APPLICATION OF MODERN TECHNOLOGY IN FERTILIZATION

-Reduction of Phosphorus Application by Using Biological Functions-

NARO Agricultural Research Center
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Agriculture in Hokkaido

<table>
<thead>
<tr>
<th></th>
<th>Taiwan</th>
<th>Hokkaido</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (km²)</td>
<td>36,000</td>
<td>83,450</td>
<td>378,000</td>
</tr>
<tr>
<td>Population (thousand)</td>
<td>23,400</td>
<td>5,430</td>
<td>128,000</td>
</tr>
<tr>
<td>Population Density ( / km²)</td>
<td>650</td>
<td>65</td>
<td>339</td>
</tr>
<tr>
<td>Arable Area (1000 ha)</td>
<td>803</td>
<td>1,150</td>
<td>4,560</td>
</tr>
<tr>
<td>Agricultural Production (mil.US$)</td>
<td>8,600</td>
<td>9,600</td>
<td>70,600</td>
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Agriculture in Hokkaido

Hokkaido:
- Northernmost among main 4 islands in Japan.
- 1/4 of cultivated land are in Hokkaido.
- Contribute approx. 20% of domestic food supply (calorie basis).
- Japanese Largest Food-Supply Base

“Clean-agriculture movement”
Eco-friendly and Environment-conservative way of agriculture is desired.

Effective use of microbial function would be important.

My Current Research Topics

Effective use of microbial function in agricultural production.

- Utilize endogenous arbuscular mycorrhizal fungi (AM fungi) in agriculture
  - Reduction of phosphate fertilizer in soybean cultivation after cropping of AM host plant.

- Dynamics of exogenously applied microbes in agricultural ecosystem
  - Longevity of Escherichia coli included in cow feces after manure application to farm land.
  - Fate of effective microbial material applied to soil or plant in agricultural environment.
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Fertilizer status, international

- Fertilizer prices abruptly increased in 2008.
- Japan depends on imports for most of chemical fertilizer material supplies.

Effective use of fertilizer is critical for sustainable development of Japanese agriculture.
Mycorrhizal Fungi

- “Myco” means “Fungi” (菌), “rhiza” means “root” (根)
- Mycorrhiza = symbiont (共生体) of root and fungi.
- Most common type of mycorrhiza: Arbuscular Mycorrhiza (AM)

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<table>
<thead>
<tr>
<th>Vesicle</th>
<th>Arbuscle</th>
<th>Intraradical Hyphae</th>
</tr>
</thead>
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<td></td>
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</tbody>
</table>
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Function of AM

Extraradical hyphae of AM fungi
- Function as extension of root
  - Absorb mineral nutrients and provide to the host.
  - Effective to phosphate uptake.
Host / Non-host of AM

- More than 70% of terrestrial plants, including moss (苔), fern (羊歯), can be colonized by AM fungi. **AM Host**

- There are some exceptions. **AM non-Host**
  
  Example of AM non-host plant:
  - Brassicaceae (油菜科) cabbage, radish, rapeseed,
  - Chenopodiaceae (藜科) spinach, sugar beat
  - Polygonaceae (蓼科) buckwheat

Previous crop effect

- AM fungi: Obligate symbiont: cannot proliferate without colonization

[Diagram showing the effect of previous crop on AM population and plant growth.]

- Cultivation of Host plant increases AM population, promoting growth of next AM crops.
- Cultivation of non-host plant decreases AM population, resulting in little growth promotion of next AM crops.
Previous crop effect in Maize

Effect of previous crops on grain yield of succeeding maize in 1991

(Arihara and Karasawa, 2000)

Previous crop effect in soybean

Previous crops
1. Sugar beat (non-host)
2. Cabbage (non-host)
3. Adzuki bean (host)
4. Maize (host)

After AM host plants, phosphate uptake of succeeding soybean is enhanced resulting growth enhancement.
Previous crop effect in various crops

A After non-Host

Soybean

B After Host

Potato

C

D

Onion

E

F

P reduction using previous crop effect

Phosphate uptake by soybean is affected by previous crop.

Oka et al., 2010
Phosphate uptake, AM colonization:
After Host > non Host
Yield:
After Host (?)non Host

After AM host plant, soybean phosphate fertilizer can be reduced without affecting crop yield.
### P reduction in farmers’ fields

#### AM in soybean, farmers’ fields

<table>
<thead>
<tr>
<th></th>
<th>ALL Samples</th>
<th>After AM Host</th>
<th>After AM non-host</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AM (%)</td>
<td>(n)</td>
<td>AM (%)</td>
</tr>
<tr>
<td><strong>All cases</strong></td>
<td>31</td>
<td>(98)</td>
<td>34</td>
</tr>
<tr>
<td><strong>Soil Type</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Andosol</td>
<td>42 a</td>
<td>(28)</td>
<td>50</td>
</tr>
<tr>
<td>Peat soil</td>
<td>28 b</td>
<td>(22)</td>
<td>30</td>
</tr>
<tr>
<td>Lowland/Upland</td>
<td>26 b</td>
<td>(47)</td>
<td>28</td>
</tr>
<tr>
<td><strong>Available P</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 10 mg P2O5/100g</td>
<td>51 a</td>
<td>(7)</td>
<td>48</td>
</tr>
<tr>
<td>10-30 mg P2O5/100g</td>
<td>30 b</td>
<td>(57)</td>
<td>33</td>
</tr>
<tr>
<td>&gt; 30 mg P2O5/100g</td>
<td>28 b</td>
<td>(34)</td>
<td>31</td>
</tr>
<tr>
<td><strong>P Fertilizer</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 70% SFR</td>
<td>41 a</td>
<td>(21)</td>
<td>48</td>
</tr>
<tr>
<td>70% SFR ≤</td>
<td>28 b</td>
<td>(77)</td>
<td>31</td>
</tr>
<tr>
<td><strong>Application</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70% SFR ≤</td>
<td>28 b</td>
<td>(77)</td>
<td>31</td>
</tr>
<tr>
<td><strong>Soil Hardness</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 1.5 MPa</td>
<td>38 a</td>
<td>(40)</td>
<td>43</td>
</tr>
<tr>
<td>1.5 MPa ≤</td>
<td>13 b</td>
<td>(5)</td>
<td>14</td>
</tr>
</tbody>
</table>

* AM colonization rate. The values with different characters indicate significant difference within the categories (p<0.05)

* AM host: wheat, potato, oats, sunflower, soybean, kidney bean, etc. AM non-host: buckwheat, white mustard, sugar beet, etc.

* SFR: Standard fertilizer recommendation
P reduction in farmers field

A) After AM host

B) After AM non-host

Median of yield ratio: maintained after AM host, but decreased after AM non-host when P was reduced for 30-50%

However... There were some cases that yield decreased for 10% even after AM host plant.
P reduction in farmers field

A) After AM host

B) After AM non-host

Phosphate Fertilizer Reduction Rate (%)

Yield Change by P-Reduction (%)

Reduced P / Normal P

P reduction / Applicable condition

Yield decrease by fertilizer reduction was occurred in high-yield field

✓ Fertilizer reduction after AM host is applicable to normal yield case

Yield Level at Stndrd Fertilization (t/ha)

(t/ha)
Phosphate fertilizer reduction affect not only yield but also initial growth of soybean plant

A) 30% P reduction

B) 50% P reduction

Considering the risk of cold weather, it is important to ensure enough initial growth.

⇒ Recommended P reduction rate was set to 30%

P reduction in Maize

Yagi et al., 2014
Summary

✓ Phosphate fertilizer to AM host plant can be reduced when they are grown after AM host plants.
✓ In case of soybean cultivation in Hokkaido, 30% reduction is recommended under normal yield level.
✓ In field maize cultivation in Konsen area, possible reduction level is 20%
✓ When endogenous AM population is low, use of AM inoculum materials would be promising.
On Going Project

- Clarifying environmental and/or host plant factors that affect AM function.
  - Temperature, water relation, cultivars...

- Establishing methods to evaluate endogenous AM population and function.
  - DNA technique, bio-assay...

- Examining compatibility of AM utilizing technique with other agricultural technology.
  - Fungicide application, plowing...

- Establishing methods to effective use of exogenous AM inoculum.

References


Thank you very much for your attention!