Growth of Root Systems and Changes in Phloridzin Content in Fibrous Roots of Container-grown Apple Transplants©

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We previously reported that the root respiratory activity in apple transplants coincided with the growth pattern of the root system and those of container-grown apple transplants were lower than field-grown transplants. The present report focuses on a phenolic compound (phloridzin) known as an allelopathic substance in the fibrous root of transplants grown in different container types: a black polyethylene container and an air-pruning container.

INTRODUCTION

It is well known that plants respond to environmental and physical stresses such as desiccation, wounding, and infection, by producing and excreting phenolic compounds (secondary metabolites). In addition, several phytotoxic compounds, i.e., ethanol, fatty acids, and cyanogenic compounds, are produced in plants when soils are flooded. Container-grown plants grow well as long as nutrients and moisture are available. However, there have been a number of problems with container-grown plants: low air-filled-porosity soil has resulted in the development of pathogenic fungi and root systems in plastic pots develop root spiraling. To alleviate these problems, a large number of innovations have been developed including air-pruning containers (Karlsson, 1997). This study was carried out to compare root growth and phenolic compounds extracted from roots in air-pruning and conventional containers with container-grown apple transplants. We previously reported that root respiratory activity in apple transplants coincided with the growth pattern of the root system and those of container-grown apple transplants were lower than in field-grown transplants (Nakamura et al., 1999). In this study, seasonal changes in phenolic compounds in fibrous roots were investigated from apple plants grown in the above mentioned container types and in the field as a control.

MATERIALS AND METHODS

One-year-old *Malus domestica* 'Fuji' transplants grafted onto *M. prunifolia* var. *ringo* were used for this experiment. They were planted in the two different containers (diam. 25 cm) and in the field. Cumulative new shoot growth was investigated and root system growth was also recorded when the transplants were dug at 2- or 4-week intervals; results were expressed as total freshweight. After fresh weight was determination, the fiberous roots were immediately separated and used for phenolic compound analysis. Lyophilized samples from the fibrous root masses were extracted with 70% aqueous acetone for 3 h under 40°C with 8.6 mM ascorbic acid added to prevent development of oxidative product. Each extract was employed for qualitative and quantitative analysis using the HPLC method; an

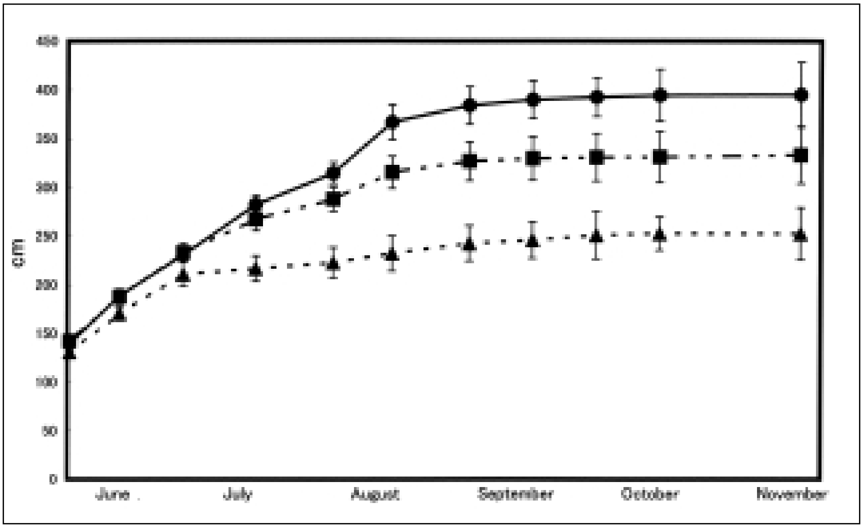

Figure 1. Growth of current shoot on apple transplants grown in either an air-pruning (-■-) or black polyethylene container (-▲-) as compared with that of field grown-transplant (-●-).

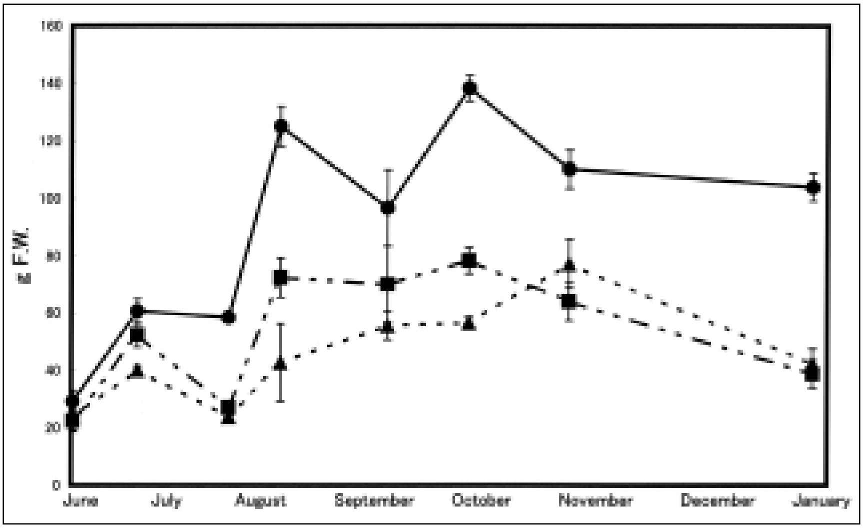

Figure 2. Change in amount of root systems on apple transplants grown in either an air-pruning (-■-) or conventional container (-▲-) as expressed by fresh weight. Roots taken from field-grown transplant was used as a control (-●-).

ODS column kept at 40°C with an acetic acid/acetonitrile gradient system was used as the mobile phase at 1.0 ml per minute flow rate.

RESULTS

The most well-developed root systems were found on apple transplants grown in the field, followed by the air-pruning container, and lastly the black poly container whose root development was approximately one-half of the field-grown transplants (Fig. 2). The current shoots grew until the end of July, however, the growth rate was different for each treatment with the black poly container being the poorest (Fig. 1). From HPLC analysis, the following phenolic compounds were identified: phloridzin, phloretin, *p*-hydroxyhydrocinnamic acid, phloroglucinol, and *p*-hydroxybenzoic acid. Phloridzin was the dominant compound. As shown in Fig. 3 the seasonal change in phloridzin content in fibrous roots exhibited two peaks in June corresponding with conspicuous root growth and in the dormant period (mainly from mid-September towards winter). A very low content of phloridzin was recorded during summer; other phenolic compounds showed similar patterns with slight differences. The content of phenolic compounds was higher in the roots of field-grown transplants than container-grown plants regardless of the type of container. However, phloretin, a breakdown product from phloridzin, was much higher in the case of the black-poly, container-grown transplants than those of field or air-pruning container even though the amount was not considerable. These results occurred even when other phenolic compounds were present in a small amount in the fibrous root (Fig. 4).

DISCUSSION

Phenolic compounds can be released by root cells in large amounts, both as a result of degradation of cell walls and from intracellular compartments, and these compounds result in a diversity of chemical reactions in the rhizosphere (Marschner, 1995). These phenolic compounds are thought to have allelopathic inhibitory effects on replanted young plants. Previously, Börner (1959) reported the inhibitory effect of extracts from tissue of apple on the growth of *M. baccata* when applied to its hydroculture medium and postulated that phloridzin might be a cause bringing about the replant problem in apples. Other compounds such as phloretin, *p*-hydroxyhydrocinnamic acid, phloroglucinol, and *p*-hydroxybenzoic acid were found as decomposition products of phloridzin. Similarly, allelopathic substances have been shown in walnuts as quinones (Davis, 1928), in peach as cyanides (Ward and Durkee, 1956), and in ragweed as phenolics (Jackson and Willemsen, 1976). Our results showed not only phloridzin but the other phenolics were present in extracts from fibrous roots throughout the experiment and this did not coincide with Börner's findings.

Seasonal changes in the content of phenolic compounds in flower buds has been shown in Elberta peach; the peak of content was in November and related to the induction of dormancy (El-Mansy and Walker, 1969). Although the organ was different, the changes in phenolics were similar to this experiment. Our previous report (Nakamura et al., 1999) on root respiratory activity of apple transplants showed a much higher value in June and a subsequent decline by August. Respiration occurs in all living cells, above and below ground, under all kinds of conditions. Therefore, the contents of phenolic compounds could be found in fibrous roots in June as high as that in this experiment. The air-pruning container used in

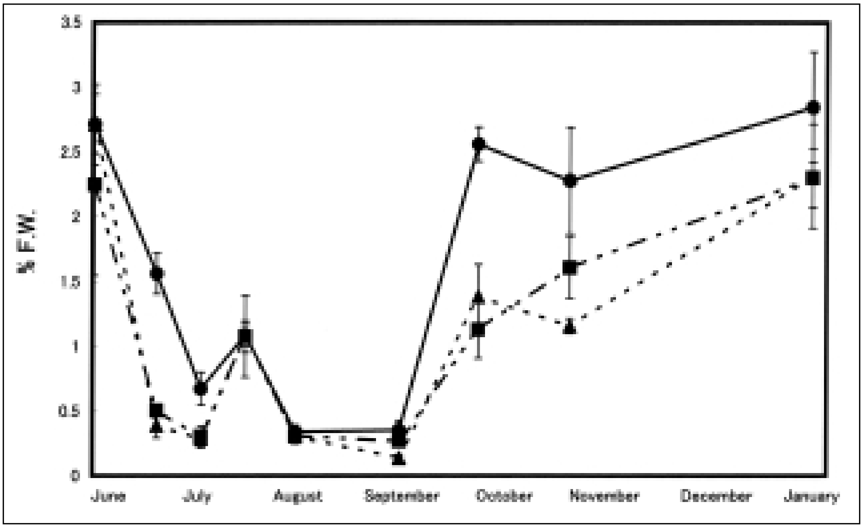

Figure 3. Seasonal change in phloridzin content in fibrous root; (-■-), air-pruning aimed-container; (-▲-), conventional container; (-●-), control.

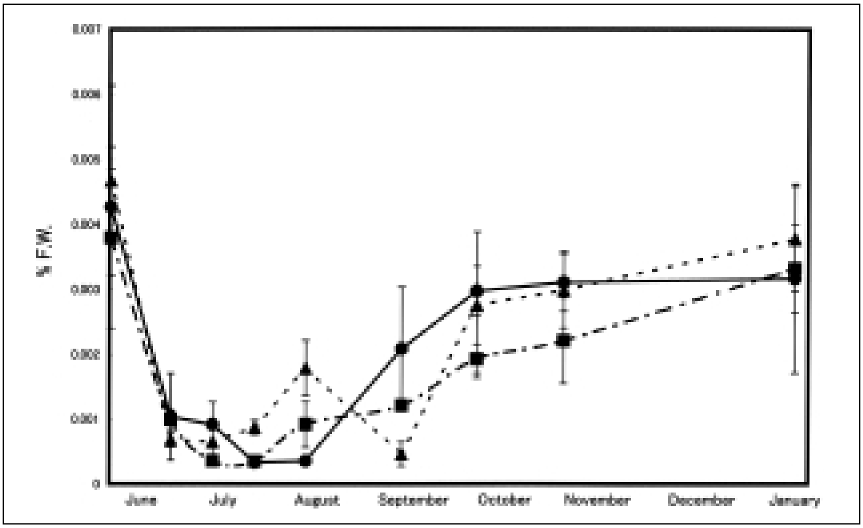

Figure 4. Seasonal change in phloretin content in fibrous root; (-■-), air-pruning aimed-container; (-▲-), conventional container; (-●-), control.

this experiment produced better root growth and lower content of phenolic compounds in the fiberous roots when compared to conventional containers in which phloretin existed even in August. It is possible that the poor development of root systems in the case of the conventional container was due possibly to harmful effects of either phloridzin or phloretin.

LITERATURE CITED

Börner, H. 1959. The apple replant problem. I. The excretion of phlorizin from apple root residues. Contributions Boyce Thompson Inst. 20:39-56.

Davis, E.F. 1928. The toxic principle of *Juglans nigra* as identified with synthetic juglone and its toxic effects on tomato and alfalfa plants. Amer. J. Bot. 15:620.

El-Mansy, J.H. and D.R. Walker. 1969. Seasonal fluctuation of flavonones in Elberta peach flower buds during and after termination of rest. J. Amer. Soc. Hort. Sci. 94:298-301.

Jackson, M.B. and **R.W. Willemsen.** 1976. Allelopathy in the first stages of secondary succession on the piedmont of New Jersey. Amer. J. Bot. 63:1015-1023.

Karlsson, S. 1997. Containerized forestry seedling production from a historical perspective. Comb. Proc. Intl. Plant Prop. Soc. 47:123-124.

Marschner, H. 1995. Mineral nutrition of higher plants, 2nd ed., Academic Press, London. **Nakamura, T., S. Sugaya,** and **H. Gemma.** 1999. The growth and respiratory activity of root systems on pot-grown apple transplant. Comb. Proc. Intl. Plant Prop. Soc. 49:649.

Ward, G.M. and **A.B. Durkee.** 1956. The peach replant problem in Ontario. III. Amygdalin contents of peach tissues. Can. J. Bot. 34:419-422.