Seasonal Patterns of Root Growth in Relation to Shoot Phenology in Grape and Apple

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Abstract

Growers plan many of their horticultural activities around certain shoot phenological stages such as bloom and veraison. Timing of root growth in relation to these stages of the shoot is of interest in fertilization scheduling and understanding carbon allocation demands of the root system. With the recent use of minirhizotron root observation tubes, a much greater understanding of patterns of root growth has been made possible. In this paper some published work and present data from on-going studies on timing of root production are reviewed. Studies discussed include on-going work in grape vineyards in Fredonia, New York, USA (*Vitis lambruscana*), and Oakville, California, USA (*V. vinifera*), and in apple orchards (*Malus* × *domestica*) in Summerland, British Columbia, Canada. Root production mainly occurs in the summer, but the specific timing varies widely between bloom and harvest from year to year. Usually there is little root growth in the few weeks prior to harvest and when the vines are dormant. Cultural practices may affect root production, usually from a combination of changes in the soil environment (moisture, temperature) and changes in photosynthetic capacity.

INTRODUCTION

Timing of root growth has important implications in the management of fruit crops, including timing of fertilization and factors influencing carbohydrate and nutrient sink activity. Early work with rhizotrons (large transparent windows) has led to the common belief that temperate crops typically have root flushes in the spring around flowering and in the fall after harvest. In *Biology of the Grapevine* (Mullins et al., 1992), for example, root growth is assumed to occur around bloom with a second major growth peak after harvest (Fig. 1). The development of the technique of root observations using minirhizotrons (small transparent tubes) allows for continuous tracking of root birth throughout the year and assessment of seasonal patterns of root production within the context of well-replicated experimental designs (Böhm, 1979; McMichael and Taylor, 1987; Comas et al., 2005). This kind of information provides for a rigorous testing of some of the widely held pre-conceptions on timing of root growth in grape and apple.

MATERIALS AND METHODS

Grapes

Grape root production was examined at two locations that contrast widely in climate and grape rootstock. The first site, Oakville, California, is characterized by hot,

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dry growing seasons (May - August average daily maximum temperature = 30.7ºC; average annual precipitation = 1.8 cm). The second site, Fredonia, New York, is characterized by cool and moist growing seasons (May - August average daily maximum temperature = 24.7ºC; average annual precipitation = 41.7 cm).

In Oakville, 'Merlot' grapevine root growth was examined in a 6-year-old vineyard planted in Bale (variant) gravelly clay loam with vines spaced 2.4 x 2.2 m and trained on a bilateral cordon with vertical shoot positioning (VSP). The entire experimental block covered about one ha and was laid out in a completely randomized block design with subplots of nine vines of each of three rootstocks (1103P, *V. berlandieri* x *V. rupestris* and 101-14 Mgt *V. riparia* x *V. rupestris*) in each of three irrigation treatments per block, with six blocks. Pertinent to this study were two rootstocks (1103 P and 101-14 Mgt) and one irrigation treatment (40% of crop coefficient evapotranspiration). Each vine had two emitters, located on either side of the vine about 50 cm from the trunk. One of the emitters was plugged to prevent watering that side of the vine.

In Fredonia, 'Concord' grapevine roots were examined for approximately six years (Comas et al., 2005). The research was conducted in a mature, 25-year-old vineyard with grapevines with permanent arms 1.8 m above the ground and spaced at 2.4 m between vines and 2.7 m between rows. Soils were very deep and very well-drained Chenango gravelly loam. Experimental treatments included two pruning treatments (balanced or minimally pruned) and two irrigation treatments (irrigated or not) in a 2 x 2 factorial design with four replications.

Apples

The apple field site was located in Summerland, British Columbia, at the Pacific Agri-Food Research Centre (49°34' N. lat., 119°39' W. long., elev. 500m). This site is characterized by a cool, dry growing season (May - August average daily maximum temperature = 23.8ºC; average annual precipitation = 11.0 cm). The soil was a Skaha loamy sand, an Aridic Haploxeroll, which is characterized by limited nutrient- and water-holding capacities. Two experiments are reported. The first experiment had 'Gala'/M9 apple trees and the second experiment had 'Golden Delicious'/M9 trees. Trees were planted in April 1997 to 1 m spacing in the row and 3 m spacing between the rows. The 'Golden Delicious' trees were planted on the outer border row of the 'Gala' block. In the first experiment, the experimental design was a randomized complete block with each row representing a block. Within a row, the experimental plots were in groups of three 'Gala'/M9 trees with a border tree of 'Spartan'/M9 on either side. For plots receiving mulch, wood waste mulch was applied to maintain a depth of 10 cm in two plots per row in 1997, 1998 and 1999. Each tree had two drippers, located on either side of the trunk about 0.5 m apart. Irrigation occurred daily, beginning near bloom and ending near harvest time in mid-October. Irrigation was set to meet 100% of the previous day's estimated potential evapotranspiration using an atmometer.

RESULTS AND DISCUSSION

Root growth in 2003 in the 'Merlot' vineyard in Oakville occurred primarily between bloom and veraison (Fig. 2). Little root growth occurred after veraison for either rootstock. There was some evidence of a pulse of root growth in early spring prior to bloom in the less vigorous rootstock (101-14 Mgt), but as indicated by the larger error bars, this root growth was inconsistent among the different blocks. When little root growth was indicated, it was usually very consistent across blocks, as seen in the months prior to bloom or prior to harvest. These results were very different from those described in text books (Mullins et al., 1992); however, they represent only one year of data.

In Fredonia, grapevine root growth patterns were examined for six years with minirhizotrons. Despite considerable year-to-year variability (Fig. 3), various factors affecting root growth were identified (Comas et al., 2005). For example, type of dormant pruning and availability of irrigation strongly influenced root growth in years of dry growing conditions (data not shown). While the precise timing of root growth can be modestly affected by pruning, irrigation and year, there was little evidence of a bimodal pattern as described in Fig. 1. Similar to 'Merlot' (Fig. 2), most root growth occurred between bloom and veraison, either as a single peak or as fairly continuous with no distinct peak. Little root growth occurred in the weeks prior to harvest or when the vines were dormant.

Apple root growth also has been commonly reported as having a bimodal pattern with root flushes around full bloom and either mid-summer (Fallahi, 1994) or harvest (Rom, 1996). During the second year (2002) after minirhizotron installation in the 'Gala'/M9 plots, a strong root flush around bloom and then modest continuous root growth through the season was observed (Fig. 4). The following year (2003), no evidence of a spring root flush was seen. Root growth steadily increased from June until August and then declined near harvest (Fig. 4). After harvest, a strong root flush occurred. In 'Golden Delicious'/M9, a fall root flush was never observed (Fig. 5). In the one year a complete season of data was available, only saw one peak period of root growth at the time of full bloom was observed. Thus these data neither support that a fall root flush is common nor that root production in apple is typically bimodal.

Review chapters on apple root growth primarily cite data based on work from rhizotrons, especially at East Malling, UK (Head, 1966 and 1967; Atkinson and Wilson, 1980). There is a surprising lack of rigor in generalizing patterns of root growth from this literature. For example, Atkinson and Wilson (1980) present data on four years of new root growth in apple of a single 'Worcester'/MM.104 tree. In three of the four years, a bimodal pattern was indicated. Thus, the generalization of a bimodal pattern is based on a single tree exhibiting the pattern only 75% of the time. Head (1966) did not show a bimodal pattern of new root production in a single tree of 'Cox's Orange Pippin'/M9 and only in one of three trees in 'Worcester'/M.M.104. In a second paper, Head (1967) shows clear bimodal patterns of total length of white root in 'Worcester'/M.M.104, but does not report on timing of new root production. Roots may remain white for 2-4 weeks during the growing season at this location (Head, 1966), so one should not infer bimodal patterns of root production based on bimodal patterns of total white roots. Thus, the historical evidence that apple root growth is bimodal is variable, restricted in location, and represents varieties and rootstocks not in common use today. A more recent study using minirhizotrons on 15 'Matsu'/M9 trees in New York over a 2-year period indicate a single peak of root growth primarily in June and July with little root growth in either the spring or fall (Psarras et al., 2000).

CONCLUSIONS

The timing of root growth can be quite variable from one year to the next. Little evidence that root growth in either grape or apple is typically bimodal or that a fall flush of roots is common was found. There are few consistent patterns when roots grow relative to shoot phenology. Roots typically did not grow near harvest time or during the dormant season when soils were cold. There is little evidence that fertilization in the fall (e.g., after September in the north temperate region) would correspond to a period of high root activity. Because of the unpredictable nature of root growth, fertilizer efficiency may be best achieved by frequent fertilization at low levels rather than large applications only once or twice a year.

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Figures

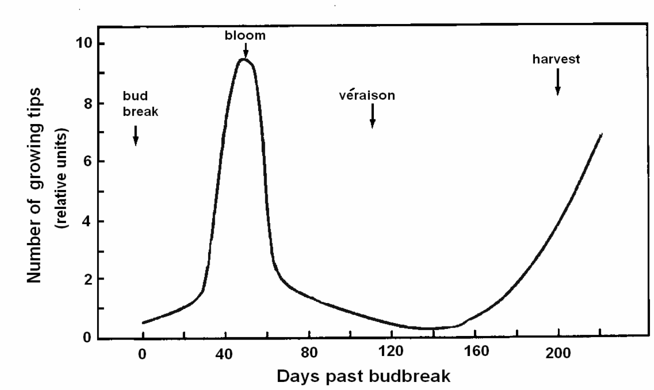

Fig. 1. Seasonal pattern of root growth in grape as typically described in text books. Data adapted from Mullins et al. (1992).

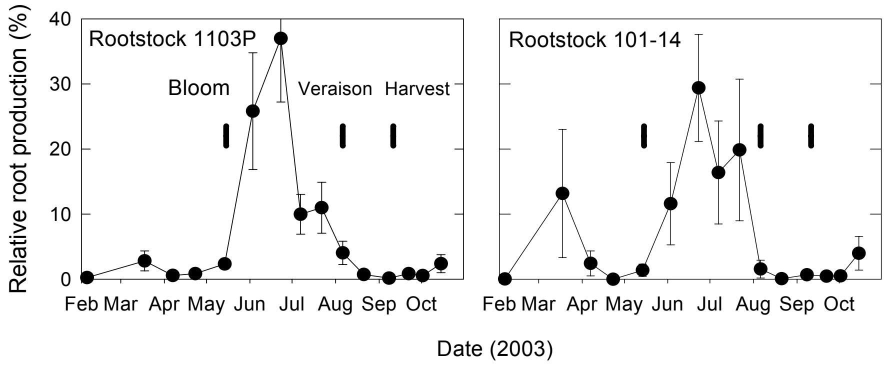

Fig. 2. Seasonal patterns of root birth in 'Merlot' grapevines on two rootstocks in Oakville, California, USA. Tick on x-axis indicates beginning of each month. In the months of November through February, essentially no roots were produced. Relative root production calculated as the percentage of roots born on a given date compared to the total number of roots born that year. Standard errors were calculated from the number of roots born on a given date for a given block compared with the total number of roots born that year in that block year.

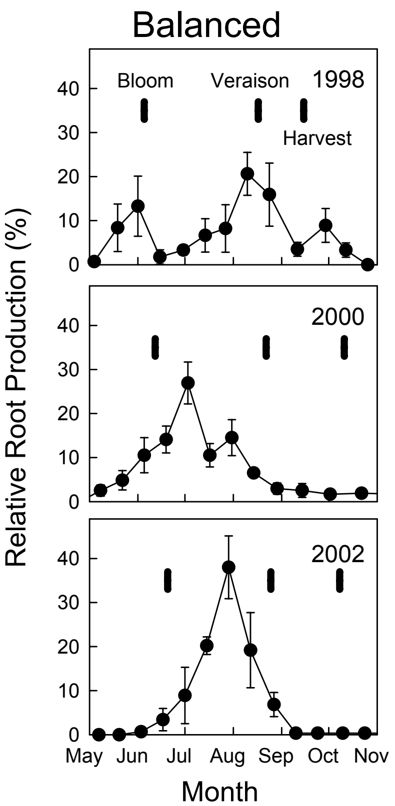

Fig. 3. Relative root production in irrigated, balanced pruned 'Concord' grapevines in Fredonia, New York, USA, in 1998, 2000 and 2002. Tick on x-axis indicates beginning of each month. In the months of November through April, essentially no roots were produced. Relative root production calculated as the percentage of roots born on a given date compared to the total number of roots born that year. Standard errors were calculated from the number of roots born on a given date for a given block compared with the total number of roots born that year in that block year (n=2 to 4). Blocks with fewer than 40 roots born per year were removed from the analysis. Thick bars indicate timing of full bloom, veraison and harvest.

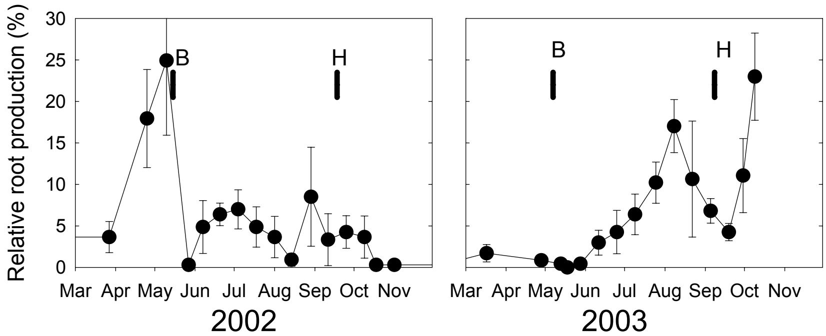

Fig. 4. Patterns of root birth (± SE) over the growing season of Gala/M9 apple trees in Summerland, British Columbia. Data calculated as in Fig. 2. Trees were fully irrigated (100% daily ET) on two sides of the tree. Only trees that were not mulched are shown. Thick vertical bars indicate timing of full bloom (B) and harvest (H) each year.

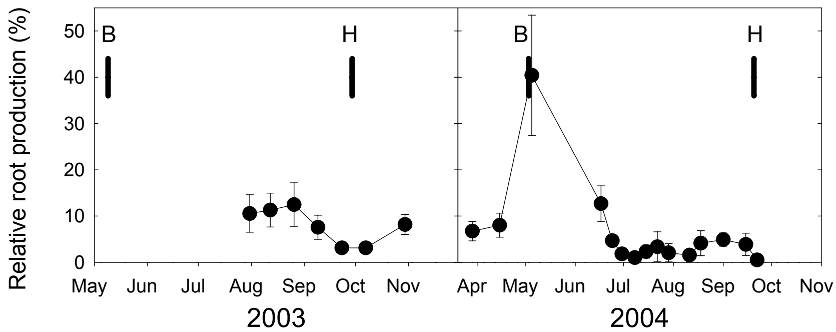

Fig. 5. Patterns of root birth (± SE) during the growing season of 'Golden Delicious'/M9 apple trees in Summerland, British Columbia, Canada. Data calculated as in Fig. 2. Trees were fully irrigated (100% daily ET) on two sides of the tree. Thick vertical bars indicate timing of full bloom (B) and harvest (H) each year.