Physical Factors Affecting Carrot Root Growth: Water Saturation of Soil

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Abstract. Effects of water saturation of the soil on early root growth of carrot (Daucus carota L.) were studied using specially designed pots containing organic soil. Water saturated soil conditions were created by raising the water table to envelop actively growing carrot root tips on the 6th day after planting pre-germinated seed. Water saturation was maintained for intervals of 12 hours to 7 days. Sixteen days after seeding (DAS), taproots subjected to as little as a 12 hour period of water saturated soil at 6 DAS were significantly shorter and exhibited more discolored root tips and forked roots than roots growing under normal moisture conditions. After 78 days of growth, the roots subjected to water saturated soil at 6 DAS were significantly shorter, weighed less, and were smaller in diameter than controls. The height of the carrot tops was not affected by treatments.

Materials and Methods

Carrots were grown in specially constructed pots made of 10.2 cm inside diameter polyvinyl chloride pipe as previously described (10). Sections of pipe 38 cm long were cut longitudinally into halves and rejoined with weatherproof tape. To facilitate removal of the soil and roots, the tape was removed, pots were split apart for examination, and roots were washed free of soil with a fine stream of water under moderate pressure. Little is known about the effects of short or temporary periods of excess soil moisture on the growth and development of carrot roots, and reported effects of excess moisture on carrot root development are mostly a result of "field observations and impressions" (9).

As a part of an in-depth study of physical and biological factors affecting carrot root configuration and disorders, we conducted several experiments to detect and quantify the effects of temporary periods of excess soil moisture upon early stages of carrot root growth.

Plants vary in their tolerance to high or excess soil moisture (3, 6, 7, 8, 11, 12, 13). Their response depends upon inherent plant characteristics (5, 12) and is also related to physical properties of the soil (4, 11, 13). Temperature also affects the tolerance of crops to high soil moisture (2, 7, 8). Barnes (1) found little difference in carrot root shape when grown under continuous conditions of high and medium soil moisture, but found significant differences in root weight and top length. Little is known about the effects of short or temporary periods of excess soil moisture on the growth and development of carrot roots, and reported effects of excess moisture on carrot root development are mostly a result of "field observations and impressions" (9).

Results

The average length of carrot taproots measured at 16 DAS was significantly reduced following exposure to water saturated soil for periods of 1 to 7 days. Root lengths after a 2-day exposure were significantly shorter than for 1-day exposure.

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but there was no significant differences in root length after 2 to 7 days exposure (Fig. 1). Over 46% of the root tips exposed for 1 day to water saturated soil were discolored and 43% were forked or branched (Fig. 2). Discoloration and forking increased significantly after 2 days exposure and nearly all roots were forked when a water saturated soil condition was maintained over 4 days.

In another experiment, employing short treatment intervals of water saturated soil, results were similar and the average total length of 16 DAS carrot taproots was significantly decreased after an exposure to as little as 0.5 day of water saturated soil (Fig. 3).

In controlled environment studies, early growth of the taproot was significantly reduced by exposure to water saturated soil for 1 to 3 days or to high temperature during the period of water saturation (Table 1). Root length decreased with increasing temperature over the range of 16-28°C during the period of exposure to the water saturated soil. Root length decreased as time of exposure to water saturated soil increased at all temperatures employed.

Both length and average weight of carrot roots at 78 DAS were significantly reduced when a water saturated soil condition was maintained for 0.5 day or longer at 6 DAS (Fig. 4). The top heights at 78 DAS were not significantly affected by treatments, although they ranged from 19.0 cm to 25.2 cm. The top diameter of the carrot root taken 2 cm from the shoulder was significantly smaller for the 1-day treatment. There were no significant effects of the other treatments. The lower diameter taken 10 cm from the shoulder decreased with increase in time of exposure to water saturated soil, the 8-day treatment being the only exception to this trend.

Discussion

Rates of early carrot taproot growth in organic soil can be severely affected by short periods (as short as 12-hr) of exposure to a water saturated soil environment. Exposure to water saturated soil conditions induced branching or forking and discoloration of root tips. Effects on length, forking, and discoloration increased with time of exposure. In repeating experiments, the growth response varied, although general trends remained essentially the same. These variances were attributed to difference in ambient greenhouse temperature during the experiments. Under controlled environmental conditions inhibition of growth due to water saturated soil increased with soil temperature over the range of 16-28°C (Table 1). Statistical analysis indicated a highly significant effect of time, temperature, and their interaction. Time of exposure was more important than temperature over the range studied. A previous study had shown that this range encompasses optimum growth temperature for early carrot root growth (10).

Growth inhibition and damage evident at 16 DAS reduced the size of mature roots, but not top growth at 78 DAS. Barnes
Table 1. Effects of various temperature and time of exposure to water saturated soil on carrot taproot length 16 days after seeding.

<table>
<thead>
<tr>
<th>Root length (cm)</th>
<th>Temperature</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16°C</td>
<td>20°C</td>
</tr>
<tr>
<td>0</td>
<td>38.6 d</td>
<td>37.0 d</td>
</tr>
<tr>
<td>1</td>
<td>15.5 d</td>
<td>a</td>
</tr>
<tr>
<td>2</td>
<td>15.9 d</td>
<td>b</td>
</tr>
<tr>
<td>3</td>
<td>20.1 d</td>
<td>c</td>
</tr>
<tr>
<td>Mean</td>
<td>22.5 d</td>
<td>22.0 d</td>
</tr>
</tbody>
</table>

F value (time) = 226.5**
F value (temperature) = 16.7**
F value (interaction) = 3.6**

*Water level raised 19 cm from the base of 38 cm pots on the 6th day after seeding and maintained for the indicated period.

**Mean separation in columns (abc) and rows (def) by Duncan’s multiple range test, 5% level.

(1) reported similar effects on roots after growing carrots in continuously high soil moisture. Generally, root damage in excess soil moisture environments has been attributed to lack of oxygen (13) and increased damage at high temperature. Our results support these conclusions since higher temperature could promote oxygen depletion by soil organisms.

The production of large numbers of forked roots and damaged root tips in some, but not all, experiments indicates that additional but undetermined factors may affect root tip damage. Oxygen levels could be one such factor. Carrot root shape is difficult to study in an artificial system such as the one employed. However, the short but otherwise normal conformation of roots grown to maturity (78 DAS) indicates that root growth can be depressed by water saturated soil during early growth but growth continues if root tips are not damaged. Alternatively, roots exhibiting discolored tips or branched taproots during early growth always develop into forked or branched roots (10, and unpublished data).

Our results explain some of the cases and occurrences of carrot root disorders which result in culls due to either branching, forking, or abnormally short roots. Growers have often observed that excess soil moisture, and high water table resulting from flooded fields due to rain or excessive irrigation can be detrimental to carrot root quality. Our study validates these grower observations.

Literature Cited


Fig. 4. Effects of time of exposure to varying periods of water saturation of soil initiated on the 6th day after seeding on taproot length and root weight of 78-day old carrots.