Introduction

Ensuring a sustainable supply of safe food is currently the most important strategy for coping with the increase in global population. There are, however, concerns about exhaustion of the world's resources of rock phosphate, a critical input for food production. Therefore, studies on the effective use of phosphorus resources have been performed in various scientific fields. We have been investigating the development of technologies allowing plants to dissolve and absorb from insoluble phosphate in the soil. This experiment investigated a mechanism of response by plants to low-phosphorus conditions, specifically plants sensitive to phosphorus deficiency, that dissolve otherwise insoluble phosphate.

Materials and Methods

Experiment 1: Ten species of plants were grown under the P deficient conditions for comparison of their growth with that of plants grown on P sufficient conditions. Although the growth of all the plants investigated was inhibited to some degree in the P deficient condition, buckwheat (*Fagopyrum esculentum*) and kenaf (*Hibiscus cannabinus*) showed relatively better growth. On the other hand, the growth of sweet basil (*Ocimum basilicum*) and red clover (*Trifolium pretense*) was significantly reduced.

We defined buckwheat and kenaf, which showed relatively good growth under P deficient conditions, and sweet basil and red clover, whose growth was significantly inhibited under these conditions (Figure 1). Therefore, we selected these four plants, and used it for following experiments. Four treatments were applied: a 1:5 dilution of Hoagland's culture medium (pH 5.5) containing 12.4 mg L^{-1} of phosphorus as standard, 2:3 and 1:3 dilutions of the standard phosphorus concentration, and a no-phosphorus culture medium. The relationship between growth and phosphorus content in the plant biomass was then investigated.

Experiment 2: Buckwheat and kenaf, which show growth inhibition under low-phosphorus conditions in the root environment; and sweet basil and red clover in which growth is considerably reduced by phosphorus deficiency in the plant biomass, were used to investigate the relationship between addition of insoluble phosphate to the culture medium and their growth. Three treatments were applied to compare the phosphorus content in the plant biomass with the degree of growth inhibition: a 1:5 dilution of Hoagland's culture medium (pH 4.4) as standard, a culture medium with the same nutritional composition, only without phosphorus, and a hydroponic medium to which aluminum orthophosphate ($AlPO_4$) had been added instead of soluble phosphate. Sweet basil showed the highest ability to dissoluble $AlPO_4$. The mechanism by which it dissolves $AlPO_4$ was then investigated.

Results and discussion

The plant species used were classified into two types: plants showing less growth inhibition under low-phosphorus conditions in the root environment, and those in which growth was markedly reduced by phosphorus deficiency in the plant biomass. The former group includes buckwheat and kenaf, with sweet basil and red clover in the latter category. On the other hand, growth inhibition was minor in buckwheat and kenaf under low phosphorus condition,

whereas the growth of sweet basil and red clover was significantly reduced (Figure 2). The results from both experiments revealed growth to be greatly reduced under acidic conditions in those plants that showed significant growth inhibition due to low phosphorus levels in the plant biomass (Data not shown). It appears that one factor determining growth under acidic conditions is a difference in sensitivity to phosphorus deficiency.

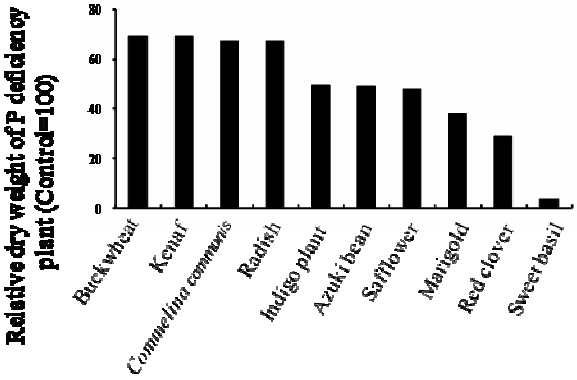

Figure 1. Influence of P deficiency to growth of various plants

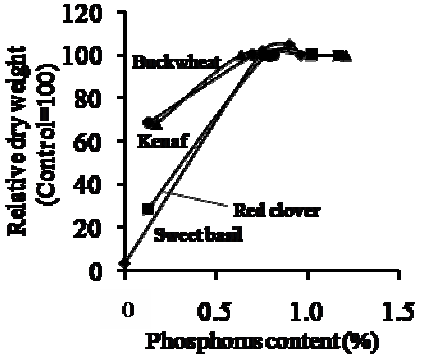

Figure 2. The relationship between growth and phosphorus content in the plants

On the other hand, although the growth rate of all the four plant species investigated was regained by adding $AlPO_4$, even under phosphorus-deficient conditions, the degree of recovery varied according to species (Figure 3). For example, sweet basil, which showed the

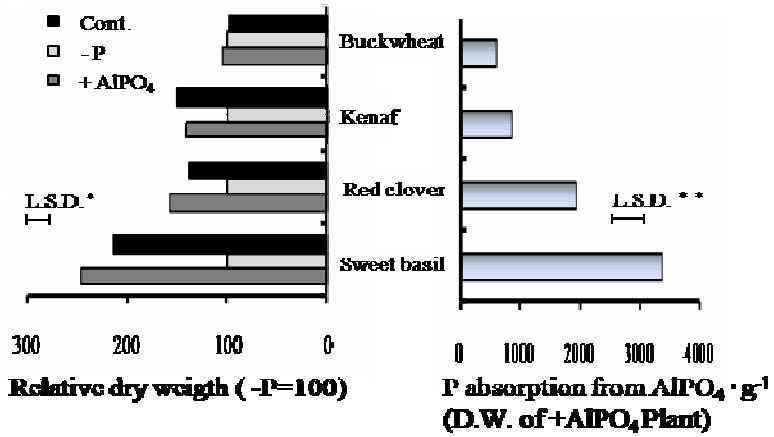

Figure 3. The relationship between recovery growth by addition of $AlPO_4$ and P absorption from $AlPO_4$
*P>0.05, **P>0.01, ***P content [(+$AlPO_4$)−(-P)] / D.W. of +$AlPO_4$

highest rate of phosphorus absorption from $AlPO_4$, showed a dramatic recovery in growth (Figure 4). When the amounts of $AlPO_4$ dissolved by substances secreted from the roots were compared among these plants, $AlPO_4$ solubility was lower in buckwheat and kenaf and higher in red clover and sweet basil. Very high $AlPO_4$ solubility was observed in sweet basil (Figure 5). We conclude that plants with a higher requirement for phosphorus release greater amounts of substances that dissolution otherwise insoluble phosphates such as $AlPO_4$ to ensure their growth.

We also investigated the substances secreted from the roots of sweet basil, a species sensitive to phosphorus deficiency, that dissolves $AlPO_4$ and report several additional findings.

Figure 4. Effects of $AlPO_4$ supply on the growth of P deficiency sweet basil

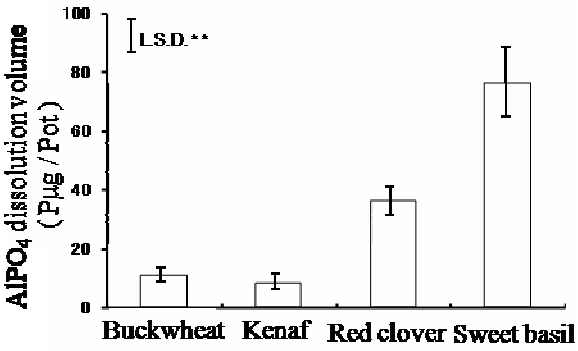

Figure 5. Amount of $AlPO_4$ dissolution by root exudates from P deficiency plants $^{**}P < 0.01$

References

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