Soil pH Affects Nutrient Balance in Cherry Rootstock Leaves

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Abstract. This study was conducted as part of a stone fruit decline project to determine the effects of soil pH (3.9 to 7.0) on soil and plant nutrient imbalance and mortality of standard (Mazzard and Mahaleb) and new (GI148-1 and GI148-8) rootstocks. Seedling mortality and soil Ca in all rootstocks and soil K and leaf Ca, K, Al, and Mn contents in all rootstocks but GI148-8 were higher at below optimum than at optimum soil pH. The nutrient imbalance suggests that the adaptation of these rootstocks to biotic and abiotic factors needs to be considered.

The stone fruit decline syndrome in the United States has been attributed to biotic (*Pseudomonas* sp., nematodes, etc.) and abiotic (low soil pH, nutrition, etc.) factors (see Melakeberhan et al., 1993 for reviews). In predominantly Mazzard (*Prunus avium* L.) rootstock-based Michigan cherry orchards, nematodes, bacterial canker, nutrition, winter injury, and low soil pH were associated with declining trees (Melakeberhan et al., 1993). Stratified rhizosphere analysis of soil in a declining sweet cherry orchard showed soil pH as low as 3.9 with increasing Al availability below pH 5.2 and proportional absorption into plant tissue (Melakeberhan et al., 1995).

Significant resources are being devoted to developing better cherry rootstocks (Ferre and Perry, 1989). In addition to the standard rootstocks, Mazzard and Mahaleb, the Giesen lines are gaining attention because of their dwarfing characteristics. However, both the standard and the new rootstocks are suitable hosts for several plant-parasitic nematodes (Melakeberhan et al., 1994b). Furthermore, the effect of root-lesion nematode (*Pratylenchus penetrans* Cobb), the nematode most commonly associated with decline in Michigan cherry orchards, on these rootstocks was worse under nutrient-deficient than under nutrient-optimum conditions at a soil pH of 7.0 (Melakeberhan et al., 1997). Therefore, the objectives of this study were to determine the effects of below optimum soil pH on soil and plant nutritional imbalance and mortality of Mazzard, Mahaleb, GI148-1, and GI148-8 cherry rootstocks.

Materials and Methods

Two greenhouse experiments were conducted at 25 ± 2 °C. Expt. I consisted of 1-year-old Mazzard seedlings planted in soil of pH 3.9, 4.7, and 7.0; Expt. II of Mazzard, Mahaleb, GI148-1, and GI148-8 seedlings in soil of pH 5.2 and 7.0. The pH of a steam-sterilized sandy loam (87% sand, 8% silt, 5% clay) soil was adjusted by mixing with 90% elemental sulfur powder at 0% to 0.7% by weight (Gupta and Cornfield, 1964) for 3 min in a cement mixer, and the soil was stored for 3 months in plastic barrels (Melakeberhan et al., 1995). Soil pH was checked every 2 weeks using a portable pH and soil moisture tester (O.S.K.E.M. System Soil Tester, Tokyo). Bare-root seedlings were obtained from Meadow Lake Nursery (McMinnville, Ore.) and stored at 4.5 ± 1 °C for ≈50 d until budbreak. Before transplanting, seedlings were kept under laboratory conditions (≈20 ± 2 °C) with roots submerged in buckets containing tap water for 24 h, selected for growth uniformity, and individually planted in 800 mL (944 g) of soil in black plastic tubes 20 cm deep and 8 cm in diameter (Melakeberhan et al., 1994b, 1995). Seedlings were watered daily with tap water and fertilized twice weekly with 20N–8.8P–16.6K, 40 mg N per application, (Peters 20–20–20 all-purpose fertilizer mix; Grace Sierra, Milpitas, Calif.). Four replications were used per treatment and the experiments were terminated 5 (Expt. I) and 15 weeks (Expt. II) after transplanting. Soil and plant nutrients were ana-

lyzed as described in Melakeberhan et al. (1997). Data were analyzed using analysis of variance, and means separated by Tukey's HSD test.

Results and Discussion

In Expt. I, all seedlings planted in soil of pH 3.9 died within the fourth week of transplanting, indicating that the more unfavorable the soil conditions, the sooner seedlings died. A seedling was considered dead if all leaves or the entire shoot showed signs of wilt. Soil concentrations of Ca at pH 3.9 (4.6 mg·g⁻¹) and 4.7 (4.2 mg·g⁻¹) were significantly lower than at pH 7.0 (6.4 mg·g⁻¹ dry weight). The concentrations of Al in stems of trees growing in soil at pH 3.9 (1433 µg·g⁻¹) were higher ($P \leq 0.05$) than those in soil at pH 4.7 (235 µg·g⁻¹) or 7.0 (139 µg·g⁻¹ dry weight). The reduction of soil Ca and increase of Al in stems with decreasing pH indicates an increase in Al availability and proportional absorption by plant roots (Melakeberhan et al., 1995).

In Expt. II, concentrations of Ca and K in the soil were consistently less at pH 5.2 than at pH 7.0 (Table 1). Concentrations of K and Ca in Mazzard, Mahaleb, and GI148-1 leaves were significantly less ($P \leq 0.05$) in soil at pH 5.2 than at pH 7.0, while the concentrations of Al and Mn were greater at pH 5.2 than at pH 7.0 (Table 1). The lower level of Ca and K in leaves at pH 5.2 (the average low pH commonly observed in declining orchards) than at pH 7.0 is to be expected because the levels of these elements in soil can become deficient at low pH (Melakeberhan et al., 1993). The increase in Mn and Al are consistent with the effects of low pH-driven nutrient imbalance (Melakeberhan et al., 1993; Neilsen et al., 1990). Despite significantly lower soil Ca levels at pH 5.2 than at pH 7.0 in GI148-8, there was no difference in leaf nutrient levels (Table 1). This may indicate possible physiological differences in nutrient uptake. Regardless of differences in leaf nutrient levels, however, all Mazzard and Mahaleb and 75% of the GI148-1 and GI148-8 seedlings in soil with pH 5.2 were dead within 10 d of the end of the study, thus clearly showing that the standard and new rootstocks are sensitive to low soil pH.

Under orchard conditions, failure to lime regularly (Melakeberhan et al., 1993) and the use of NH₄-based commercial fertilizers as

Table 1. The concentrations of Ca and K at pH 5.2 and 7.0 in soil, and the concentrations of Ca, K, Mn, and Al in leaves of Mazzard, Mahaleb, GI148-1, and GI148-8 cherry rootstocks at 15 weeks after planting.

Rootstock	Soil pH	Nutrient concn					
		Soil		Leaves			
		Ca	K	Ca	K	Mn	Al
		mg·g ⁻¹		mg·g ⁻¹		µg·g ⁻¹	
Mazzard	5.2	4.58 b ²	0.462 b	06.9 b	13.7 b	377 a	131 a
	7.0	5.72 a	0.808 a	10.7 a	17.6 a	76 b	80 b
Mahaleb	5.2	5.34 b	0.692 b	10.8 b	15.7 a	211 a	127 a
	7.0	6.10 a	1.115 a	13.6 a	18.5 a	103 b	78 b
GI 148-1	5.2	3.46 b	0.462 b	09.0 b	14.3 b	143 a	208 a
	7.0	5.84 a	0.962 a	13.8 a	17.5 a	116 a	51 b
GI 148-8	5.2	2.18 b	0.538 a	12.4 a	17.6 a	121 a	61 a
	7.0	6.00 a	0.692 a	12.4 a	17.7 a	121 a	77 a

²Mean separation within rootstocks and elements by Tukey's HSD, $P \leq 0.05$.

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nitrogen sources (Peryea and Burrows, 1999) are among the reasons for low soil pH. Neither the required time for a typical orchard soil pH to decline to the levels tested in the present study, nor how mature trees respond to the nutritional changes observed here, are known. This study shows that soil pH below the optimum range reduced soil and plant concentrations of K and Ca and increased Al and Mn concentrations in plant tissue. As pH declines below 5.5, the availability of Al and the potential for Al toxicity (Foy, 1974; Melakeberhan et al., 1995) and nutritional imbalance (Hoyt and Neilsen, 1985; Melakeberhan et al., 1993; Neilsen et al., 1990) increase, which, in turn, could lead to a predisposition to biotic factors and tree death (Melakeberhan et al., 1994a, 1997). Therefore, the adaptation of these rootstocks to soil abiotic and biotic factors needs to be considered carefully.

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