**Chloride and Chloride Sources for Reducing Foliar Diseases and Improving Onion Yield and Flavor**

**Location:**
The University of Georgia
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**Cooperators:**
Investigator: Dr. William M. Randle, Professor of Horticulture, expertise in mineral nutrition of onion, onion flavor manipulation.

**Prolog:**
We believe that this proposal fits PPI’s initiative of: Managing Crop Production for End-Use Quality. Reduced flavor onions are a designer crop that provides a unique marketing opportunity with enhance bioactive compounds. The sulfur compounds responsible for flavor are also therapeutic and combat abnormalities from cancer to hearth disease. Cooking destroys the formation of many of the therapeutic compounds. Reduced flavor onions ("sweet onions") are eaten raw and as such, are a good vehicle to deliver these therapeutic compounds intact. Our initial experiments suggest that chloride will help produce sweeter onions and K may be involved in improved sugar translocation. While the focus of this proposal is on the involvement of Cl in disease reduction, the secondary effect of Cl in reducing flavor intensity fits the designer foods category.

We also believe work we are involved in here at UGA fits with your other initiative, Narrowing the Yield Gap with Knowledge and Technology. We have been involved in precision agricultural techniques and data feed-back that provides farmers with information to make solid decisions regarding their practices.

**Justification:**
According to 2002 USDA statistics, onions are a top five vegetable crop in the U.S. with production at nearly 145,000 acres and a farm-gate value of $750 million. Production is spread across the four corners of the United States and Canada. Optimum mineral nutrition has always played an important role in maintaining onion productivity, quality, and plant health. However, recent data and observation suggests that chloride and potassium nutrition may be under-utilized or mis-applied.

In most plants, chloride is an essential, but minor element which is thought to be toxic at high concentrations. Onions, however, have a high requirement for chloride, which is not well known. If supplied at high levels, several studies by our group have shown that chloride is the 4th most utilized essential element, superceded by only nitrogen, potassium, and phosphorus (Coolong and Randle, 2003; Randle, 2000). The reason for this may lie in its requirement for stomatal regulation. In most plants, potassium ions imported into guard cells causing stomatal movement are balanced by the breakdown of starch which forms negatively charged organic acids (mainly malate) (Dittrich and Raschke, 1977). Because onion plants do not have starch in their guard cells, they have evolved a mechanism of utilizing chloride anions to counter the influx of potassium cations (Schnabl and Ziegler, 1977). However, chloride fertilization in onion is overlooked and avoided because of an often misinterpreted association with sodium. Current
recommendations for onion production in Oregon, Michigan, New York, Georgia, Texas, and California call for no additional chloride to be added to fertilization regimes. If chloride status in the plant is compromised, poorly functioning guard cells can lead to a number of abnormalities including reduced photosynthesis that may lower yields, and reduced transpiration which can lead to water congestion and increased foliar disease (Schwartz and Mohan, 1995). Recent observations and analyses in commercial onion fields suggest that lower chloride status has an association with higher disease incidence (unpublished data). 2003 soil analyses of several fields in Georgia revealed Cl at less than 10 pounds to the acre. Elevated chloride levels have affected disease severity in several grasses and potato, and most recently in reducing Stemphylium vesicarium in pears.

Chloride can be applied using two common agricultural sources, KCl and CaCl$_2$. KCl has special appeal for onions in that K$^+$ is required for phloem loading of photosynthates (Marschner, 1995). During bulbing, onions transport massive amounts of carbohydrates and proteins to the swelling bulbs. However, current fertility programs attempt to reduce nutrient availability during bulbing which helps bulbs mature and go dormant. It is believed by onion producers that K$^+$ needs to be applied, or at least available, in larger quantities during active bulbing, although no scientifically based recommendations exist. Research is needed to establish if a higher K$^+$ requirement exists, and if so, how much K$^+$ needs to be presented to affect translocation and bulb yields. Because K$^+$ can compete with Ca$^{2+}$, and Ca$^{2+}$ is needed for cell wall and membrane integrity associated with good post-harvest qualities, the effect of K$^+$ on Ca$^{2+}$ utilization needs to be investigated. This is to insure that an imbalance in these cations does not take place which adversely affects bulb shelf-life and storage.

Product quality is important in marketing onions and sometimes drives sales, especially in the value added segment commonly known as “sweet onions”. Sweet onions are increasing in market share and now approach 30% of total onion acreage. Moreover, sweet onions command a premium price which can exceed normal onions by as much as 3 times (The Packer). Optimum mineral nutrition can affect overall plant health, productivity, and bulb quality. In preliminary trials by our program, we have shown that bulb sulfur content decreases with increasing Cl fertility which results in lower bulb pungency (data available on request). High sulfur environments are a major limitation to the production of low pungency onions (Randle, 2001).

Objectives:
1. Determine how Cl affects bulb pungency and bulb yield.

Material and Methods:
Experiment 1
Plants of “Sweet Vidalia” were seeded in October of 2004 and grown under greenhouse conditions for 6 weeks. In mid-December, plants were transplanted into 1x1x0.4m boxes filled with washed river sand. Plants were then grown to maturity under greenhouse conditions using a modified Hoaglund’s solution. Four treatment combinations were used to test different sources of chloride and its effects on bulb pungency and bulb yield. The treatments were as follows:

1. 400 ppm CaCl applied weekly at 1 L
2. 400 ppm KCl applied weekly at 1 L
3. 400 ppm KCl for 4 weeks then 400 ppm CaCl for 4 weeks at 1 L
   March 7, 14, 21 and 28 KCl, then April 4, 11, 18, and 25 CaCl
4. Control (no additional Cl)

When plant foliage lodged, bulbs were harvested and cured at ambient temperatures for one week. Bulbs were then graded and weighed and prepared for flavor analyses. Bulb pungency and soluble solids were done according to Randle and Bussard (1993). Data were analyzed using SAS software.

Experiment 2.

A field experiment was conducted in the Vidalia growing regions on the farm of Mark Shuman. The variety “Georgia Boy” was used for this experiment. Plants were grown, transplanted and fertilized according to commercial practices for Vidalia onions. Beginning in January, additional chloride was applied at a rate of 20 lbs per acre; one plot received four monthly applications, one plot received three monthly applications, one plot received two monthly applications, one plot received one monthly application, and one plot received no additional chloride. Calcium chloride and potassium chloride were used as sources of chloride. Each plot consisted of a two-acre block. Onions were ready for harvest on May 5, 2005. The plants were undercut and allowed to field cure for three days. Four replicates of 50 bulbs each were then sub-sampled, weighed and analyzed for bulb pungency and soluble solids. Data were analyzed by SAS software.

Results and Discussion:

Experiment 1. Plant growth was similar for the different chloride treatments, although the plants receiving both Ca and K sources of chloride appeared to be healthier and slightly larger throughout the growing season. The lowest pungency was found using KCl only with 3.7 umols pyruvic acid development and was significantly different than the no additional chloride control group. The highest pungency (4.7) was found with the KCl and CaCl treatment which was also significantly different from the low chloride control. The higher pungency may have been due to the fact that these plants grew much better throughout the experiments, and achieved greater mass. Soluble solids was unaffected by chloride treatments. Bulb weight, on the other hand, was greatest when both Ca and K sources of chloride were used, and the increase was significantly different from the no chloride control. The lowest yield was found when using additional CaCl.

Table 1. The effects of different chloride sources on bulb pungency, soluble solids, and bulb yield in greenhouse grown onions. Treatments with different letters are significant at a probability level of 5%.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Bulb Pungency uMol</th>
<th>Soluble Solids %</th>
<th>10-Bulb weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KCl</td>
<td>3.7a</td>
<td>8.1a</td>
<td>3010a</td>
</tr>
<tr>
<td>CaCl</td>
<td>4.2b</td>
<td>8.3a</td>
<td>2950a</td>
</tr>
<tr>
<td>KCl and CaCl</td>
<td>4.7c</td>
<td>8.1a</td>
<td>3455b</td>
</tr>
<tr>
<td>Control</td>
<td>4.2b</td>
<td>8.0a</td>
<td>2800a</td>
</tr>
</tbody>
</table>
Experiment 2.
Visible differences were observed among the chloride treatments and the control plots, where the control plots were slightly more yellow in appearance than the plants that received chloride. It is now known that chloride is deficient in the Vidalia area and what we were seeing was a growth response to this deficiency. No additional chloride resulted in higher bulb pungency when compared to all of the treatments that received at least one additional chloride application. There were no significant differences among any of the chloride treatments suggesting that the effect on bulb pungency was the result of chloride application just before harvest. Soluble solids was unaffected by chloride application. The greatest bulb yields were found with the higher chloride applications and the lowest bulb yield resulted from no additional chloride being applied to the crop. This data suggests that the addition of chloride will be beneficial to the Vidalia onion crop, both in lowering pungency and increasing bulb yield.

Table 2. The effects of chloride application on bulb pungency, soluble solids, and bulb yield from field grown onions. Treatments with different letters are significant at a probability level of 5%.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Bulb Pungency</th>
<th>Soluble Solids %</th>
<th>50-Bulb weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 months Cl</td>
<td>3.7a</td>
<td>10.5a</td>
<td>15.1b</td>
</tr>
<tr>
<td>3 months Cl</td>
<td>4.0a</td>
<td>10.5a</td>
<td>14.8b</td>
</tr>
<tr>
<td>2 months Cl</td>
<td>4.0a</td>
<td>9.5a</td>
<td>14.9b</td>
</tr>
<tr>
<td>1 month Cl</td>
<td>4.1a</td>
<td>9.9a</td>
<td>14.0ab</td>
</tr>
<tr>
<td>No Cl</td>
<td>4.8b</td>
<td>9.9a</td>
<td>13.1a</td>
</tr>
</tbody>
</table>

**Literature Cited:**