

Cold Temperature Tolerance of G.16 and G.935 Apple Roots

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Abstract

G.16 had similar root tissue cold hardiness as M.26 EMLA. Significant root death, 40%, occurred at temperatures of -12°C in both rootstocks. Tree growth of M.26 EMLA after 40 days in a greenhouse was reduced by exposure to -10°C and colder, whereas tree growth of G.16 was reduced by -12°C. In a separate experiment, G.935 had greater cold hardiness than M.26 EMLA, based on shoot growth following exposure to freezing temperatures to a low of -16°C. Root tissue relative electrical conductivity (REC) increased linearly with decreasing temperature in both G.935 and M.26 EMLA, but the rate of increase in REC was greater in M.26 EMLA.

INTRODUCTION

Winter injury to the root systems of fruit trees causes significant tree losses and yield reductions in the northern regions of the United States and Canada. This type of injury occurs periodically when snow cover is thin or nonexistent. As a result, lack of insulation of the soil results in lethally cold temperature for the root system (Wildung et al., 1973; Czynczyk, 1979). Replanting is the only option when significant tree losses occur, causing substantial financial losses for the grower. Rootstocks vary in their tolerance to freezing soil temperatures (Embree, 1988). To prevent economic losses caused by cold temperature injury to the root system, rootstocks with greater winter hardiness should be selected.

Most commercial orchards in the United States are planted with tender Malling rootstocks that lack cold tolerance (Embree, 1988). Based on greater tree survival following winters with freezing soil temperatures, some Geneva rootstocks have been shown to have greater cold tolerance than Malling rootstocks (Robinson et al., 2004). Controlled studies are needed to measure the relative cold hardiness of new Geneva rootstocks.

MATERIALS AND METHODS

Experiment 1

In May 2006, ungrafted M.26 EMLA and G.16 trees, with a trunk diameter of 0.32 cm, were planted in an outdoor nursery at a spacing of 25 cm. In October, trees were dug and repotted in sand, and placed in cold storage at -1 to 2°C until analysis in February.

Prior to exposing the trees to freezing temperatures, the sand was rinsed off roots and the root systems were wrapped in moist paper towels and placed in plastic bags. The trees were then exposed to temperatures ranging from -6 to -14°C. Other control trees were unfrozen. Temperature was decreased at a rate of 3°C per hour, but held at set temperatures for 30 min. Freezing of whole plants was conducted using a programmable freezer (LoCold Freezer 40-914, ScienTemp, Adrian, MI). Upon removal from the freezer, trees were placed in an insulated cooler overnight. Half of the trees were planted in pots with fine sand, pruned back to 12 cm, and placed in a heated greenhouse for 40

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days to assess recovery from injury based on the amount of shoot and root growth. The second set of trees was destructively sampled for root mortality two days after freezing. Roots were separated into living and dead fractions, dried at 70°C for one week and weighed.

Experiment 2

In 2007, ungrafted M.26 and G.935 rootstocks, with a trunk diameter of 0.64 cm, were planted in pots with pasteurized field soil, sand and calcined montmorillonite clay (Turface, Buffalo Grove, IL, USA) mixed at a ratio of 2:2:1 by volume. Trees were grown in pots outdoors until late October when they were placed in cold storage at a temperature of 0°C until analysis in February.

Freezing of trees was done following a similar procedure as in Experiment 1, but with exposure to temperatures ranging from -8 to -16°C and an unfrozen control. Temperature was decreased at a rate of 2°C per hour.

Relative electrolyte leakage was measured using a temperature compensated Digital Electrical Conductivity Meter (model 1056, Amber Science, Eugene, OR) on 1 g of root tissue per tree. The root sample was placed in 20 ml of deionized water for 48 hours after which electrical conductivity was measured. Root samples were autoclaved and maximum electrical conductivity was measured after 48 hours. Relative electrolyte conductivity (REC) was calculated as $\{(initial\ EC / autoclaved\ EC) * 100\}$.

The experiments were designed as a completely randomized design with five single tree replications in 2006 and 12 single tree replications in 2007. Tree growth and REC data were analyzed using the PROC GLM procedure and tree survival using the PROC GENMOD procedure of SAS (SAS Institute, Cary, NC).

RESULTS

Experiment 1

Root tissue survival was not affected by freezing temperatures from -6 to -10°C when measured by visual estimation of browning two days after freezing (Fig. 1). Significant root death (40% on a dry weight basis) occurred at -12°C with no difference between G.16 and M.26 EMLA. Following 40 days in a greenhouse, root tissue survival was reduced by prior exposure to -10°C in both rootstocks. Shoot dry weight of M.26 was reduced by exposure to -10°C and of G.16 by exposure to -12°C. All trees survived exposure to -10°C. Following exposure to -12°C, 20% of the M.26 trees and 50% of the G.16 trees died which was not significantly different between the two rootstocks.

Experiment 2

G.935 had greater root tissue cold hardiness than M.26 EMLA. Shoot dry weight of M.26 EMLA was reduced by exposure to temperatures of -12°C and colder (Fig. 2). In contrast, G.935 dry weight was not significantly affected until exposure to a temperature of -14°C. Shoot dry weight was greater for G.935 than for M.26 EMLA most likely because G.935 commenced growth one week earlier. Root tissue REC increased linearly with exposure to decreasing temperatures ($P=0.0001$). There was an interaction between rootstock and temperature ($P=0.0135$) indicating the rate of increase in REC was greater for M.26 EMLA.

Trees of both rootstocks survived exposure to temperatures as cold as -14°C. Tree survival of G.935 after exposure to -16°C was 100%, which was significantly greater than M.26 EMLA trees, 75% of which survived -16°C.

DISCUSSION

Compared to M.26 EMLA, roots of G.16 had similar cold hardiness and G.935 had greater cold hardiness. The reported cold temperature tolerance of M.26 EMLA roots is -10.6 to -12°C (Wildung et al., 1973; Embree, 1988) which is similar to results of this study. Based on shoot regrowth, M.26 EMLA roots were damaged by exposure to -10°C

in Experiment 1 and -12°C in Experiment 2. Greater survival of M.26 EMLA in Experiment 2 was most likely due to a greater number of roots per tree compared to Experiment 1 when roots were sparse.

ACKNOWLEDGEMENTS

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Figures

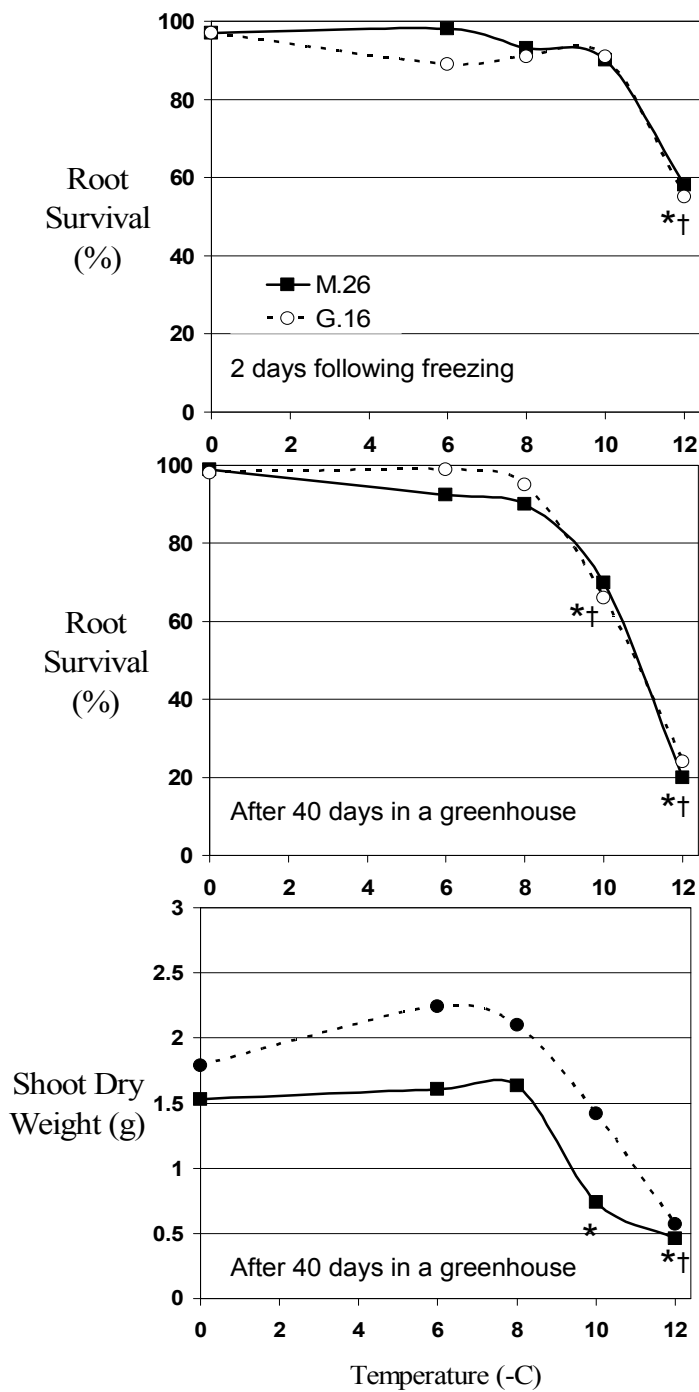


Fig. 1. Root tissue survival and shoot regrowth of M.26 EMLA and G.16 after exposure to freezing temperatures and 40 days in a greenhouse. * indicates a significant difference from the unfrozen control for M.26 EMLA, and † indicates significance for G.16.

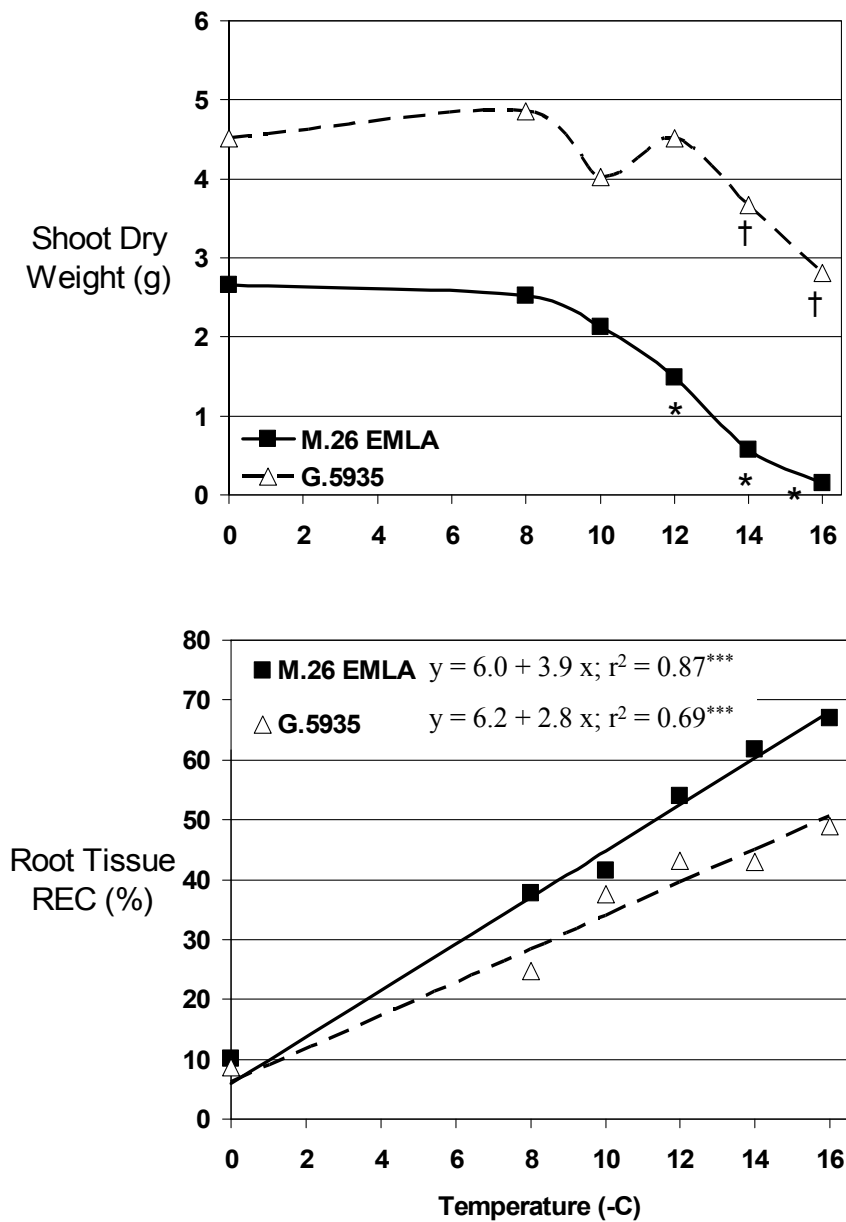


Fig. 2. Root tissue relative electrical conductivity (REC) two days after exposure to freezing temperature and shoot regrowth after 40 days in a greenhouse. * indicates a significant difference from the unfrozen control for M.26 EMLA, and † indicates significance for G.935 (G.5935).