The Effect of Fertilizers and Osmotic Pressure on Germination

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Some of the more important factors that affect germination of seed are temperature, moisture, aeration, and alkalinity. Dissolved salts, whether derived from natural sources as in saline soils or from fertilizers, impair the availability of water to plants by increasing the osmotic effect of the soil solution. The extent of the germination impairment by fertilizers depends on the solubility of the fertilizer and the concentration of the salt solution. In the work reported herein, the germination of sugar beets was studied under various moisture and fertilizer treatments in the greenhouse. In addition, sugar beets seeds were germinated in a germination cabinet in iso-osmotic concentrations of ammonium nitrate and mannitol solutions to determine if nitrogen was detrimental to germination.

Literature Review

Numerous workers (2, 6, 11) have reported on the effect of moisture, while others (1, 5, 8) have studied the effect of fertilizers, on germination. Snyder (10) found that the emergence of sugar beet seedlings was decreased when soil moisture levels were low and when fertilizer was banded with the seed. Hunter and Erickson (7) showed that, in order to germinate, sugar beet seeds had to obtain a minimum moisture content of 31.0 percent, and that the soil moisture tension should not exceed 3.5 atmospheres. Stout and Tolman (12) reported that ammonia released from nitrogenous compounds of seed hull extracts by enzymatic hydrolysis inhibited the germination of sugar beets.

Procedure

The soil used in the greenhouse experiment had received neither manure nor fertilizer during the previous 15 years. The field capacity and permanent wilting point of this loam soil were found to be at moisture percentages of 22.4 and 8.2, respectively. Soils were then prepared at the following three moisture levels:

1. Soil at one-quarter of the available moisture (P = 11.75)
2. Soil at one-half of the available moisture (P = 15.30)
3. Soil at three-quarters of the available moisture (P = 18.85)

1 Agronomist, Experimental Farm, Canada Department of Agriculture, Lethbridge, Alberta.
2 Numbers in parentheses refer to literature cited.
The following five fertilizer treatments were used: 1.) Check—no fertilizer. 2.) 50 lbs. per acre P₂O₅. 3.) 50 lbs. per acre P₂O₅ plus 25 lbs. per acre N. 4.) 50 lbs. per acre P₂O₅ plus 50 lbs. per acre N. 5.) Mannitol at molarity equal to treatment 3.

The sources of fertilizer were triple superphosphate (0-46-0) and ammonium nitrate (33.5-0-0). Treatment five was calculated on the assumption that the 0-46-0 fertilizer had a molecular weight of 260 since it is made up primarily of mono-calcium phosphate (M.W. = 252.09). The fertilizer requirements were calculated for 22-inch spacings, although the rows in the experiment were only two inches apart.

The experiment was carried out in quadruplicate in enamelled developing trays. Each tray represented a moisture treatment with the five fertilizer treatments randomized within it. A two-inch layer of prepared soil was placed in each tray. The fertilizers were then spread uniformly in rows, and the seed was placed on top of the fertilizer at 3/4-inch centers within the rows. Approximately one inch of soil was placed over the seed. The trays were then covered with plastic (2 mill polythene) and sealed with adhesive tape to prevent evaporation. The temperature in the greenhouse was kept relatively constant at 70° F.

Germination counts were taken as warranted during a 15-day period. The trays were uncovered, counts were taken, the emerged seedlings removed, and the trays resealed. At the end of the 15-day period all seeds that had healthy radicles of 5 mm. or longer were considered germinated.

In the germination cabinet study iso-osmotic solutions of ammonium nitrate and mannitol were prepared, ranging from 2 to 10 atmospheres, at 2-atmosphere intervals. International Critical Tables were used to obtain freezing point depressions for the different molal concentrations. Osmotic pressures were then calculated directly, using the formula O.P. = 12.06 Δ, where O.P. is osmotic pressure and Δ is the freezing point depression. By converting molal to molar concentrations from the density data of the International Critical Tables, and plotting concentration versus osmotic pressure on a graph, the preparation of solutions was greatly facilitated as direct volumetric dilution was then possible.

Germination studies were carried out on washed sand in small sub-irrigated petri dishes as described by Rayment (9). Each dish had a glass tube drain fused to the bottom. Six-ounce dispensing bottles were used as reservoirs for the solutions. The
dishes and bottles were assembled with rubber stoppers as illustrated in Figure 1. A glass tube leading from each bottle through the stopper to the outside provided for irrigation by expiration. Twenty-five seeds were used in each petri dish. The assembled dishes in four replicates, were placed in a germinating cabinet in which the temperature was kept constant at 20° C. The dishes were irrigated twice daily for seven days, at the end of which time the germination counts were taken.

The variety of sugar beets used throughout the tests was decorticated Kuhn.

Figure 1.—Apparatus used for germination in sand substrate with solutions of varying osmotic pressures. The petri dish contains the sand, the dispensing bottle the solution, and the glass side-arm permitted sub-irrigation of the sand with the solution. Lethbridge, Alberta. 1957.
The statistical calculation was made on angular transformations of the percentage data. The inverse-sine transformations of Fisher and Yates (4) were used. The percentage values of 0 were arbitrarily replaced by \( \frac{1}{4}n \), where "\( n \)" is number of replicates. When a percentage value of 0 occurred repeatedly under a given treatment, that portion of the data was withdrawn from the statistical analysis.

### Table 1.—Mean Percentage Germination and Significant Differences\(^1\) Between Treatment Means of Sugar Beets, at Three Soil Moisture Levels, Lethbridge, Alberta, 1957.

<table>
<thead>
<tr>
<th>Moisture Level (Pw)</th>
<th>Fertilizer Treatment (Pounds per Acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 P(_2)O(_5) + 50 N</td>
<td>246 Mannitol 25 N 50 P(_2)O(_5) Check</td>
</tr>
<tr>
<td>18.85 17 31 42 81 82</td>
<td></td>
</tr>
<tr>
<td>50 P(_2)O(_5) + 50 N</td>
<td>246 Mannitol Check 50 P(_2)O(_5)</td>
</tr>
<tr>
<td>15.30 2 11 12 76 88</td>
<td></td>
</tr>
<tr>
<td>50 P(_2)O(_5) + 50 N</td>
<td>246 Mannitol 50 P(_2)O(_5) Check</td>
</tr>
<tr>
<td>11.75 0 0 4 48 78</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Any two means underscored by the same line are not significantly different at the 1% level.

### Table 2.—Mean Percentage Germination of Sugar Beets at Various Osmotic Pressure Levels and Significant Differences\(^1\) Between Them, Lethbridge, Alberta, 1957.

<table>
<thead>
<tr>
<th>Osmotic Pressure Levels in Atmospheres</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 8 6 2 4</td>
</tr>
<tr>
<td>14 42 70 84 85</td>
</tr>
</tbody>
</table>

\(^1\) Any two means underscored by the same line are not significantly different at the 1% level.
Figure 2.—Germination of sugar beets. Lethbridge, Alberta, 1957.

Results and Discussion

Figure 2 shows the germination under the various fertilizer and moisture treatments in the greenhouse. Table 1 shows the mean percentages of germination for the comparable treatments, and the significant differences between them as determined by Duncan's (3) new multiple range test.

Table 2 shows the mean percentages of germination at the different osmotic pressures and the statistical significance between them, and corresponding information for the treatment × level interaction appears in Table 3. The average lengths of primary roots of the germinated seedlings are shown in Table 4.

From Table 1 it can be seen that the germination of sugar beets was significantly higher on the check than on the other treatments at the lowest moisture level. At the highest moisture level, germination on the 50 lbs. P₂O₅ treatment was significantly higher than on the mannitol and the two nitrogen treatments. However, there was no significant difference in germination be-
Table 3.—Mean Percentage Germination of Sugar Beets at Various Treatments x Levels and Significant Differences* Between Them, Lethbridge, Alberta. 1957.

<table>
<thead>
<tr>
<th>Treatments x Levels</th>
<th>Ammonium nitrate</th>
<th>Mannitol</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 atmospheres</td>
<td>25</td>
<td>37</td>
</tr>
<tr>
<td>8 atmospheres</td>
<td>46</td>
<td>69</td>
</tr>
<tr>
<td>6 atmospheres</td>
<td>72</td>
<td>82</td>
</tr>
<tr>
<td>4 atmospheres</td>
<td>-</td>
<td>85</td>
</tr>
<tr>
<td>2 atmospheres</td>
<td>-</td>
<td>85</td>
</tr>
</tbody>
</table>

* Any two means underscored by the same line are not significantly different at the 1% level.

Table 4.—Length, in Millimetres, of Primary Roots of Sugar Beet Seedling Germinated in Solutions of Various Osmotic Pressures, Lethbridge, Alberta. 1957.

<table>
<thead>
<tr>
<th>Osmotic Pressure in Atmospheres</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium nitrate</td>
<td>18</td>
<td>18</td>
<td>13</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Mannitol</td>
<td>35</td>
<td>35</td>
<td>18</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

Between the latter three treatments. Germination on the 50 lbs. P₂O₅ treatment was significantly higher than on the check at 15.30 percent soil moisture level.

When no fertilizer was used, the germination of sugar beets was relatively unaffected by the soil moisture levels used in this experiment. If half or more of the available soil moisture is in the soil, 50 pounds of P₂O₅ could be used safely for sugar beets. Even with one-quarter of the available moisture in the soil, approximately half of the seeds germinated on the phosphorus treatment. Since field-grown sugar beets are thinned to one plant per foot within the row, such a reduction is not necessarily serious. The practice in southern Alberta of applying 100 pounds of 11-48-0 fertilizer with the seed at planting time is fairly sound. Fertilizers that are more soluble than 11-48-0, such as 16-20-0, could seriously retard the germination of sugar beets, especially if the rate of application were more than 100 pounds per acre.

Studies in the germination cabinet showed that the germination of sugar beets was unaffected by osmotic pressures of up to
4 atmospheres (Table 2). A non-significant reduction was observed at 6 atmospheres. At osmotic pressures over 6 atmospheres, the germination was significantly reduced. The critical tolerance for sugar beets of osmotic pressure, soil moisture tension, or total soil moisture stress would thus appear to be somewhere between 6 and 8 atmospheres.

Table 3 shows that at osmotic pressures of 2, 4, and 6 atmospheres there were no significant differences in the percentages of germination between an organic and an inorganic solution. As the osmotic pressure was increased, germination was lower in the inorganic solution until at 10 atmospheres it was significantly lower than in the organic solution. It would appear that, as the moisture becomes less available to sugar beet seeds, germination is retarded by either the nitrate or ammonium ions or both.

From Table 4 it is evident that the primary roots of the germinated seedlings were longer in the mannitol solutions than in the ammonium nitrate solutions and that the length of the roots decreased with increasing solution concentrations.

Summary

Germination results of sugar beets at three soil moisture levels and under five fertilizer treatments, along with the results of germination at iso-osmotic concentrations of mannitol and ammonium nitrate solutions, are reported.

When no fertilizer was used, germination was relatively unaffected by the soil moisture levels. With 50 lbs. per acre P₂O₅, a significant reduction in germination resulted only at the lowest moisture level (Pw = 11.75).

There was no significant difference in germination between the 50 lbs. P₂O₅ plus 25 lbs. N treatment and the mannitol treatment at any of the moisture levels.

At all three moisture levels, germination was significantly lowered with either 25 pounds or 50 pounds of nitrogen when applied in addition to the 50 pounds of P₂O₅. The highly soluble fertilizer, ammonium nitrate, should not be placed in close contact with beet seeds when soil moisture is limited.

Germination of sugar beets was significantly lowered in solutions whose osmotic pressures exceeded 6 atmospheres.

With increasing osmotic pressures at iso-osmotic concentrations, germination of sugar beets was lower in ammonium nitrate solutions than in mannitol solutions, suggesting toxicity of the nitrate or ammonium ions.
Literature Cited


(5) Gaywala, P. M. 1933. The effect of the contact of chemical fertilizers with seeds on their germination. Agr. and Livestock in India 3:256-263.


(9) Rayment, Alfred Frederick. 1956. The tolerance of various forage crops to salinity with special reference to seed germination. A thesis presented to the School of Graduate Studies of the University of Alberta for the M.Sc. degree.

