Research progress on the mechanism of crop potassium efficient use--a China perspective

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Potassium use and circle related to all of the scales from nanometer to the earth

Each step in up-scaling is critical to the challenges we face on the efficient use of potassium nutrition
World potash reserves are huge. Its life based on current production is 235 years and a reserve base exceeding 500 years (Fixen, 2009).

The natural distribution of potash reserves in the world is quite concentrated and in other word is inefficient for agriculture. There are over 150 countries consume potash, but only 12 of them have potash production. Total 92% of world potash reserves are located in Canada, Russia, Belarus and Germany, and their far from the main potash consumers such as China, Brazil and India who consumed 52.4% of world’s potash in 2009.
92% reserves, consumed <10% of world’s potash

4.6% reserves, consumed >50% of world’s potash
Extracting K from seawater

- There is 550,000 billion T of K2O in seawater, it is 30,000 times of land total reserves.
- The technological routes of extracting K from sea water mainly include:
  - chemical precipitation,
  - solvent-extracting,
  - membrane separation,
  - multi-purpose recovery,
  - ionic exchange,
  - modified zeolite.
K salt exploitation, process and consumption in China

Salt lakes
- NaCl
- Bittern

Sea water
- K salt
- Byproducts

K feldspar

Industry
- 35% Detergent
- 25% Glass, chinaware
- 20% Spin, coloration
- 13% Chemical
- 7% Others

Agriculture
- 95%

Ground water

Others
- 7%
In all of the 13 billion hectares farmland soil of the world, there were 22.5% of them under mineral nutrient stress and only 10.1% of them have no any natural stress. About 40% of the mineral nutrient stress was due to soil potassium deficiency (Clark, 1982; Jiang, 2004).

Based on national fertilizer input and agricultural output, Sheldrick’s (2003) calculation showed that there was $7.7 \times 10^6$ t of potassium removed from China’s farmland annually.
Plant K use efficiency (KUE) mainly depends on correlated two efficiencies:
  a) absorption efficiency
  b) using efficiency

Crop K use efficiency in agriculture mainly includes 3 significations:
  a) ability of crop resist K stress;
  b) sensitive of crop to K stress;
  c) crop harvest index.
Crop K absorb efficiencies

- In general, tuber crops, leguminous crops and cruciferae crops have higher K absorb efficiency compare with gramineous crops. In the gramineous crops, the K absorbs efficiencies of maize and barley are significant higher than that in wheat.

- No significant difference on K use efficiency between different varieties for rice, wheat and barley when soil K was sufficient, but if under soil K deficient condition the K absorb rates of high efficient varieties could reach about 2 times, 2 times and 4 times over low efficient varieties.
Soil potassium

Soil K was existed in 4 forms: structural K, non-exchangeable K, exchangeable K and water-soluble K.

There is a complex and dynamic chemical balance existed and the balance is greatly depends on the situation of each forms and the environment conditions.

The soil soluble K can be directly absorbed by plant through three different ways namely interception, mass flow and diffusion.
Root characters

Different soil condition would affect root growth, and root can also adapt the soil environment with different ways.

In general, the plant genotype that has higher soil K absorb efficiency is always with larger root/coronal ratio, wide distribution in portrait and side directions, larger root length and semi-diameter, more radicel and longer root hair, larger root absorb surface and activity absorb surface, better root absorb dynamic parameters ($V_{\text{max}}$, small $K_m$ and $C_{\text{min}}$) and large root cation exchange capacity (CEC).
Root secretion & rhizosphere microbe

Plant potassium use efficiency is greatly affected by root secretion and rhizosphere microbe.

Rhizosphere is an important site for substance exchange between plant and soil, while root secretion is an important medium for the substance exchange.
There is substitute effect of other ions to potassium ion existed in some plant. The $K^+$ which accumulated in vacuole can make osmotic potential for cell growth, and cell growth needs the osmotic materials has good mobility. In addition, $K^+$ has some other specific physiological functions. Therefore, only a fat lot ion in some specific plants can partly replace $K^+$, and most of the relative reports were focused on the substitute effect of $Na^+$ to $K^+$. 

Substitute effect of other ions
Harvest index (HI)

Harvest index also called economic coefficient, is the ratio of economic yield onto total harvest yield.

HI reflected the ability of plant translocation the resource (include K) to harvest organs.
Molecular inheritance

- Quantitative inheritance, controlled by polygene, existing gene interaction.

- There are two absorption systems in the cell membrane of plant root, i.e. high affinity system and low affinity system.

- At least 15 potassium absorb genes (high-affinity $K^+$ transporters) have been cloned from plant and/or microbe (mainly rice).
Research on the mechanisms of K high use efficiency with different cotton genotypes
Root box experiment with two cotton genotypes-HEG & LEG
Single and double grafting

With K

- HEG/LEG Single graft
- LEG/HEG Single graft
- HEG/LEG Double graft
- HEG Double graft
- HEG/LEG Double graft
- LEG

Without K

- Single graft
- Double graft
# DW of different cotton organs (%)

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Stem</th>
<th>Branch</th>
<th>Leaves</th>
<th>Bolls</th>
<th>Root</th>
<th>Fall leaves</th>
<th>Fall boll</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEG+K</td>
<td>27.9</td>
<td>9.9</td>
<td>7.3</td>
<td>12.9</td>
<td>21.9</td>
<td>10.6</td>
<td>9.5</td>
</tr>
<tr>
<td>HEG-K</td>
<td>18.4</td>
<td>3.8</td>
<td>8.5</td>
<td>14.6</td>
<td>17.6</td>
<td>30.4</td>
<td>6.7</td>
</tr>
<tr>
<td>LEG+K</td>
<td>25.1</td>
<td>8.8</td>
<td>5.5</td>
<td>7.7</td>
<td>17.1</td>
<td>23.2</td>
<td>12.5</td>
</tr>
<tr>
<td>LEG-K</td>
<td>17.4</td>
<td>4.5</td>
<td>7.9</td>
<td>6.0</td>
<td>15.5</td>
<td>38.5</td>
<td>10.2</td>
</tr>
</tbody>
</table>
Boll number

Bolls/plant

- LEG-K
- LEG+K
- HEG-K
- HEG+K
K distribution and use

The economic use efficiency of high use efficiency cotton genotype (33.9%) was 2 times of that in low use efficiency cotton genotype.

The percentage of K loss by cast from the low use efficiency cotton genotype was 1.6 times of that in high use efficiency cotton genotype.

The accumulated K in high use efficiency cotton genotype was 2 times of that in low use efficiency cotton genotype.

\[ \text{EUE of K\%} = \left( \frac{\text{K in bolls}}{\text{K in whole plant}} \right) \times 100\% \]
\[ \text{K loss by cast } \% = \left( \frac{\text{K in cast}}{\text{K in whole plant}} \right) \times 100\% \]
Activity of soil catalase

The graph shows the activity of soil catalase in different treatments. The y-axis represents the activity in ug/g, ranging from 0 to 900. The x-axis represents different treatments: 103+K, 103-K, 122+K, and 122-K. The bars indicate the activity levels for both root zone (紫线) and non-root zone (蓝线) samples.
Micrograph of root hair scan

HEG

LEG
Compare of root hair and vessels

HEG

LEG
Results

The results of our cotton root box and grafting experiments showed that the differences between K HEG and LEG cotton were mainly presented on the ability of soil K absorption, K transportation and distribution in different plant organs.
Mechanisms of cotton K use efficiency

- **High absorb efficiency**
  - Root type
  - Root Absorb dynamics
  - Root secretion

- **H efficiency**
  - Environment stress
  - Reproductive organs
  - Photosynthesis & transpiration

- **Cotton genotype**
  - Conductive tissues
  - Metabolize materials

- **High use efficiency**
  - Water & Nutrition

- **Sufficient K supply**
  - Cotton H efficiency mechanisms
  - Efficient distribution
Thanks!