Effects of waterlogging on root system of soybean

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Abstract

A problem in soybean culture in Japan is excessive soil moisture and waterlogging, because soybean is often grown in field converted from lowland paddy field. Growth of taproot and its lateral roots is suppressed by waterlogging, while formation of adventitious roots is promoted. Thus, soybean plants often form shallow root system under waterlogging conditions. Molding may be an effective management to avoid waterlogging stress. Adventitious roots develop well in the gathered soil of molding, which results in quick recovery of root activity after waterlogging evaluated by bleeding rate.

Media summary

Waterlogging prohibits the growth of taproot but often promotes adventitious root formation in soybean. Soil molding alleviates waterlogging stress with enhancement of adventitious root formation.

Key Words

Soybean (*Glycine max* (L.) Merr.), Waterlogging, Adventitious root, Molding, Bleeding rate

Introduction

Soybean (*Glycine max* (L.) Merr.) is one of the most important oil crop and also used for numerous traditional foods in Japan, consumed approximately five million tons per year. The Japanese self-production of soybean, however, is only 5% (as of 2000), whereas Japan has an economic problem of overproduction of rice. Thus, conversion of lowland paddy fields to upland soybean field is encouraged by Japanese government. A problem of soybean culture in such fields converted from paddy fields is excessive moisture with high water table in soil, sometimes even with flooding after heavy rain.

Because the root is the plant organ which is directly exposed to oxygen deficiency and soil reduction caused by waterlogging, studies on the effects of waterlogging on the growth and activity of root system should contribute to the establishment of adequate management to alleviate the waterlogging stress in soybean culture.

In this paper, influence of waterlogging on the growth of taproot and the formation of adventitious roots is discussed. In addition, effects of molding treatment in soybean culture to avoid and recover from waterlogging are evaluated.

Effects of waterlogging on root growth

Soybean is relatively tolerant to waterlogging among upland crops, but its growth is suppressed in anoxic conditions. Root system of soybean usually becomes shallow under waterlogged conditions (Sallam and Scott 1987, Scott et al. 1989).

Figure 1 shows root system of soybean seedlings grown in vermiculite with and without waterlogging. Germinated soybean seeds (cv. Enrei) were sown in vermiculite in 1/ tall beakers following the growing methods of pea seedlings (Niki and Gladish 2001). The tall beakers were flooded with water up to the surface of vermiculite 3 days after sowing. The root system was washed out of the vermiculite on 5 days after sowing. Axis elongation of taproot was clearly inhibited by two-day treatment of waterlogging. Distribution of soybean roots in soil is defined by growth direction and final length of axis and long 1st-order lateral roots of taproot. Thus, inhibitive effect of waterlogging to elongation of axis and lateral roots of taproot results in shallow distribution of soybean root system.

In addition, waterlogging often enhances formation of adventitious roots, which mostly develop in shallow soil layer. Figure 2 shows roots of soybean plants (cv. Enrei) grown in pots (30cm in diameter and 30cm deep) with Andosol soil. Adventitious roots emerged from basal part of stems in waterlogged conditions and considerably contributed to whole root mass. The adventitious roots may be adaptive to waterlogged conditions because of better accessibility to aboveground oxygen.

Molding as a possible management to avoid waterlogging stress

Molding is the practice to gather soil to plant row making ridge-like soil mold during plant growth. Molding is a common management to improve plant growth and yield, although the scientific knowledge of its effects, in particular on root physiological activity is limited. Furubayashi et al. (2002) treated field-grown soybean (cv. Enrei) with and without modling in 2001 and 2002, in which the precipitation during the growth period is insufficient and sufficient, respectively. With molding, large amount of adventitious roots developed in the gathered soil, while root biomass below the gathered soil (mostly, tap root system) was rather decreased. Activity of whole root system of soybean was evaluated by bleeding rate, which is the amount of xylem sap per hour exuded from cut stem of detopped plant by root pressure. Molding treatment increased bleeding rate in late stage of plant growth and grain yield in both years. The high root activity indicated by bleeding rate in plants treated with molding is probably due to the large proportion of adventitious roots in the root system, because bleeding rate was much declined by pruning of adventitious roots in gathered soil (Morita et al. 2001).

Molding may be an effective management to avoid waterlogging stress. Furubayashi. et al. (2004) compared the growth of soybean with and without molding during and after 20-days waterlogging. Molding increased total root length of soybean under waterlogging because of well development of adventitious roots in gathered soil. Bleeding rate and shoot growth (e.g., shoot dry weight, leaf area) were not affected by molding during the waterlogging period, but their recovery after waterlogging was earlier in plants with molding. More field studies may be necessary to confirm the positive effects of molding to alleviate waterlogging stress, because this experiment (Furubayashi et al. 2004) was conducted only in a loamy Andosol field.

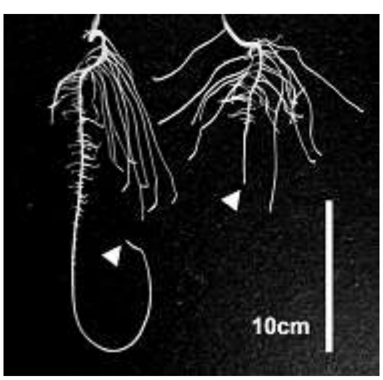
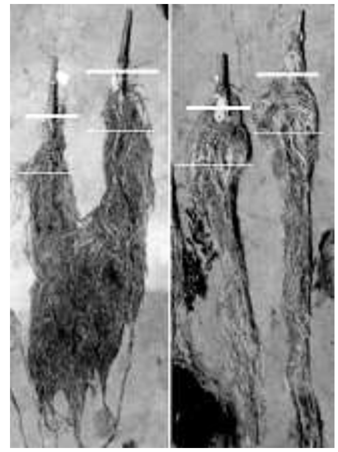


Figure 1. Root system of 5-day old soybean seedlings grown in vermiculite with/without waterlogging. White arrowheads: apex of the axis of taproot. Left: control (grown in vermiculite with 30% v/v water content). Right: waterlogged for two days.

A: Zoomed up view of the soil surface. Numerous fine roots appeared on the soil surface after waterlogging for 20 days. White arrows indicate new adventitious roots emerged from basal part of stems



B. Root system washed out of soil. Thick white bars: soil surface. Thin white bars: base of stems. Adventitious roots emerged from the part of stems between the thick and thin bars. Left=control, Right=waterlogged.

Figure 2. Roots of soybean gown in flooded soil in a pot experiment.

Conclusion

Adventitious roots probably play an important role for the tolerance to waterlogging in soybean. Molding before rainy period can be a possible management to alleviate waterlogging stress, because it enhances adventitious root formation in gathered soil. Root nodulation in adventitious roots should be considered in further studies because root nodules could much affect nitrogen balance in soybean plants.

References

Furubayashi S, Abe J, Morita S and Yamagishi J (2002). The effect of molding treatment on the growth, yield and bleeding sap rate of soybean (*Glicine max*) in two years with different precipitation. Bulletin of Kanto Branch of the Japanese Journal of Crop Science 17, 60-61. *in Japanese*

Furubayashi S, Abe J and Morita S. (2004). The effects of molding on the growth of soybean (*Glycine max* Merr.) under flooding condition. Japanese Journal of Crop Science 73 (Extra issue 1), in press. *in Japanese*

Morita S, Furubayashi S, Abe J and Yamagishi J (2001). The effect of molding treatment on bleeding sap rate in soybean (*Glycine max*). Bulletin of Kanto Branch of the Japanese Journal of Crop Science 16, 44-45. *in Japanese*

Niki, T. and Gladish D. K. (2001). Changes in growth and structure of pea primary roots (*Pisum sativum* L. cv. Alaska) as a result of sudden flooding. Plant Cell Physiol. 42:694-702.

Sallam A and Scott HD (1987). Effects of prolonged flooding on soybeans during early vegetative growth. Soil Science 144, 61-68.

Scott HD, DeAngulo J, Daniels MB and Wood LS (1989). Flood duration effects on soybean growth and yield. Agronomy Journal 81, 631-636.