ハナモモ実生苗における断根処理後の根量の静電容量計測による非破壊的推定法

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A nondestructive method for estimating the root mass of young peach trees after root pruning using electrical capacitance measurements

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Abstract

The objective of this study was to estimate the root mass of young ornamental peach seedlings using nondestructive measurements of electrical capacitance (EC). We measured the root mass of peach seedlings to determine the relationship between EC and the root mass. Ornamental peach seedlings grown the field in Andosol showed good linear correlations between EC and root dry mass (R^2=0.896), and EC and fresh mass (R^2=0.897). Similar correlations (R^2=0.806 for dry mass) were observed in an experiment with Japanese pear rootstocks. A study of the root mass and the root EC before and after root pruning treatment showed that this technique can detect the reduction in root mass in young peach trees (R^2=0.669). The study results also indicate that the EC method may be a feasible, repeatable, and useful nondestructive means of estimating the root mass (fresh or dry) of peach trees.

Key words: Electrical capacitance (EC), LCR meter, Ornamental peach (*Prunus persica* (L.) Batsch), Root mass, Root pruning.

1. Introduction

Woody perennials undergo a juvenile stage before reaching the reproductive stage. Various treatments, such as phytohormones, growth retardants, and culture conditions (including physical constraints and grafting), have been investigated to shorten the juvenile phase (Meilan, 1997). Increasing the growth rate of the young seedling can often shorten the juvenile period (Zimmerman, 1971; Aldwinckle, 1975), because a minimum size must be attained before the tree reaches its adult state (Zimmerman, 1972).

The ornamental peach 'Yaguchi' usually takes 3 years to flower. To hasten the breeding process, we attempted to induce seedlings to flower within 1 year of germination via various methods, such as early sowing and pruning roots to control root growth. Root pruning treatments were more effective in inducing early flowering (Tsukahara *et al.*, 2006, 2007). To investigate the appropriate root mass to be pruned to induce flowering, a nondestructive field measurement method for the root mass must be established with sufficient accuracy.

The electrical capacitance (EC) of root systems correlates well with the root dry weight (Kendall *et al.*, 1982; Dalton, 1995; van Beem *et al.*, 1998). The root EC method may offer a nondestructive and rapid method for estimating root mass. Psarras and Merwin (2000) applied the root EC method to a woody species, *i.e.* young potted apple trees. However, the relationship between root mass and the EC of peach root systems has never been reported. Recently, Morinaga *et al.* (2006) applied for a patent for a method to measure Satsuma mandarin plants using an LCR meter. The objective of this field study was to develop a simple calibration relationship that would estimate the root mass for young ornamental peach seedlings using nondestructive EC measurements. To determine whether field measurements of root EC can detect differences in root mass after root pruning, we

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investigated the relationship between the root EC and the reduction in root mass after root pruning treatments in young peach trees.

2. Materials and Methods

2.1 Plant Materials and Growth Environment

Ornamental peach (*Prunus persica* (L.) Batsch) seedlings, cultivars 'Ohatsumomo', were sown in an outdoor nursery at Utsunomiya University in mid-March, 2007. Before sowing, the seeds were stratified for 2 months at 5℃. The soil was Andosol (Kuroboku soil).

We also used 3-year-old Japanese pear trees (*Pyrus pyrifolia* Nakai) 'Kousui' grafted on pear rootstocks (*Pyrus betulaefolia* Bunge) for experiments. They were used for comparative experiments with the same family Rosaceae. These trees were grown in the nursery.

2.2 Electrical Capacitance Measurement

The root EC method measures the electrical capacitance of an equivalent parallel resistance-capacitance circuit formed by the interface between soil-water and the plant root surface. There is a correlation between the electrical capacitance and the surface area of root portion of the plant body (Dalton, 1995).

The electrical capacitance (EC: Unit=pico farad (pF)) was measured using an ELC-133A portable LCR meter (Escort Instrument Corp., USA) at frequency of 1 kHz as described by Morinaga *et al.* (2006), while the soil was watered to field capacity by around 45 minutes prior to the EC measurements.

For the nursery measurements (Ex. 1), a steel rod was inserted 20 cm into the soil, 10 cm away from the base of the peach stem, while the positive lead of the LCR meter was attached to the steel rod above the soil, and the negative lead to a steel needle inserted in the stem 3.5 cm above the soil surface (Fig. 1A).

For the potted tree measurements (Ex. 2), a steel rod was inserted 12 cm into the soil, 6 cm away from the base of the stem, while the negative lead was attached to a steel needle inserted in the stem 5 cm above the soil surface.

2.3 Experimental Design and Conditions

2.3.1 Root Pruning Treatment (Ex. 1)

In early November, 2007, EC was measured in 27 'Ohatsumomo' trees. After taking the first set of EC readings in the nursery, the root system of each seedling was pruned in a semicircle within a radius of 10 cm of the central axis of each root system in a circle furrow, to a depth of 25 cm (Fig. 1B). After semi cylindrical root pruning, the removed roots were washed thoroughly, and the fresh and dry root masses were determined. The second EC measurement was carried out in the same manner, then the root system was pruned in the remaining semicircle as described above (Fig. 1B), and the EC values of the cylindrically pruned trees were measured. After the last set of EC readings, the trees were destructively sampled. The shoots, leaves, and roots of each tree were weighed (fresh mass), oven-dried at 60℃ for 1 week, and reweighed to determine the dry mass.

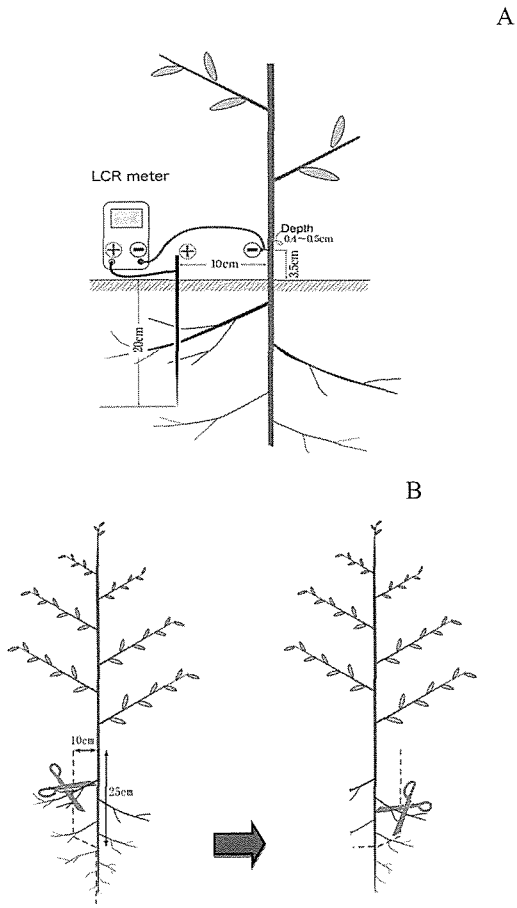

Fig. 1. A: System used for peach root EC measurement. B: Illustration of the root pruning treatment.

2.3.2 Potted Tree Measurements (Ex. 2)

In summer, 2007, EC of 18 Japanese pear 'Kousui' trees were measured as described above.

Two sets of EC readings were taken in late June and early July in the same manner as described above, using the same trees. After the EC measurements were taken, each tree was harvested to determine the fresh and dry mass.

2.4 Statistical Analysis

Simple regression analysis was carried out to relate EC to both dry and fresh mass.

3. Results and Discussion

3.1 Electrical Capacitance and Root Pruning (Ex.1)

In the 'Ohatsumomo' seedlings root pruning experiment, good correlation was observed between the root dry mass before and after the pruning treatment (Fig. 2). Approximately 20% of the root dry mass was removed after the first semi cylindrical pruning, while the remaining root dry mass was halved by the cylindrical pruning. Similar results were obtained for the root fresh mass.

A portable EC meter was used to quantify the root mass under field conditions and we analyzed the root EC data before the roots of 'Ohatsumomo' were pruned (n=27) (Fig. 3). A simple linear regression showed a strong positive correlation between the root EC and the root fresh mass (R^2=0.897), and EC and the root dry mass (R^2=0.896). Equations (1) and (2) show the statistical results for root fresh and dry mass, respectively:

$$RFM = -14.90 + (0.200 \times EC) \quad (1)$$

$$RDM = -5.496 + (0.089 \times EC) \quad (2)$$

Where RFM is the root fresh mass (g), RDM is the root dry mass (g), and EC is the root EC (pF).

Our results agree with those of Preston *et al.* (2004), in which EC predicted the root mass in young hybrid poplar trees. Our results also indicated that EC correlates positively with the dry weight of whole 'Ohatsumomo' seedlings (Fig. 4). This may be due to the uninterrupted well-balanced growth of shoots and roots in unregulated culture conditions.

Morinaga *et al.* (2006) reported in their invention that the EC was correlated with both the root weight and total plant weight for Satsuma mandarin trees. They also noted that the invention was not limited to any specific example, although it was described using a specific sample.

The results of our field study indicate that the EC method is an acceptable and useful nondestructive method for estimating the fresh and dry root mass of

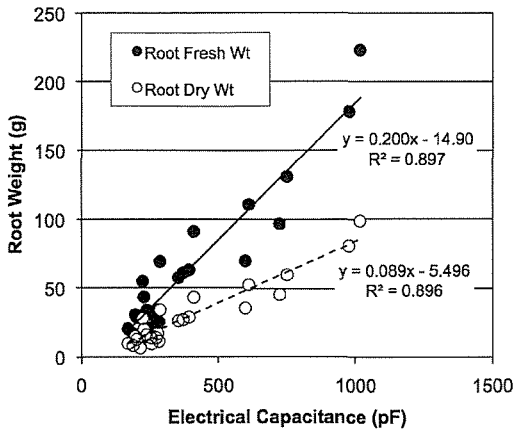

Fig. 3. Relationship between root mass and EC for ornamental peach 'Ohatsumomo' trees under field conditions (2007).

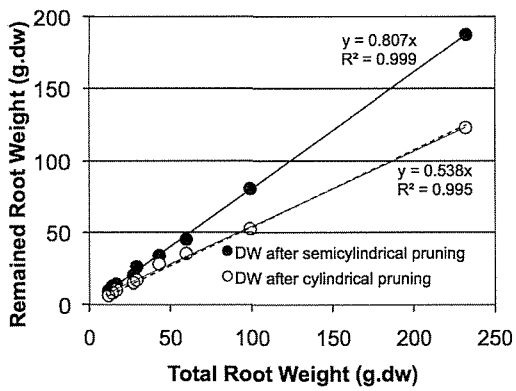

Fig. 2. Relationship between ornamental peach 'Ohatsumomo' remained root dry mass before and after root pruning treatment (2007).

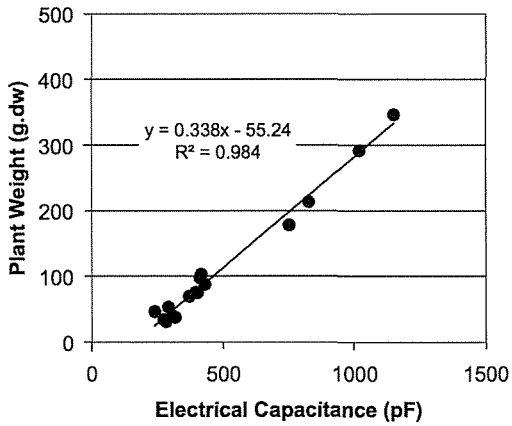

Fig. 4. Relationship between 'Ohatsumomo' peach whole-plant mass and EC under field conditions (2007).

'Ohatsumomo' seedlings. We obtained the estimated pruned-off root weight by substituting the actual weight of roots pruned from the plants into Equation (2). A fair correlation exists between the estimated and actual pruned-off root mass (Fig. 5). However, Fig. 5 also shows that at low EC levels, the estimates of root dry mass are less accurate and more research is required to further develop the EC method.

3.2 Electrical Capacitance in Potted Trees (Ex. 2)

Root EC was correlated with root mass for potted pear rootstock (*Pyrus betulaefolia* Bunge) and the field-grown peach 'Ohatsumomo' (Fig. 6). The root

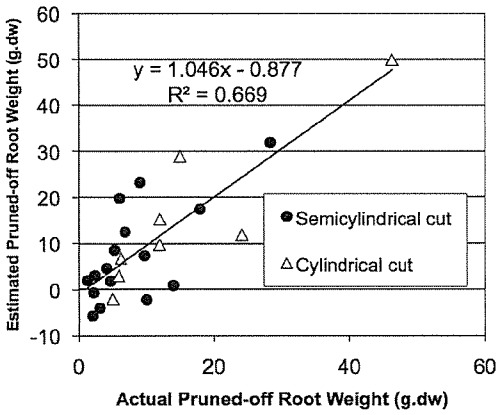

Fig. 5. Relationship between estimated pruned-off root weight and actual pruned-off root weight in field pruning treatment of 'Ohatsumomo' peach trees (2007).

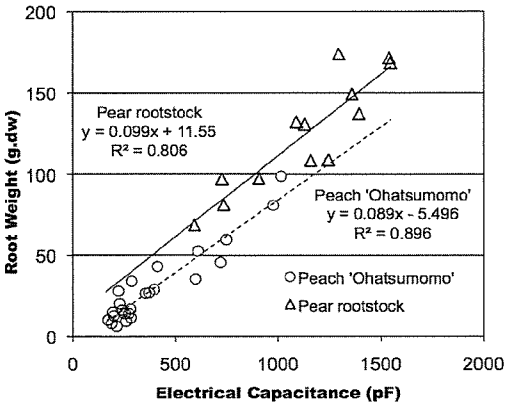

Fig. 6. Relationship between root dry mass and EC for potted plants, pear rootstock. Data for 'Ohatsumomo' are added from Ex. 1 for comparison (2007).

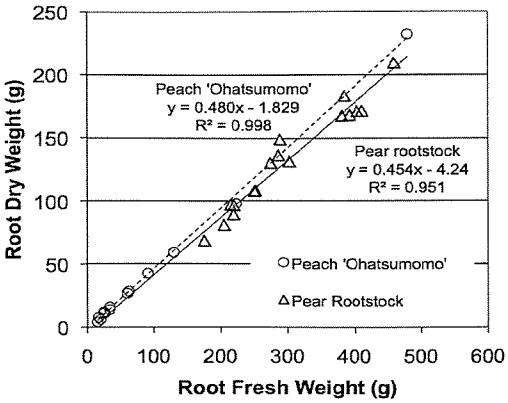

Fig. 7. Relationship between root dry mass and root fresh mass for 'Ohatsumomo' peach and pear rootstock (2007).

EC of the peach root was greater than that of the pear rootstock, despite little difference in dry matter content for these two species (Fig. 7).

Varietal differences in EC per unit root dry weight have been reported. Psarras and Merwin (2000) showed that root EC was greater in M.9 rootstocks than that in MM.111 rootstocks and there was a strong correlation between root EC and root biomass for M.9. According to Dalton (1995), the root surface area is directly proportional to the EC. Anatomical, morphological, or physiological characteristics may explain the differences in EC per unit root dry weight (Fig. 6). For this reason, the EC method has the potential to become a valuable tool to understand variations among species and varieties.

4. Conclusions

The results of this study indicate that the EC method is a feasible, repeatable, and useful nondestructive method for estimating the fresh or dry root mass of peach trees. If a standard curve was made each year, effective correlation between the root EC and root mass of field-grown young peach trees would be possible. Similar results were observed in Japanese pear rootstocks in the potted test. A study of the root mass and the root EC before and after the root pruning treatment respectively showed the potential of this technique to detect reductions in root mass in young peach trees.

References

Aldwinckle, H. S., 1975: Flowering of apple seed-

lings 16–20 months after germination. *HortSci.*, **10**, 124–126.

Dalton, F. N., 1995: In-situ root extent measurements by electrical capacitance methods. *Plant and Soil*, **173**, 157–165.

Kendall, W. A., Pederson, G. A., and Hill, R. R., 1982: Root size estimates of red clover and alfalfa based on electrical capacitance and root diameter measurements. *Grass Forage Sci.*, **37**, 253–256.

Meilan, R., 1997: Floral induction in woody angiosperms. *New Forests*, **14**, 179–202.

Morinaga, K., Kusaba, S., Muramatsu, N., Shimazaki, M., and Hoshi, N., 2006: Method for measuring the weight of a plant body. European Patent EP1726924.

Preston, G. M., McBride, R. A., Bryan, J., and Candido, M., 2004: Estimating root mass in young hybrid poplar trees using the electrical capacitance method. *Agroforest. Syst.*, **60**, 305–309.

Psarras, G., and Merwin, I. A., 2000: Water stress affects rhizosphere respiration rates and root morphology of young 'Mutsu' apple trees on M.9 and MM.111 rootstocks. *J. Am. Soc. Hort. Sci.*, **125**, 588–595.

Tsukahara, K., Fujishige, N., Yamane, K., Yamaki, Y., and Honjo, H., 2006: Shortening the juvenile period in ornamental peach seedlings by root pruning. *J. Jpn. Soc. Hort. Sci.*, **75** (Suppl. 2), 373(in Japanese).

Tsukahara, K., Fujishige, N., Yamane, K., Yamaki, Y., and Honjo, H., 2007: Cultural regulation of flower bud formation of ornamental peach seedlings-Towards the shortening the juvenile period. In *ISHS Lecture Papers at VIII Int. Symp. Temperate Zone Fruits in the Tropics & Subtropics.* 88–89.

van Beem, J., Smith, M. E., and Zobel, R. W., 1998: Estimating root mass in maize using a portable capacitance meter. *Agron. J.*, **90**, 566–570.

Zimmerman, R. H., 1971: Flowering in crabapple seedlings: Methods of shortening the juvenile phase. *J. Am. Soc. Hort. Sci.*, **96**, 404–411.

Zimmerman, R. H., 1972: Juvenility and flowering in woody plants: A review. *HortSci.*, **7**, 447–445.

ハナモモ実生苗における断根処理後の根量の静電容量計測による非破壊的推定法

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要　　約

圃場で栽培したハナモモ当年生実生苗の根量を静電容量計測により非破壊的に推定する方法を開発した。圃場で生育したハナモモ実生では，根の乾物・生体重ともに静電容量と高い正の相関が認められた。鉢植えのニホンナシ台木 (ホクシマメナシ) においても，同様の相関が認められた。圃場栽植のハナモモについて 2 段階の断根処理を行いながら計測した静電容量値と根乾量の関係式から，断根処理による根の剪除量を評価可能と考えられた。静電容量法はハナモモ根量 (乾物・生体) の圃場での評価に利用可能な非破壊的推定法であることが示された。

キーワード： LCR メータ，根量，静電容量，断根処理，ハナモモ