Nitrate Versus Chloride Nutrition Effects in a Soil-Plant System on the Growth, Nitrate Accumulation and N, K, Na, Ca and Cl Content of Carrot *Daucus carota* L.

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Abstract: The experiment was conducted to evaluate the effects of various NO₃/Cl percentages on growth, nitrate accumulation and mineral absorption in carrot *Daucus carota* L. plants in a controlled environment. The experiment included two Cl sources (KCl and CaCl₂) and five NO₃/Cl percentages at 100/0, 90/10, 80/20, 70/30, and 60/40 with total-N concentration of 400 mg NO₃/kg soil in 100/0 treatment. The fresh and dry weights of shoots and storage roots, and the length and diameter of storage roots increased significantly more with mixed NO₃/Cl treatments and Cl sources than with single NO₃ (100/0) treatment. Growth was enhanced up to the 80/20 NO₃/Cl treatments. With Cl present in the treatments, the concentration of total-N unchanged and NO₃ decreased, and Cl and K increased both of the Cl sources. In KCl treatments, Na absorption decreased calcium content significantly differed among the treatments. It was concluded that nitrogen fertilization provided with combined Cl forms and NO₃/Cl percentages can enhance the quality of carrots and at the same time decrease the N fertilizer input rate.

Key Words: Nitrate, Nitrate accumulation, Chloride, Carrot, *Daucus carota* L.
Introduction

Competitive effects in uptake between Cl and NO$_3^-$ are well documented in the literature (1,3). In practical terms this may affect crop quality. Muraka et al. (4) showed that application of Cl to potatoes decreased both total-N and NO$_3^-$-N in the tops although protein-N was not affected. Chloride has a number of nonspecific functions in the plant. It raises the cell osmotic pressure and as a result of the hydrophilic nature of the ion increases the hydration of plant tissues. Increases in grain yield in response to applications of Cl have been reported by several authors (5-7). According to Bergman (8), chloride ions do not form constituents of organic substance, but act only in ionic form and like nitrate and alkaline ions, they affect plasma volume, and this enables them also to influence enzyme reactions, although not specifically. As already pointed out by Schmalfuss in the 1930s, Cl ions can replace nitrate ions in their colloid-chemical functions and are supposed in this way to have a positive effect on the nitrogen household of plants by helping to prevent excessive nitrate concentrations (8). Chloride can partly replace NO$_3^-$ as an osmoticum (9,10). Increasing the concentration of chloride in the nutrient medium can depress NO$_3^-$ uptake by the competition between these two ions (11-13).

Nitrogenous fertilizers, mainly of the NO$_3^-$ variety, are used widely in vegetable agriculture, resulting in an accumulation of NO$_3^-$ in the plants if the uptake exceeds the reduction to ammonium (14). Nitrate accumulation in edible plant tissues is recognised as undesirable for human health (15). When nitrate-rich vegetables are consumed by certain individuals, NO$_3^-$ may be formed from NO$_2^-$ after ingestion, causing metheamoglobinemia (16). The presence of nitrate in the blood might also result in the formations of nitrosamines which are believed to be carcinogenic (17). Nitrate accumulation in plants is governed by several factors: morphological and genetical characteristics of the plants, amount and source of N supplied to the plants, photoperiod, temperature, competitive ions etc. (15). Of these factors, the amount and source of N and competitive ions that are absorbed as osmolyte can easily be controlled by growers.

The aim of this study was to evaluate whether the replacement of NO$_3^-$ with Cl in a soil-plant system would depress NO$_3^-$ accumulation in carrot Daucus carota L. plants. A further goal was to establish optimal N application rates that would promote maximal yield of good quality but avoid toxic accumulatin of NO$_3^-$.

Material and Methods

The soil used in the experiment was clay in texture consisting of 43.78 % clay, 39.08% silt, and 17.4% sand, 12.48% CaCO$_3$, and with a pH (1:2.5 H$_2$O extract) of 7.61, 0.56 mmhos/cm electrical conductivity (EC), 17 mg/kg available P, and 1700 mg/kg exchangeable K, 0.15% total-
N, and 1.5% organic matter. Kick-Brauckman pots were filled with 8 kg air dry soil. The experiment was carried out between October 1996 and February 1997 in a controlled experiment glasshouse at Ankara University. Carrot Daucus carota L. seeds were sown at a rate of 20 seeds per pot. After a good standing in November they were thinned to four plants per pot. At this stage of growth, treatment was initiated. Two Cl sources (KCl and CaCl₂) and five NO₃/Cl percentage ratios (100/0, 90/10, 80/20, 70/30, and 60/40) were checked in a 5 x 2 factorial experiment in four replicates. The nitrate source was Ca(NO₃)₂ supplying 400 mg NO₃/kg soil in the 100/0 treatment. Phosphorus (H₃PO₄) was added at a rate of 100 mg/kg to each pot as basal fertilization. Shoot and storage root fresh weight and the length and diameter of storage root were measured at harvest. Then shoot and storage root were washed and dried at 70 °C in order to determine the dry weights and were subsequently ground for NO₃, total-N, Cl, Na, K, and Ca determinations.

Nitrate was determined as described by Cataldo et al. (18), total-N by kjeldahl digestion according to the method of Bremner (19), and Cl, Na, K, and Ca by the methods described by Johnson and Ulrich (20). The yield and chemical data were analysed statistically with ANOVA and treatment means were compared with the LSD test (p<0.05).

**Results**

Partial replacement of NO₃ by Cl enhanced the shoot fresh and dry weights (p<0.01) compared with single NO₃ treatment (Table 1). Calcium chloride as a Cl source seemed to be more effective on shoot fresh and dry weights than KCl. The highest fresh and dry weights were obtained with a 80/20 ratio.

A similar effect of NO₃ replacement with Cl was also seen in length and diameter, and fresh and dry weights of storage root (Table 2). However, no statistically significant changes occurred after 80/20 NO₃/Cl replacement. Each increment in Cl applied created a slight increase in these parameters especially in CaCl₂ treatments. Substitution of NO₃ by either Cl, KCl or CaCl₂ was found not to affect the length, diameter, or the fresh or dry weights of storage root.

<table>
<thead>
<tr>
<th>NO₃/Cl (%)</th>
<th>PW FW (g)</th>
<th>CaCl₂ Average</th>
<th>DW FW (g)</th>
<th>CaCl₂ Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>100/0</td>
<td>20.92</td>
<td>22.07</td>
<td>21.50b</td>
<td>2.95</td>
</tr>
<tr>
<td>90/10</td>
<td>26.29</td>
<td>26.90</td>
<td>26.60 ab</td>
<td>3.88</td>
</tr>
<tr>
<td>80/20</td>
<td>29.74</td>
<td>35.73</td>
<td>32.74 a</td>
<td>4.42</td>
</tr>
<tr>
<td>70/30</td>
<td>29.39</td>
<td>33.08</td>
<td>31.24 a</td>
<td>4.29</td>
</tr>
<tr>
<td>60/40</td>
<td>28.07</td>
<td>33.90</td>
<td>30.99 a</td>
<td>4.17</td>
</tr>
<tr>
<td>LSD 5%</td>
<td>7.95</td>
<td></td>
<td>1.14</td>
<td></td>
</tr>
</tbody>
</table>

CI source NS NS
NO₃/Cl rates ** **
Interaction NS NS
NS: non significant, ** P<0.01

Table 1. Fresh (FW) and dry (DW) weights (g) of shoot as affected by NO₃ versus Cl nutrition. Values followed by different letters are significantly different at P< 0.05, n= 4.
Although there was a slight decrease, the nitrogen content of shoot and storage root was unaffected by either NO₃ replacement or the Cl source (p > 0.05) (Table 3). But the NO₃ content of plant parts (shoot and storage root) was influenced by NO₃ replacement the Cl source interactively and individually.

Shoot NO₃ content decreased with increasing Cl to NO₃ ratio and by Cl source from 12353 mg/kg to 4570 mg/kg without causing any significant decreases or changes in yield or N content. Storage root NO₃ content was also decreased by NO₃ replacement compared with single NO₃ (100/0) treatment from 5323 mg/kg to 3509 mg/kg, but Cl treatment, with CaCl₂ increased the NO₃ content of storage root compared with KCl.

A perusal of Table 4 indicates that because there is an antagonistic effect between Na and K, all NO₃/Cl mixtures decreased the Na absorption of shoot and storage root when KCl was used as Cl source, while it was increased in CaCl₂ treatments. The sodium content of the shoot and storage root was found to be higher in CaCl₂ treatments, and the Na content of storage root was decreased by NO₃ replacement with Cl source. Shoot K content increased by the Cl source and NO₃ replacement by Cl. Storage root K content was affected only by the Cl source and KCl was found to be more effective.

### Table 2.

<table>
<thead>
<tr>
<th>NO₃/Cl (%)</th>
<th>FW (g)</th>
<th>DW (g)</th>
<th>L (cm)</th>
<th>D (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>KCl</td>
<td>CaCl₂</td>
<td>Average</td>
<td>KCl</td>
</tr>
<tr>
<td>100/0</td>
<td>44.31</td>
<td>54.06</td>
<td>49.19 a</td>
<td>4.45</td>
</tr>
<tr>
<td>90/10</td>
<td>103.53</td>
<td>78.47</td>
<td>91.00 ab</td>
<td>11.79</td>
</tr>
<tr>
<td>80/20</td>
<td>118.15</td>
<td>118.02</td>
<td>118.09 a</td>
<td>12.85</td>
</tr>
<tr>
<td>70/30</td>
<td>119.56</td>
<td>115.39</td>
<td>117.48 a</td>
<td>12.37</td>
</tr>
<tr>
<td>60/40</td>
<td>98.17</td>
<td>128.70</td>
<td>113.43 a</td>
<td>12.15</td>
</tr>
<tr>
<td>LSD 5%</td>
<td>44.22</td>
<td>5.14</td>
<td>1.87</td>
<td></td>
</tr>
</tbody>
</table>

CI source NS NS NS NS

NO₃/Cl rates ** ** **

Interaction NS NS NS NS

NS: Non significant, ** P<0.01

### Table 3.

<table>
<thead>
<tr>
<th>NO₃/Cl (%)</th>
<th>N (%)</th>
<th>NO₃ (mg/kg)</th>
<th>N (%)</th>
<th>NO₃ (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>KCl</td>
<td>CaCl₂</td>
<td>KCl</td>
<td>CaCl₂</td>
</tr>
<tr>
<td>100/0</td>
<td>3.67</td>
<td>3.78</td>
<td>12230 a</td>
<td>12353 a</td>
</tr>
<tr>
<td>90/10</td>
<td>3.67</td>
<td>3.50</td>
<td>7650 ct</td>
<td>10953 ab</td>
</tr>
<tr>
<td>80/20</td>
<td>3.35</td>
<td>3.45</td>
<td>6454 de</td>
<td>9500 bc</td>
</tr>
<tr>
<td>70/30</td>
<td>3.37</td>
<td>3.61</td>
<td>60.13 de</td>
<td>7683 ct</td>
</tr>
<tr>
<td>60/40</td>
<td>3.19</td>
<td>3.63</td>
<td>6762 de</td>
<td>4570 e</td>
</tr>
<tr>
<td>Average</td>
<td>3666</td>
<td>4870</td>
<td></td>
<td>1630</td>
</tr>
</tbody>
</table>

CI source NS NS NS NS

NO₃/Cl NS NS NS NS

Interaction NS NS NS NS

NS: Non significant, ** P<0.01, * P<0.05
The Cl content of shoot and storage root of carrot was significantly affected by the ratio of NO₃/Cl and Cl forms (Table 5). Chloride contents of shoot in the CaCl₂ treatment was found to be higher than in the KCl treatment. Either KCl or CaCl₂ increased Cl content of shoot and storage root of carrot approximately 1% in all NO₃/Cl mixtures compared with single NO₃ treatment (100/0). The calcium content of shoot was increased with CaCl₂ as the Cl source compared with KCl. Storage root Ca content was affected by either NO₃ replacement or the Cl source, showing a slight decrease in KCl treatment.

Discussion

Nitrate versus chloride nutrition of carrot plants had a significant effect on the fresh and dry yield of shoot and storage root and the length and diameter of the latter. Increasing Cl and...
decreasing NO₃ in the growth medium increased the shoot and storage root growth. It has been reported that considerable amounts of Cl in the growth medium increased or caused no differences in yield (5, 6, 21). Foehse and Jungk (22) showed that the number and length of root hairs increased during nitrate deficiency. Furthermore, it is well established that the root:shoot increases under deficiency, which is generally due to decreased shoot dry matter production (23, 24). Partial replacement of NO₃ by chloride decreased the NO₃ content of both shoot and storage root. The reduced effect of Cl is due to the competition between Cl and NO₃ as has been suggested by Kirkby and Knight (2), Wehrman and Hahndel (11), and Stienstra (12), and İnal et al. (25). In the present study, calcium chloride increased the storage root nitrate content compared with KCl. However Maynard et al. (26) and Barker and Maynard (27) have stated that Ca had no effect on nitrate accumulation. Nitrate/Chloride mixtures and Cl sources did not make any significant difference in the total N content of plant parts, according to Bergman (8) Cl ions have a positive effect on the N household of plants. In a study on sugar beet, it was shown that increasing the Cl concentration from 2 to 5 mmol increased the accumulation of both chloride and ammonium N in tissues (28). As reported by İnal et al. (25), the Cl content of plants was significantly affected by the different N forms and Cl in the nutrient solution. In the present study the Cl content of plant parts also increased. Plant Na content decreased by KCl addition to the medium and K content increased depending on the rate of KCl added. Increasing K decreased the Na content suggesting an antagonism between Na and K as stated by Siegel et al. (29). As a result of calcium addition, with CaCl₂, the Ca of carrot shoot increased. However this effect of CaCl₂ was not seen in storage root Ca content and partial replacement of Cl with either of the two sources has no certain effect on storage root Ca content.

In summary, both the Cl source and NO₃/Cl rates help in decreasing the NO₃ content of carrot without causing reductions in yield, meaning the use of NO₃/Cl percentages can enhance the quality of carrots by decreasing the N fertilizer input rate.

References


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