SOYBEAN YIELD IS AFFECTED BY PREVIOUS CROPS AND MYCORRHIZAL FUNGAL COLONIZATION UNDER NO P FERTILIZER CONDITION A JAPANESE STUDY WITH APPLICABILITY TO DEVELOPING REGIONS

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ABSTRACT

At present, all phosphoric acid fertilizer materials are obtained from imported phosphate rock, but since the global phosphate rock reserve is decreasing, alternative techniques to supply the plant phosphorus must be developed. Arbuscular mycorrhizal fungi (AMF) symbiotically inhabit the cortical cells of vascular plant roots. These fungi absorb phosphorus and other nutrients from the soil facilitating the uptake of these nutrients by host plants. Utilization of this natural relationship may be beneficial for crop production especially that of leguminous crops whose roots absorb phosphorus poorly as compared with gramineous crops. The maintenance of AMF spore density in field soil is an important criterion for enhancing crop production. AMF spore density and colonization have been shown to increase following the cultivation of AMF host crops. We evaluated how the cultivation of AMF host (wheat) and non-host (rapeseed) crops affects the subsequent soybean crop by assessing AMF spore density and AMF colonization, phosphorus uptake by soybean and yields of soybean over a four-year period. Every year wheat or rapeseed was cultivated from autumn to spring and soybean from spring to autumn under no P_2O_5 fertilizer condition. From the first to fourth year, AMF spore density was higher in the plot after the cultivation of wheat (wheat plot) than in the rapeseed plot. From the second to fourth year, the AMF colonization ratio was higher in the wheat plot than in the rapeseed plot. In the first year, there was no difference in the AMF colonization ratio, growth, and P uptake by soybean plants between the rapeseed plot and wheat plot. However, from the second year to fourth year, AMF colonization ratio, plant growth, and P uptake by soybean in the wheat plot were higher than those in the rapeseed plot. The soybean yields in both plots gradually decreased from the first to fourth year. Furthermore, in the second and the fourth year, soybean yields were higher in the wheat plot than in the rapeseed plot. There was a significant correlation between the AMF colonization ratio and soybean yield. Therefore, we concluded that AMF colonization is not determined by AMF spore density alone, with other factors influencing the AMF colonization of subsequent soybean plants. And that it is important to increase the AMF colonization ratio to increase soybean yield under no P_2O_5 fertilizer condition. And AMF will be useful for P_2O_5 absorption of crops in developing countries.

KEYWORDS

Arbuscular mycorrhizal fungi, Cropping system, No P_2O_5 fertilizer condition, Soybean (*Glycine max* (L.) Merr.), Yield.

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Effects of Winter Crop on Arbuscular Mycorrhizal Fungal Colonization and Subsequent Soybean Yields under No P_2O_5 Fertilizer Condition

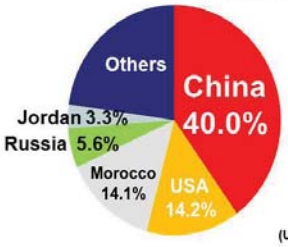
(Nihon University)

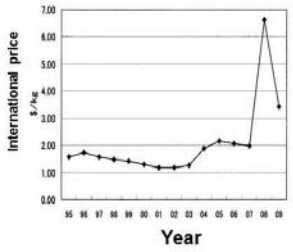
Katsunori ISOBE

1

Phosphate Rock Production in the World

198.0 Million ton (2011)



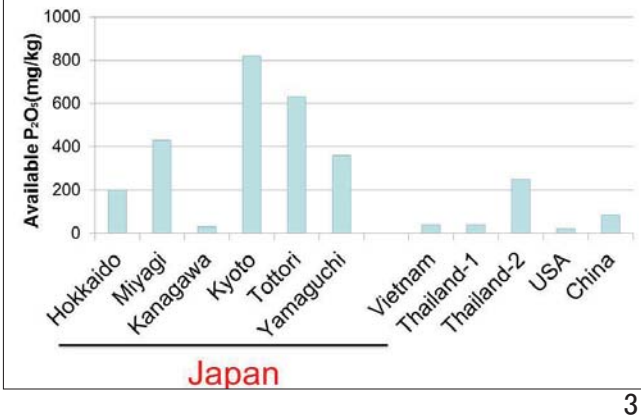


International price of phosphate rock

(USGS 2011)

2

Available P_2O_5 in field soil



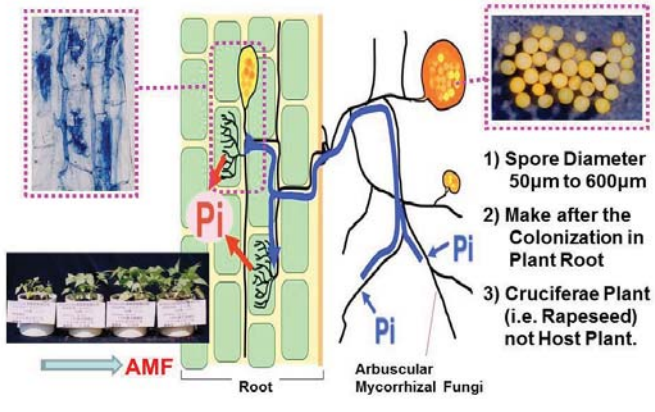
3

Supply of phosphoric acid to crops in the future

- Efficient phosphoric acid fertilizer application method
- Cultivars with efficient phosphoric acid absorption
- Phosphoric acid supply from other materials
- Efficient phosphoric acid absorption from soil

4

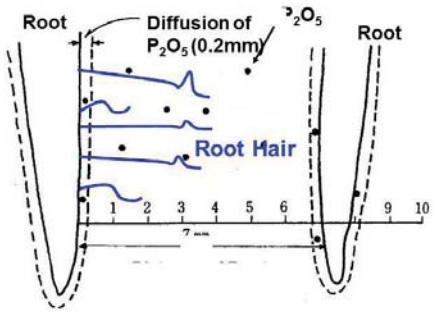
Arbuscular Mycorrhizal Fungi



1) Spore Diameter 50μm to 600μm
2) Make after the Colonization in Plant Root
3) Cruciferae Plant (i.e. Rapeseed) not Host Plant.

5

P_2O_5 diffusion in soil and P_2O_5 absorption by root



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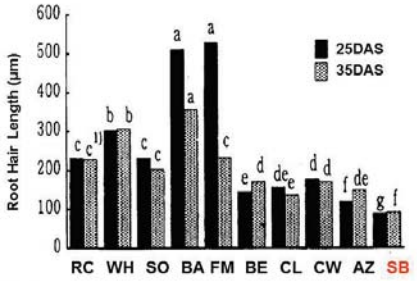
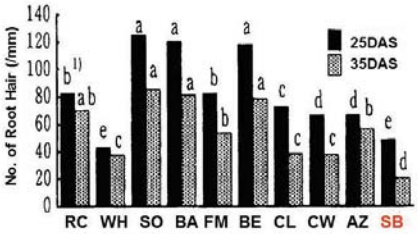
Root Hair Length



RC;Rice, WH;Wheat, SO;Sorgo, BA;Barley, FM;Finger Millet, BE;Bean, CL;Clover, CW;Cowpea, AZ;Azuki bean, SB;Soybean

7

Number of Root Hair



RC;Rice, WH;Wheat, SO;Sorgo, BA;Barley, FM;Finger Millet, BE;Bean, CL;Clover, CW;Cowpea, AZ;Azuki bean, SB;Soybean

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Field experiment purpose & outline

- Purpose -

Establishment of efficient using method of soil phosphoric acid with cropping system and AMF in soybean cultivation

- Outline -

- From 2008 to 2011, cultivated soybean in same field
- No P-fertilizer, N,K-fertilizer application every year
- Andosol (Volcanic soil)
- Rapeseed or Wheat cultivation in winter

9

Effects of the Different Winter Crops with no P fertilizer on the Subsequent Soybean Growth

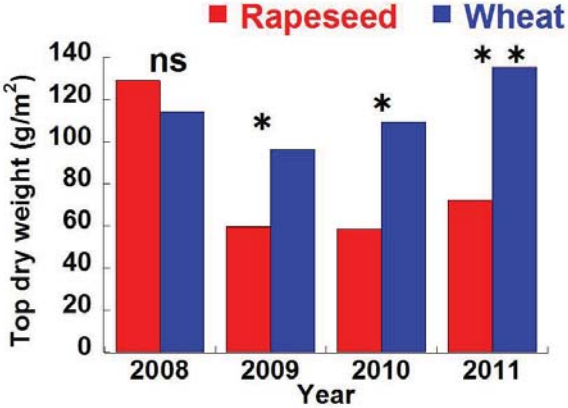
Rapeseed plot

Wheat plot

2008 2009 2010 2011

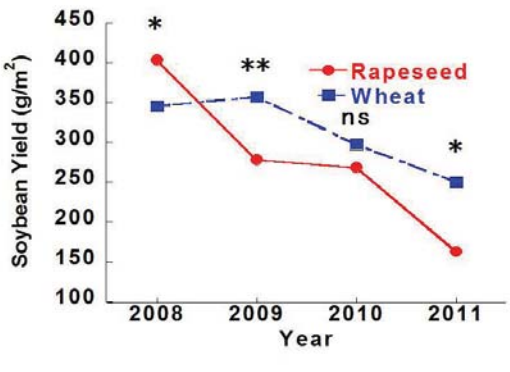
10

Soybean top dry weight at flowering time



11

Effects of winter crops cultivation on the subsequent soybean yield with no P fertilizer



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After Rapeseed or Wheat Cultivation with no P Fertilizer, ・・・

- The growth and yield of soybean decreased sharply (After rapeseed cultivation)
- The growth and yield after wheat cultivation was better than those after rapeseed cultivation.

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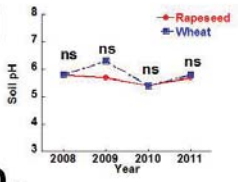
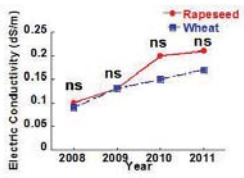
Effects of the Different Winter Crops Cultivation on the soil Chemistry

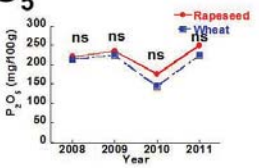
pH



EC



P_2O_5



Soil chemistry (pH, EC, P_2O_5) between two plots was not different.

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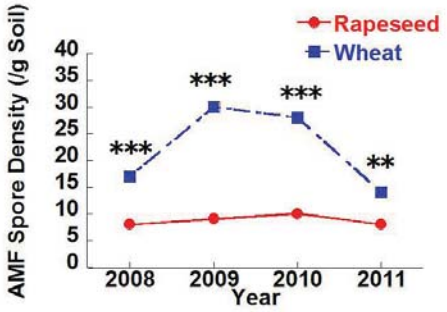
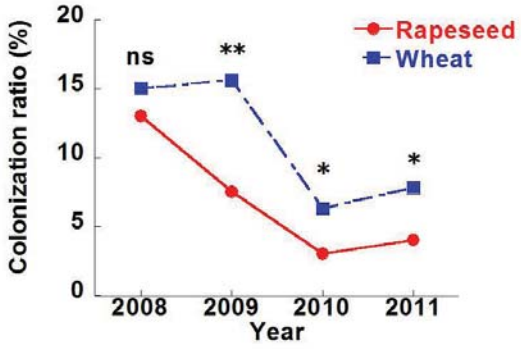
Effects of the Different Winter Crops Cultivation on AMF Spore Density



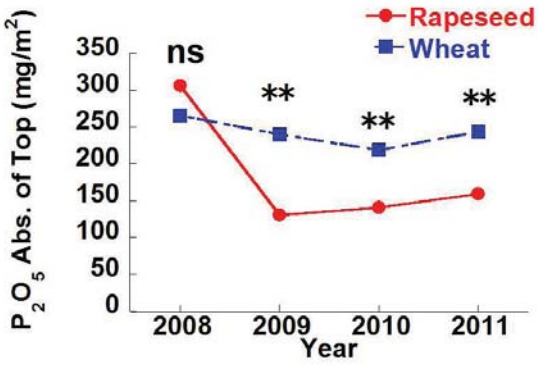
15

AMF Colonization Ratio of Subsequent Soybean Root



16

P_2O_5 Absorption of Subsequent Soybean Top



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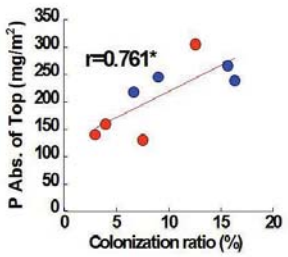
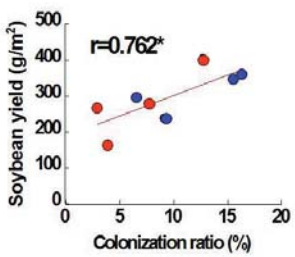
Correlation between colonization ratio and P absorption, soybean yield





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Conclusion

When AMF host plant cultivated before soybean cultivation,・・・

- **The number of AMF spore in soil and colonization ratio of soybean root increased**
- **The soil phosphoric acid was used efficiently in soybean cultivation**
- **The soybean growth and yield became better**

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Chair Tobita: Let us start the afternoon session. This session is about the technologies associated with phosphorus utilization for agriculture production. So, I'd like to introduce the first speaker Dr. Katsunori Isobe. He is from Nihon University, Japan and he is Associate Professor. His expertise is in the area of Crop Science. He worked at Agriculture Research Center, Japan, at Nebraska University, US, and Nihon University also. Today, his presentation title is "Soybean Yield Is Affected by Previous Crops and Mycorrhizal Fungal Colonization under No P Fertilizer Condition, A Japanese Study with Applicability to Developing Regions." Dr. Isobe-san, the floor is yours.

Dr. Katsunori Isobe: Thank you, Dr. Tobita. Good afternoon. It is my great pleasure to be able to speak our research at this symposium. The title of today's presentation is "Effects of Winter Crop on Arbuscular Mycorrhizal Fungal Colonization and Subsequent Soybean Yields under No Phosphoric Acid Fertilizer Condition." Today, I would like to talk about some important problems about the phosphoric acid absorption in crop production.

Phosphoric acid is one of the most important nutrients for plant growth and now most of phosphoric acid fertilizer is made from the phosphate rock. Recently many researchers reported that phosphate rock will be depleted in the near future. This figure shows the production of phosphate rock in the world. In 2011, the total production of phosphate rock was 198 million tons, about 40% of production in China and 14% in the US. Production of phosphate rock is biased in some countries. This means that distribution of phosphoric acid resources is not uniform in all countries. International price of phosphate rock sharply increased from 2008. Now for many countries' farmer it has become difficult to purchase the phosphoric acid fertilizer.

We analyzed the available phosphoric acid content in Japan and many countries' field. In Japan, large amount of phosphoric acid were accumulated in the field soil by long time of fertilization. However, there's lot of low phosphoric acid content soil in the world so productivity of these fields were very low.

Therefore, it is important to provide the phosphoric acid to crops; for example, efficient phosphoric acid fertilizer application method, breeding new cultivars with efficient phosphoric acid absorption, phosphoric acid supply from other materials on behalf of phosphate rock, efficient phosphoric acid absorption from soil.

Arbuscular mycorrhizal fungi are one of the most useful soil microorganisms. When arbuscular mycorrhizal fungi colonized in the plant roots, fungi absorb phosphoric acid from the soil and absorbed phosphoric acid transferred from fungi to host plants. If arbuscular mycorrhizal fungi colonized the plant root, plant growth yield became better. Thus, by utilizing these fungi efficiently, crop can be cultivated without phosphoric acid fertilizer or under low phosphoric acid conditions. Arbuscular mycorrhizal fungi make many spores in the soil. To make spore, arbuscular mycorrhizal fungi must colonize in plant roots. About 80% of land plant is host plants of arbuscular mycorrhizal fungi, but Cruciferae plants, for example rapeseed, is one of not host plants; and after rapeseed cultivation, the number of spore in soil did not increase.

This figure shows the phosphoric acid diffusion in soil and phosphoric acid absorption by plant roots. In soil, diffusion distance of phosphoric acid is within 0.2 millimeters. Plant root can absorb phosphoric acid within only 0.2 millimeters from root surface; therefore, plants cannot absorb almost all of the phosphoric acid in the soil. The root hair is very important for phosphoric acid absorption. When plant extends the root hair in soil, plant can absorb the phosphoric acid more widely. Therefore, we analyzed the root hair number and root hair length of some important crops.

This figure shows the root hair length of various important gramineous and ramineous crops. Plant material is rice, wheat, sorgo, barley, finger millet, bean, white clover, cowpea, Azuki bean and soybean. The root hair length of soybean was shorter than that of the other crops.

This figure shows the number of root hairs per 1 millimeter root length. The number of root hair of soybean was also fewer than that of the other crops. Therefore, soybean is disadvantageous crop for phosphoric acid absorption. In other words, I consider that soybean is one of low productivity crops under low phosphoric soil condition.

We try the field experiment about phosphoric acid absorption and soybean yield improvement to use arbuscular mycorrhizal fungi in soil by host crop cultivation. Then, we cultivate soybean plants continuously in same field from 2008 to 2011 with no phosphoric acid fertilizer. In this experiment, nitrogen and potassium fertilizer were applied every year. With Japanese typical volcanic soil, Andosol, and in winter before soybean cultivation rapeseed, it is non-host plant, or wheat, it is host plant, cultivated in this field every year.

This picture shows soybean plants from first year to fourth year. Soybean picture, the upper rows were after rapeseed cultivation in same field and in lower after wheat cultivation in same field.

In the first year, soybean growth in rapeseed plot and wheat plot were almost same.

However, from second year to fourth year the growth in wheat plots were greater than those in rapeseed plots.

This figure shows the soybean top dry weight at flowering stage. In the first year dry weight of both plots almost same, but from second year the soybean top dry weight of rapeseed plot decreased. On the other hand, that of wheat plots was hardly changed. So from second year to fourth year, the soybean dry weight of wheat plot was higher than that of the rapeseed plot.

This figure shows the soybean yield in this experiment. Red line shows the soybean yield after rapeseed cultivation and blue line shows after wheat cultivation. With no phosphoric acid fertilizer, soybean yield of rapeseed plot sharply decreased from first year to fourth year. The reason of decrease in soybean yield was probably the lack of phosphoric acid for soybean growth. And the yield of wheat plot decreased from first year to fourth year too, but from second year to fourth year soybean yield of wheat plot was higher than that of rapeseed plot. From 2008 to 2011, we cultivated soybean in the same field with no phosphoric acid fertilizer.

In this experiment, rapeseed or wheat were cultivated before soybean cultivation. After rapeseed cultivation, the soybean growth and yield decreased sharply from first year to fourth year. However, after wheat cultivation, soybean growth and yield was better than those after rapeseed cultivation.

Why soybean yields were different between rapeseed plot and wheat plot? At first, we analyzed the soil chemistry after rapeseed or wheat cultivation. Soil pH, EC, and phosphoric acid in both plots were not different every year. From these results, the soil chemistry do not cause of the difference of soybean yield between both plots.

Wheat is host plant of arbuscular mycorrhizal fungi and rapeseed is not host plant. This figure shows the number of spore after rapeseed or wheat cultivation from first year to fourth year. Every year in wheat plot the number of spore higher than those in rapeseed plots.

This figure shows the arbuscular mycorrhizal colonization ratio of soybean root after rapeseed or wheat cultivation. In the first year, there was no significant difference between rapeseed plot and wheat plot. However, from second year to fourth year colonization ratio were much higher in wheat plot than in rapeseed plots. The reason of higher colonization ratio of wheat plot might be the increasing of arbuscular mycorrhizal fungi spore by the host plant cultivation.

This figure shows the phosphoric acid absorption of soybean after rapeseed or wheat cultivation. In the first year, there was no difference between both plots. In second year that of rapeseed decreased from first year; however, that of wheat plot is like same to first year. So from second year to fourth year the phosphoric acid absorption were much higher in wheat plots.

We clarify what did determine phosphoric acid absorption soybean growth and yield. The amount of phosphoric acid absorption and soybean yield were positively correlated with arbuscular mycorrhizal fungi colonization ratio. From this result the difference of phosphoric acid absorption soybean growth and yield between both plots caused by the difference of colonization ratio. When arbuscular mycorrhizal fungi utilized efficiently, crop production might be improved in low phosphoric acid condition.

To sum up, when host plant of arbuscular mycorrhizal fungi cultivated before soybean cultivation, the soybean phosphoric acid used efficiently and soybean growth and yield became better in no phosphoric acid fertilizer condition.

I hope our research will be the model case of crop production in phosphoric acid deficient soil in the world. Thank you.

Chair Tobita: Thank you, Dr. Isobe-san. I think he had clearly showed us the mechanism of phosphorus absorption mechanism enhancement mechanisms and he presented also a strong evidence of this mechanism in soybean cultivation in Japan. Okay, thank you very much. We have enough time to have several comments and questions from the audience. Could you raise your hands? Yes.

Mr. Osato: Thank you very much, a great presentation. My name is Osato. I am afraid my question is too fundamental, but from your figures number of root hairs decreased in 35 days after sowing than the 25 days after sowing. I am afraid would 10 days later less than…

Dr. Katsunori Isobe: Yeah.

Male Questioner: I cannot understand. Of course, more hair root is better to invite the phosphorus.

Dr. Katsunori Isobe: Yeah, thank you. Our data is each crop average of 10 cultivars, but if different condition, root hair length or number may be changed. I think so, okay.

Chair Tobita: Any other questions? Yes, Watanabe-san. Microphone, please use it.

Dr. Takeshi Watanabe: My name is Watanabe, JIRCAS. Thank you very much for your interesting presentation. Unfortunately, wheat does not grow well in tropical region. So, as alternative crop, as host of AMF, could you tell me some alternative AMF host crop or host plant?

Dr. Katsunori Isobe: On behalf of wheat, yeah, tropical host plants, yeah. For example, sorgo and corn, it is host plant and to make many spores in soil, yeah. Okay?

Chair Tobita: Any other questions related with this? So, we should have some perspective of this mechanism to the tropical area or developing regions. Okay. From the chairman, what is the perspective of this mechanism of AMF to enhance the P absorption on the crops to the developing regions? If you have any idea, so could you…

Dr. Katsunori Isobe: Every time host plant introduced is very important to keep the density of arbuscular mycorrhizal fungi. If use non-host plants, interaction of host plant of non-host plants, it is important to cultivation in tropical area. I think so.

Chair Tobita: Okay. Thank you. Okay, thank you very much. Just time up.