Effects of Calcium Chloride Concentration on the Plants Growth in Vegetation-based Low Impact Development Facilities

2015. 11.
Contents

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II. LID and Vegetation Environment

III. Growth conditions of plants as affected by the concentration of roadside deicing salts (CaCl2) in the solution

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Changing Water Environment in Urban Area

Increase of Urbanization Rate and Impermeable Areas

Urbanization Rate

Year


Urbanization (%)

0 10 20 30 40 50 60 70 80 90 100

GNI (US$1,000)

0 5 10 15 20 25 30

Impermeable Area Ratio by Local Governments (%)

(unit : %)

1970 2013

Increased by 2.7 times

Gangwon-do 3.2 7.9%
Gyeongsangbuk-do 5.1
Chungcheongbuk-do 6.6
Jeollanam-do 6.8
Jeollabuk-do 7
Gyeongsangnam-do 7.8
Chungcheongnam-do 8.3
Jeju-do 8.7
Gyeonggi-do 13.7
Ulsan megalopolis 17.2
Daejeon megalopolis 22
Incheon megalopolis 22.3
Daegu megalopolis 23.3
Gwangju megalopolis 27
Busan megalopolis 30.3
Seoul Metropolis 54.4

*Source : Ministry of Environmental, 2013)
### 1. Increase of Urbanization Rate and Impermeable Areas

#### 10 Local Governments with Highest Rate of Impermeable Areas

<table>
<thead>
<tr>
<th>Local Government</th>
<th>Impermeable Ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ansan</td>
<td>7.8%</td>
</tr>
<tr>
<td>Siheung</td>
<td>21.6%</td>
</tr>
<tr>
<td>Gunpo</td>
<td>47.8%</td>
</tr>
<tr>
<td>Anyang</td>
<td>96.0%</td>
</tr>
<tr>
<td>Osan</td>
<td>48.4%</td>
</tr>
<tr>
<td>Gwangmyeong</td>
<td>93.5%</td>
</tr>
<tr>
<td>Mokpo</td>
<td>7.8%</td>
</tr>
<tr>
<td>Suwon</td>
<td>21.6%</td>
</tr>
<tr>
<td>Seoul</td>
<td>47.8%</td>
</tr>
<tr>
<td>Bucheon</td>
<td>96.0%</td>
</tr>
</tbody>
</table>

(Source: Ministry of Environment, 2013)

#### Change of Urbanization Rate and Rate of Impermeable Areas (Seoul)

- **Population density (person/km²):**
  - 1962: 5,001
  - 2010: 17,472
  - 2020: 16,348

- **Urbanization rate (%):**
  - 1962: 7.8%
  - 2010: 21.6%
  - 2020: 47.8%

- **Impermeable ratio (%):**
  - 1962: 5,001
  - 2010: 17,472
  - 2020: 16,348

#### Circulation in 1962

- **Usual Inflow into Rivers:** 327.0
- **Usual Inflow into Surface Runoff:** 97.4
- **Usual Inflow into Underground Water:** 216.6
- **Evapotranspiration:** 240.7
- **Underground Water:** 45.3
- **Surface Runoff:** 460.9

#### Circulation in 2002

- **Usual Inflow into Rivers:** 82.2
- **Usual Inflow into Surface Runoff:** 19.7
- **Usual Inflow into Underground Water:** 216.6
- **Evapotranspiration:** 240.7
- **Underground Water:** 45.3
- **Surface Runoff:** 460.9

#### Increase of Impermeable Ratio Areas due to Urbanization (Seoul)

- **Usual Inflow into Rivers:** 327.0 (34.2%)
- **Usual Inflow into Surface Runoff:** 97.4 (10.2%)
- **Usual Inflow into Underground Water:** 216.6 (22.6%)
- **Evapotranspiration:** 240.7 (26.2%)
- **Underground Water:** 45.3 (13.2%)
- **Surface Runoff:** 460.9 (48.2%)
Changing Water Environment in Urban Area

2 South Korea’s Rainfall Pattern and Water Supply Circumstance

- (Average Rainfall per Year) Increased from 1,156mm in the 1990’s to 1,375.4mm in the 2000’s by 19%
- (Water Supply) 100 million m$^3$ surplus in 2001, 1.8 billion m$^3$ shortage in 2011.
- (Property Damage by Flood) 8-times increase (0.26 trillion in 1977~1986, to 2.12 trillion in 1997~2006)

| Year | Demand (Unit: 0.1 billion m$^3$/year) | Supply (Unit: 0.1 billion m$^3$/year) | Discrepancy
|------|--------------------------------------|--------------------------------------|----------------
| 2001 | 337                                  | 338                                  | 1
| 2006 | 347                                  | 346                                  | ▲ 1  
| 2011 | 370                                  | 370                                  | ▲ 18

- Water Disputes between Regions
  - **(Wicheon Industrial Complex Dispute)** Dispute over contamination of Nakdong River between Daegu, Gyeongbuk and Busan
  - **(Pyeongchang River Water Acquisition Project)** Dispute due to decreased waterflow and pollution between Jecheon, Gyeongbuk and Yeongweol, Gangwon-do
  - **(Yongdam Dam Project)** Dispute due to water depletion between Jeonju and Chungnam
Changing Water Environment in Urban Area

3. Influence of the Urban Water Environment Change

- Deteriorated Water Management Conditions
- Disaster Increase
- Tropical Night
- Energy Use Increase
- Heat Island
- Flood
- Draught
- Ground water level decreased
- Stream Flow Depletion
- Distortion of Water Circulation
- Climate Change
- Underground Water Source Depletion
- Heat Island
- Elevation
- Changed Discharge Pattern
- Pollution
- Evaporation
- Exhaust Gas
- Rain Water

Flood
Draught
Ground water level decreased

- Disaster Increase
- Tropical Night
- Energy Use Increase
- Heat Island

- Plans/strategies are required against climate change in cities and urbanization
(Article 10) Rainwater Infiltration and Drainage System
- (Scope of Application) Rainwater infiltration, surface drainage and deep soil layer drainage system for parks, pedestrian roads and other areas subject to design
- (Definition) Rainwater infiltration is the process of making rainwater and surface water enter the soil to reduce surface runoff and save groundwater
- (Planning of Rainwater Infiltration and Storage System)
  • For parks, lawn, vegetable gardens, to facilitate rainwater infiltration, the vegetated land must be planned to be curved and to have concave areas every 100 m²
  • Infiltration wells for concave areas that are lower than the surrounding landscape
  • Linear infiltration system such as gravel trench and grass trench on the bottom of the slope of the landscape conservation areas and the bottom of green buffer zones
  • To facilitate rainwater infiltration and lower the groundwater level in large areas, ponds or swamps must be planned for lower areas.
  • To facilitate rainwater reuse, rainwater retaining tanks and system has to be installed
- (Natural Drainage System)
  • Rainwater infiltration system such as grass trenches, gravel trenches, infiltration wells, swamps must be planned taking into account of the topographic conditions, soil features and surface conditions.
  • When planning natural drainage system, surface drainage system and deep soil layer drainage system have to be integrated.
LID and Vegetation Environment

1. Laws and Regulations related to Landscape Design

Landscape Architecture Design Standards, 2013, Ministry of Land, Infrastructure and Transport

(Article 10) Rainwater Infiltration and Drainage System
- (Rain Gardens) Bioretention areas that utilize vegetation to capture polluted runoff and release filtered runoff to the soil.
  • Rain gardens must be planned using the vegetation already established or those that can grow without disrupting the surrounding environment
  • If rainwater treatment is questionable, the volume of water that comes from the down pipes to rain garden can be adjusted.
1. Laws and Regulations related to Landscape Design

Landscape Architecture Design Standards 2012, LH

(6.10) Rain Gardens on Urban Roadsides

- **Concept** General term for the facilities planned to minimize rainwater runoff and to maximize natural evaporation and absorption of water by soil (wetlands, waterways, roadside vegetation)

- **Planning Standards**
  
  To maximize rainwater infiltration, the slope of green buffer shall need to be less than 20 percent, except when the buffer is focused on noise reduction.

  Rain Gardens shall need to be planned in such way that it prevents the inflow of nonpoint pollutant sources into the garden areas.
The Effects of LID and Vegetation Areas

Increased Rainwater Inflow

- Stress on plants due to water level changes
  - Rainwater inflow and increase in the water level may cause flooding, excessive moisture and vegetable diseases
  - Water stress on plants from repeated periods of excess soil moisture alternating with periods of likely insufficiency, may hinder plant growth or cause the plants to wither and die.
  - Repeated flooding and drying may change the chemical and physical properties of soil

[Examine of vegetation damage state by humidity]

[Soil moist state]
The Effects of LID and Vegetation Areas

Inflow of Pollutants

- Increase of urban areas and impermeable areas resulted in increased pollutant load from nonpoint source pollution
  - (Efflux of nonpoint source pollution in urban areas) BOD increased 92 times, and SS increased 24 times from before development
- Urban areas accounted for the largest portion of nonpoint pollutant discharge among different land types

Nonpoint Pollutant Discharge by Land Types

(Ministry of Environment, 2012)

Percentage of Nonpoint Pollutant Discharge in River Discharge Load (BOD)

<table>
<thead>
<tr>
<th>Year</th>
<th>1998</th>
<th>2003</th>
<th>2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>27%</td>
<td>52.6%</td>
<td>68.3%</td>
<td>72.1%</td>
</tr>
</tbody>
</table>

Nonpoint Pollutant Discharge by Land Types

(BOD, tons/day, Ministry of Environment)

Trend of Nonpoint Source Pollution

(Source-Ministry of Environment http://nonpoint.me.go.kr)

(Source-http://csf.kiep.go.kr)
2. The Effects of LID and Vegetation Areas

Inflow of Pollutants

- Survey on growth conditions of roadside plants (Yeongtong, Suwon)
  - A lot of Japanese Spurge (Pachysandra terminalis Siebold & Zucc.) were withering and dying
  - Growth condition of plants was poor due to Inflow of polluted rainwater from the road

- Nitrogen and phosphorus concentration measures (Yeongtong, Suwon)
  - Found absorption of pollutants, nitrogen and phosphorus.

Note

Artificial Wetlands 1
Artificial Wetlands 2
Artificial Wetlands 3

Korean Boxwood Collected Area
Japanese Spurge Collected Area
Rainwater Entry

<table>
<thead>
<tr>
<th></th>
<th>Entry</th>
<th>Center</th>
<th>Exit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japanese Spurge</td>
<td>0.33</td>
<td>0.31</td>
<td>0.3</td>
</tr>
<tr>
<td>Korean Boxwood</td>
<td>0.25</td>
<td>0.29</td>
<td>0.15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Entry</th>
<th>Center</th>
<th>Exit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japanese Spurge</td>
<td>2.16</td>
<td>2.18</td>
<td>2.11</td>
</tr>
<tr>
<td>Korean Boxwood</td>
<td>2.72</td>
<td>3.83</td>
<td>2.75</td>
</tr>
</tbody>
</table>
The Effects of LID and Vegetation Areas

Plant damage by de-icers (calcium chloride)

- De-icers bounced off or splashed from the road can damage the plants
- De-icer containing water or melted snow can be splashed on plants and cause leaf discoloration or cause the leaves to fall
- The soil under snow will accumulate salt and hinder plant growth
  - Hinders plants’ absorption of moisture and nutrients
  - Decreases plants’ resistibility and causes plant malnourishment

[Plants damaged by de-icers]

Photo from SBS news report
Vegetation-Based LID Facilities and Plant Growth

- Vegetation-based LID facilities are established on a vegetation-based environment that goes through repetition of flooding and drying.
- Inflow of pollutants and de-icers to the LID facilities established on roadsides may hinder plant growth or cause the plants to wither and die.

Introducing the LID method

Changes in water level (flooding)

Increased groundwater level

Hinder plant growth

Selection of plants suitable for LID application

Flood-tolerant plants

Moisture-loving, shallow-rooted plants

Improved function of vegetation-based LID

inflow of de-icers

Salt-tolerant plants
Growth conditions of plants as affected by the concentration of roadside deicing salts (CaCl2) in the solution

## Experiment Materials

### Plants

<table>
<thead>
<tr>
<th>Plants</th>
<th>Size</th>
<th>Repetition (reps)</th>
<th>Salt Treatment (tr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadleaf Liriope (<em>Liriope platyphylla</em>)</td>
<td>2~3 tillers</td>
<td>3 pots x 4 reps</td>
<td>12 x 5 tr = 60 pots</td>
</tr>
<tr>
<td>Japanese Spurge (<em>Pachysandra terminalis</em>)</td>
<td>4 inch pot</td>
<td>3 pots x 4 reps</td>
<td>12 x 5 tr = 60 pots</td>
</tr>
<tr>
<td>Sedum (<em>Sedum middendorffianum</em>)</td>
<td>4 inch pot</td>
<td>3 pots x 4 reps</td>
<td>12 x 5 tr = 60 pots</td>
</tr>
<tr>
<td>Japanese Iris (<em>Iris ensata var. spontanea</em>)</td>
<td>4 inch pot</td>
<td>3 pots x 4 reps</td>
<td>12 x 5 tr = 60 pots</td>
</tr>
<tr>
<td>Silver Grass (<em>Miscanthus sinensis var. purpurascens</em>)</td>
<td>4 inch pot</td>
<td>3 pots x 4 reps</td>
<td>12 x 5 tr = 60 pots</td>
</tr>
<tr>
<td>Common Reed (<em>Phragmites communis</em>)</td>
<td>4 inch pot</td>
<td>3 pots x 4 reps</td>
<td>12 x 5 tr = 60 pots</td>
</tr>
<tr>
<td>Fountain Grass (<em>Pennisetum alopecuroides</em>)</td>
<td>4 inch pot</td>
<td>3 pots x 4 reps</td>
<td>12 x 5 tr = 60 pots</td>
</tr>
<tr>
<td>Japanese Spindle (<em>Euonymus japonica</em>)</td>
<td>5 inch pot</td>
<td>3 pots x 4 reps</td>
<td>12 x 5 tr = 60 pots</td>
</tr>
<tr>
<td>Korean Boxwood (<em>Buxus koreana</em>)</td>
<td>5 inch pot</td>
<td>3 pots x 4 reps</td>
<td>12 x 5 tr = 60 pots</td>
</tr>
<tr>
<td>Evergreen Azalea (<em>Rhododendron indicum</em>)</td>
<td>5 inch pot</td>
<td>3 pots x 4 reps</td>
<td>12 x 5 tr = 60 pots</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>600 pots</td>
</tr>
</tbody>
</table>

### Soil

- Used gardening bed soil (Shinsung Mineral Co., Korea)
- Mixed 0.17kg, 0.34kg, 1.02kg, 1.7kg of de-icers (CaCl2) depending on the volume of soils, and created 0% (Control), 0.5%, 1.0%, 3.0% and 5.0% concentrations.
Growth conditions of plants as affected by the concentration of roadside deicing salts (CaCl\(_2\)) in the solution

**Experiment Results**

**Broadleaf Liriope**

[Growth of the *Liriope platyphylla* as grown in roadside deicing salts (CaCl\(_2\)) concentration in the amended soil]

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant growth (cm)</th>
<th>Leaf numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant height</td>
<td>Leaf length</td>
</tr>
<tr>
<td>Control</td>
<td>12.33b ( ^{2} )</td>
<td>9.18 a</td>
</tr>
<tr>
<td>0.5%</td>
<td>9.41 b</td>
<td>8.76 a</td>
</tr>
<tr>
<td>1.0%</td>
<td>13.87 a</td>
<td>8.71 a</td>
</tr>
<tr>
<td>3.0%</td>
<td>9.18 c</td>
<td>8.24 a</td>
</tr>
<tr>
<td>5.0%</td>
<td>9.10 c</td>
<td>8.99 a</td>
</tr>
</tbody>
</table>

\(^{2}\)Different letters in the same column indicate a significant difference at \(P<0.05\) according to Duncan’s multiple range test \((n=12)\)

- The level of growth and development of the aerial part was the highest in the Control Group but did not find statistical significance
- Highly adaptive to calcium chloride
Growth conditions of plants as affected by the concentration of roadside deicing salts (CaCl₂) in the solution

Japanese Spurge

[Growth of the Pachysandra terminalis as grown in roadside deicing salts (CaCl₂) concentration in the amended soil]

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant growth (cm)</th>
<th>leaf numbers (ea)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant height</td>
<td>Leaf length</td>
</tr>
<tr>
<td>Control</td>
<td>20.60a²</td>
<td>4.97 b</td>
</tr>
<tr>
<td>0.5%</td>
<td>18.8 b</td>
<td>5.97 a</td>
</tr>
<tr>
<td>1.0%</td>
<td>18.70 b</td>
<td>5.01 b</td>
</tr>
<tr>
<td>3.0%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5.0%</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
²Different letters in the same column indicate a significant difference at P<0.05 according to Duncan’s multiple range test (n=12)

Started to show leaf chlorosis after 7 days, at 3.0% concentration.
**Growth conditions of plants as affected by the concentration of roadside deicing salts (CaCl₂) in the solution**

### Sedum

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant biomass (g)</th>
<th>Shoot F.W.</th>
<th>Shoot D.W.</th>
<th>Root F.W.</th>
<th>Root D.W.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td>-</td>
<td>-</td>
<td>5.41a²</td>
<td>1.09 a</td>
</tr>
<tr>
<td>0.5%</td>
<td></td>
<td>-</td>
<td>-</td>
<td>4.68 ab</td>
<td>0.97 a</td>
</tr>
<tr>
<td>1.0%</td>
<td></td>
<td>-</td>
<td>-</td>
<td>4.86 ab</td>
<td>1.02 a</td>
</tr>
<tr>
<td>3.0%</td>
<td></td>
<td>-</td>
<td>-</td>
<td>4.77 ab</td>
<td>1.12 a</td>
</tr>
<tr>
<td>5.0%</td>
<td></td>
<td>-</td>
<td>-</td>
<td>2.69 b</td>
<td>0.79 a</td>
</tr>
</tbody>
</table>

²Different letters in the same column indicate a significant difference at P<0.05 according to Duncan’s multiple range test (n=12)

γF.W.=Fresh weight, D.W.=Dry weight

- Started to wither and die after 7 days, at 1.0% concentration and all of the plants dies by the end of the experiment
Japanese Iris

[Effect of the different roadside deicing salts (CaCl₂) on the biomass of the *Iris ensata var. spontanea* ratio in the amended soil]

| Treatments | Plant biomass (g) |  |  |  |
|------------|------------------|  |  |  |
|            | Shoot F.W. | Shoot D.W. | Root F.W. | Root D.W. |
| Control    | 0.65 a | 0.16 b | 25.04 a | 6.88 a |
| 0.5%       | 0.79 a | 0.27 ab | 22.00 ab | 5.62 ab |
| 1.0%       | 0.51 a | 0.15 b | 16.64 ab | 3.96 ab |
| 3.0%       | 0.72 a | 0.38 a | 14.57 ab | 3.93 ab |
| 5.0%       | 0.83 a | 0.24 ab | 13.99 ab | 3.23 b |

*Different letters in the same column indicate a significant difference at p<0.05 according to Duncan’s multiple range test (n=12)*

*F.W.=Fresh weight, D.W.=Dry weight*

---

The fresh weight of the aerial part started to decrease rapidly from 1.0% concentration. Physiologically weak against salt

---

**Growth conditions of plants as affected by the concentration of roadside deicing salts (CaCl₂) in the solution**

[Effect of the different roadside deicing salts (CaCl₂) on the biomass of the *Iris ensata var. spontanea* ratio in the amended soil]
Growth conditions of plants as affected by the concentration of roadside deicing salts (CaCl2) in the solution

Silver Grass

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant biomass (g)</th>
<th>Shoot F.W.</th>
<th>Shoot D.W.</th>
<th>Root F.W.</th>
<th>Root D.W.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>2.02 a²</td>
<td>1.07 a</td>
<td>38.27 a</td>
<td>15.49 a</td>
<td></td>
</tr>
<tr>
<td>0.5%</td>
<td>1.27 a</td>
<td>0.73 a</td>
<td>32.11 a</td>
<td>14.53 a</td>
<td></td>
</tr>
<tr>
<td>1.0%</td>
<td>1.92 a</td>
<td>0.96 a</td>
<td>37.04 a</td>
<td>15.72 a</td>
<td></td>
</tr>
<tr>
<td>3.0%</td>
<td>1.37 a</td>
<td>0.79 a</td>
<td>19.91 a</td>
<td>8.02 a</td>
<td></td>
</tr>
<tr>
<td>0.5%</td>
<td>1.38 a</td>
<td>0.99 a</td>
<td>19.35 a</td>
<td>7.89 a</td>
<td></td>
</tr>
</tbody>
</table>

²Different letters in the same column indicate a significant difference at P<0.05 according to Duncan’s multiple range test (n=12)

³F.W.=Fresh weight, D.W.=Dry weight.

- Showed significant decline in growth from 3.0% concentration. Physiologically weak against salt.
Growth conditions of plants as affected by the concentration of roadside deicing salts (CaCl\(_2\)) in the solution

**Common Reed**

[Effect of the different roadside deicing salts (CaCl\(_2\)) on the biomass of the *Phragmites communis* ratio in the amended soil]

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant biomass (g)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shoot F.W.(^{y})</td>
<td>Shoot D.W.</td>
<td>Root F.W.</td>
<td>Root D.W.</td>
</tr>
<tr>
<td>Control</td>
<td>1.12 a(^2)</td>
<td>0.55 a</td>
<td>3.57b</td>
<td>1.09 a</td>
</tr>
<tr>
<td>0.5%</td>
<td>0.91 a</td>
<td>0.40 a</td>
<td>13.55 a</td>
<td>3.67 a</td>
</tr>
<tr>
<td>1.0%</td>
<td>1.16 a</td>
<td>0.57 a</td>
<td>8.31 ab</td>
<td>3.58 a</td>
</tr>
<tr>
<td>3.0%</td>
<td>0.85 a</td>
<td>0.44 a</td>
<td>6.46 b</td>
<td>1.71 a</td>
</tr>
<tr>
<td>5.0%</td>
<td>0.41 a</td>
<td>0.27 a</td>
<td>4.73 b</td>
<td>1.24 a</td>
</tr>
</tbody>
</table>

\(^2\)Different letters in the same column indicate a significant difference at P<0.05 according to Duncan’s multiple range test (n=12)

\(^y\)F.W.=Fresh weight, D.W.=Dry weight.

- The aerial part and subterranean part showed no differences in terms of growth, development and physiological condition
- Showed strong salt-resistance
Fountain Grass

[Effect of the different roadside deicing salts (CaCl$_2$) on the biomass of the *Pennisetum alopecuroides* ratio in the amended soil]

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant biomass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shoot F.W.</td>
</tr>
<tr>
<td>Control</td>
<td>14.19 a$^x$</td>
</tr>
<tr>
<td>0.5%</td>
<td>9.53 a</td>
</tr>
<tr>
<td>1.0%</td>
<td>4.14 a</td>
</tr>
<tr>
<td>3.0%</td>
<td>3.46 a</td>
</tr>
<tr>
<td>5.0%</td>
<td>3.08 a</td>
</tr>
</tbody>
</table>

$^x$Different letters in the same column indicate a significant difference at P<0.05 according to Duncan’s multiple range test (n=12)

$^y$F.W.=Fresh weight, D.W.=Dry weight.

- The aerial part and subterranean part showed no differences in terms of growth, development and physiological condition
- Showed strong salt-resistance
Korean Boxwood

[Growth of the *Buxus koreana* as grown in roadside deicing salts (CaCl₂) concentration in the amended soil]

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant growth (cm)</th>
<th>leaf numbers (ea)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant height</td>
<td>Leaf length</td>
</tr>
<tr>
<td>Control</td>
<td>32.07a z</td>
<td>2.36 a</td>
</tr>
<tr>
<td>0.5%</td>
<td>27.84 a</td>
<td>1.89 a</td>
</tr>
<tr>
<td>1.0%</td>
<td>25.80 a</td>
<td>2.17 a</td>
</tr>
<tr>
<td>3.0%</td>
<td>26.77 a</td>
<td>1.73 a</td>
</tr>
<tr>
<td>5.0%</td>
<td>26.08 a</td>
<td>1.80 a</td>
</tr>
</tbody>
</table>

zDifferent letters in the same column indicate a significant difference at P<0.05 according to Duncan’s multiple range test (n=12)

- Showed salt-resistance until 3.0% concentration but the subterranean part of the plants showed significant decline in growth beyond 3.0% concentration
Growth conditions of plants as affected by the concentration of roadside deicing salts (CaCl₂) in the solution

**Japanese Spindle**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant growth (cm)</th>
<th>leaf numbers (ea)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant height</td>
<td>Leaf length</td>
</tr>
<tr>
<td>Control</td>
<td>20.91 az</td>
<td>5.02 a</td>
</tr>
<tr>
<td>0.5%</td>
<td>19.85 a</td>
<td>4.67 a</td>
</tr>
<tr>
<td>1.0%</td>
<td>20.89 a</td>
<td>4.77 a</td>
</tr>
<tr>
<td>3.0%</td>
<td>20.76 a</td>
<td>4.70 a</td>
</tr>
<tr>
<td>5.0%</td>
<td>14.53 a</td>
<td>3.37 a</td>
</tr>
</tbody>
</table>

Different letters in the same column indicate a significant difference at P<0.05 according to Duncan’s multiple range test (n=12)

- Did not find differences in growth. Showed strong salt-resistance
- However, the leaves did start to turn yellow with increasing salt concentration
### Evergreen Azalea

[Growth conditions of *Rhododendron indicum* as affected by the concentration of roadside deicing salts (CaCl$_2$) in the solution]

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant growth (cm)</th>
<th>leaf numbers (ea)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant height</td>
<td>Leaf length</td>
</tr>
<tr>
<td>Control</td>
<td>60.33 ab$^z$</td>
<td>2.24 a</td>
</tr>
<tr>
<td>0.5%</td>
<td>57.67 ab</td>
<td>2.20 a</td>
</tr>
<tr>
<td>1.0%</td>
<td>58.00 ab</td>
<td>2.28 a</td>
</tr>
<tr>
<td>3.0%</td>
<td>55.50 b</td>
<td>-</td>
</tr>
<tr>
<td>5.0%</td>
<td>72.00 a</td>
<td>-</td>
</tr>
</tbody>
</table>

$^z$Different letters in the same column indicate a significant difference at P<0.05 according to Duncan’s multiple range test (n=12)

- Leaves showed chlorosis at 3.0% concentration and all the leaves withered and died after the experiment.
Conclusion

Summary of Results

- The growth of Sedum, Japanese Iris were poor to grow for calcium chloride treatment except the control group in more than 1.0%
  - These Plants are very sensitive to calcium chloride

- Broadleaf Liriope, Common Reed, Fountain Grass, Japanese Spindle were able to grow and survive at the ratio 3.0%
  - These Plants are the possible state can absorb salts due to moisture and it can be applied to ground cover plants in the roadside
To achieve the purpose of introducing plants, those plants with high level of environmental adaptability are needed

- **Salt Resistance**
  - Broadleaf liriope, Common Reed, Fountain Grass and Japanese Spindle for LID facilities that have the risk of plant damage from de-icers

The plants need proper maintenance

- Native species, rather than foreign species, are recommended
- The weeds that are prolific need to be eliminated early on
- For successfully rooting, the plants should be watered for the first couple months
- Plants that don’t require regular care are recommended
Thank You