all stages of development. Since seed yields did not appreciably increase when nitrogen application was boosted from 80 to 160 pounds per acre in 1954, but the nitrogen content of the midribs did, this may mean that an 80-pound application was sufficient under the conditions of the experiment that year. There is always a possibility that an application between 80 and 160 pounds might have been more effective than the lower of the two amounts of nitrogen in increasing seed yield.

**Phosphorus and seed yield.** It has already been stated that the application of 215 pounds of phosphoric acid per acre in the form of concentrated superphosphate (42 percent) did not appreciably increase seed yields. The difference of 230 parts per million of phosphorus (fig. 7) between the phosphorus content of midribs from lettuce benefiting from the application of phosphoric acid and that of the midribs not so fertilized on June 21, 1954 is statistically valid at odds of 99:1. Likewise at the end of the season just before seed harvest the difference of 190 parts per million of phosphorus,
while somewhat less, was still valid at odds of 19:1. Yet in spite of such differences in phosphorus content, there was no real difference in seed yield from the lettuce grown on soil receiving phosphoric acid and that grown without phosphoric acid in the fertilizer. These results seem to suggest that under the conditions of these experiments the natural supply of phosphoric acid in the soil was adequate for seed production, even though chemical analyses showed that the phosphorus content of the mid-ribs was increased by an application of phosphoric acid in the fertilizer, and later decreased before August 3 to a level considerably below the minimum indicated as sufficient by McCollum (1952).

**Discussion**

The results of studies reported herein suggest several profitable cultural practices in the production of lettuce seed. They also support suggestions made as a result of earlier studies (Hawthorn 1951) as to the use of gypsum blocks as a means to determine when to irrigate.

For highest lettuce seed yields the maintenance of a high soil moisture seems desirable, as does the provision for a generous supply of nitrogen. The full utilization of applications of nitrogen is assured by adequate moisture and also the full benefits of additional soil moisture can be obtained only if the supply of nitrogen is adequate. If these practices are combined, results are likely to be more favorable than when either one is carried out alone.

Excessive soil moisture needs to be avoided. Such a condition may not only reduce seed yields directly through leaching necessary nutrients, especially nitrogen, but indirectly through loss of stand caused by rots, such as sclerotinia watery rot, which tend to increase under high soil moisture conditions. The frequency of irrigation necessary to maintain an excessively moist condition adds to labor costs, as well as water costs, and thus decreases profit. Water not required for lettuce is available for some other crop.

Since seed yields increased in two of three years as the application of nitrogen was increased from none to 40 to 80 pounds per acre (equivalent to none to 200 to 400 pounds of 20 percent ammonium sulfate), but did not noticeably increase with an application as large as 160 pounds in 1954, the use of nitrogen in amounts greater than 80 pounds of N per acre is probably not generally profitable. The most desirable amount to use would depend on the general fertility of the soil and past practices, as well as the potential returns.

The need for additional phosphorus was not clearly indicated by the results of these experiments. However, there was a slight tendency for the yield of lettuce seed to be higher on those plots where phosphorus was applied. A moderate application of superphosphate would thus probably be desirable, unless the soil was known to be extremely fertile or had received liberal applications of phos-
phorus in connection with the previous crop.

The studies again indicated the value of gypsum blocks and an electrical resistance bridge as useful tools to determine when to irrigate. The use of such equipment is only one of a number of methods used in estimating soil moisture. Gypsum blocks have the advantage of being inexpensive, and related directly to soil moisture tension in all soils that contain less than 0.2 percent soluble salts. With such blocks soil moisture tension can be determined rapidly, conveniently, and at any time suitable to the operator. The irrigation interval and amount of water required vary with the soil. If gypsum blocks are used in a soil which dries out quickly, the resistance readings increase rapidly and thus indicate the need for irrigation more frequently than in a soil which dries out slowly. As pointed out in an earlier report (Hawthorn 1951), it is not necessary for a grower to bury blocks at all the various depths from which records were taken in this study. To maintain the high soil moisture indicated as favorable for high lettuce seed production four to six blocks would need to be placed 12 inches below the soil surface between two normally spaced plants in scattered locations throughout the field. When the majority of these gave readings of 5,000 ohms or more, the field would need irrigation.

Records indicated that the period between irrigations may vary from 9 to 17 days, depending upon climatic conditions, age of crop, and possibly other factors. A soil will often look drier than it actually is. The readings of soil moisture tension obtained from the blocks seem to give a more accurate picture of soil moisture conditions and the need for irrigation than is normally possible by general observation. Certainly this method is more accurate than any systematic irrigation at uniform, stated intervals. Soil moisture conditions in any one field, depending on its size, can often be determined in 15 to 20 minutes.

If for some reason such as a shortage of water or of labor, one wished to maintain a moderate rather than a high soil moisture condition, he could bury the blocks at a depth of only 6 inches and then irrigate whenever the majority of readings were 40,000 or 50,000 ohms, depending upon how soon he could arrange for a water turn. While the less frequent irrigations would probably result in a somewhat lower seed yield than could be expected from lettuce grown under high soil moisture conditions, yield reduction would not be as great as if a low soil moisture were maintained. In these studies it has been observed that the resistance usually increases rapidly after reaching 40,000 ohms, so that within a few days it will be much higher. If one waits for the majority of readings to reach 75,000 ohms or more (the limit allowed at the 6-inch depth in the medium treatment of these experiments) the soil may become too dry for desirable seed yields if water cannot be obtained promptly. Under experimental conditions the interval between irrigations of a medium treatment varied from 22 to 39 days.
Summary

Seed crops of Black Seeded Simpson lettuce in 1952 and 1953 and an overwintered crop of Great Lakes lettuce in 1953-54 were grown in a series of experiments designed to determine the effect of soil moisture and fertility on plant growth, time of maturity, yield, and viability of seed. In 1953 and 1954 lettuce midribs were analyzed to determine the relation of the parts per million of both nitrate nitrogen and phosphorus found therein to the moisture and fertility treatments under which the lettuce was grown. In all years a field design based on the split-plot technique was used so that the effect of the various treatments could be studied both separately and in combination. Soil-moisture treatments were based on pre-established arbitrary soil moisture tensions, and in addition records of soil-moisture tension were maintained from depths ranging from 6 to 60 inches below the soil surface by means of gypsum blocks and the use of an electrical moisture bridge.

Soil moisture tension increased during the growing season at all depths in the low moisture treatment, with the tension being the greatest at 6 inches and the least at 60 inches.

High soil moisture was definitely associated with high seed yield in two of three years, but in 1952 frequency of irrigation (9 irrigations) in the high moisture treatment apparently was excessive and resulted in a seed yield statistically no different from that obtained in the medium moisture treatment with only 2 irrigations.

Low soil moisture was always associated with low seed yields.

The tallest and shortest plants were distinctly associated in all three years with high and low soil moisture, respectively.

Without exception during the three years, lettuce grown under low moisture conditions matured first, and that grown in the high moisture plots matured last. The number of days between the seed harvest of low and medium, and between medium and high moisture treatments ranged from 2 to 4 days depending upon the year.

Viability of seed was unaffected by the soil moisture level under which the lettuce was grown.

In 1952 and 1954 seed yields increased as the applications of nitrogen as ammonium sulfate were stepped up from 0 to 40 to 80 pounds per acre, but did not noticeably respond any further to an application of 160 pounds in 1954. In 1953 there was also a tendency for seed yield to increase with additional nitrogen, but the effect was not clear cut.

Although differences in plant height attributable to nitrogen were small, they were measurably consistent. The tallest plants were associated with the greatest applications of nitrogen and the shortest with the treatment to which no nitrogen was applied.

The amount of nitrogen fertilizer applied to the soil had no effect on either time of seed maturity or its viability.

Phosphorus had no measurable effect on seed yield, time of maturity, plant height, or viability of seed, although there was a slight tendency for seed yields to be higher from the plots receiving phosphoric acid.

Only in 1952 were there any inter-
actions between soil moisture and fertilizer so far as seed yield and plant height are concerned. That between soil moisture and nitrogen was the most important. Nitrogen was the most effective in increasing seed yields with high soil moisture and least with low soil moisture.

Both the nitrate nitrogen and phosphorus content of the midribs of healthy basal leaves progressively decreased as the seedstalk and seed developed.

As seedstalks developed, nitrate nitrogen content of the midribs decreased most rapidly under high soil moisture conditions and least rapidly under low moisture conditions.

Although the nitrate nitrogen and phosphorus content of lettuce midribs decreased as seedstalks developed in all plots, the midribs of lettuce grown on plots which had received the largest amounts of nitrogen and phosphate fertilizer with one exception always had the most parts per million of nitrate nitrogen and phosphorus at all times of sampling. Lettuce grown on plots receiving no nitrogen or phosphoric acid always had the least.

**Literature Cited**


