

**Project Title:** Physiological implications of harvest pruning raisin grapes.

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**Summary:**

In response to diminishing returns, the California raisin industry is rapidly adopting mechanical raisin harvesting practices to reduce cost. The first step of mechanical raisin harvest generally involves severing the fruiting canes, a practice known as harvest pruning (HP). The potential physiological implications of HP are uncertain, so an experiment was established to assess the effects of HP on ‘Thompson Seedless’ grapevines. The vines were 40-years-old, on their own roots, head-trained and cane pruned, and supported by a single wire trellis. Before budbreak, similar vines were harvested to determine how dry matter and non-structural carbohydrates (CHO) were partitioned in the vine. These data will be used as a baseline to determine how HP might affect vine growth and carbohydrate reserves. Total dry mass of roots, trunk, and canes averaged about 14 kg · vine<sup>-1</sup>. Most of the vine’s mass, about 68%, was trunk, about 30% was roots, and only 2% was canes. Starch was the primary CHO, accounting for about 6% dry matter of each organ. Sucrose was the next most abundant CHO, with a concentration of 2%, 1.5%, and 1.0%, in roots, trunk, and canes, respectively. Because of its mass, the trunk had the highest CHO content, and thus was the most important storage organ. Fruit achieved 20 Brix by the end of August, at which time vines had a leaf area of about 21.6 m<sup>2</sup>. About 60% of the canopy leaf area was from canes, and thus removed by HP. The net CO<sub>2</sub> assimilation rate (A) of mature leaves on renewal shoots began to decline after about 8 August, but they maintained a positive A until at least 31 October. Reduced A was due, in part, to chlorophyll degradation as evidenced by a decline in SPAD units occurring over the period that A declined. Harvest pruning generally did not affect A of mature leaves on renewal shoots, but those leaves maintained a positive A for at least 60 d after HP indicating that HP reduced the vines’ photosynthetic capacity. Soil respiration also declined between summer and winter, probably in response to decreasing soil temperatures. Soil respiration was similar among HP and non-HP vines, except about 30 d after HP, when HP vines had about 30% lower soil respiration values than non-HP vines. Root growth was monitored bi-monthly via minirhizotrons installed on 9 June. Extensive root activity was observed in summer and fall, but analyses of most data collected after HP are still being analyzed.

**Objectives of the Proposed Research:**

Grapevines undergo tremendous changes during their annual phenology that can greatly alter the degree and pattern of photosynthetic carbon allocation (Mullins, 1992). Such allocation

patterns probably have a significant impact on long-term vine performance because they determine the amount of carbohydrates available for storage and fruit development, and may influence the ability of vines to produce roots during critical periods of nutrient absorption. Information on how harvest pruning, which removes mature fruit, canes, and foliage, may influence vine performance is limited, and no previous studies have examined the effect that harvest pruning may have on root growth. The purpose of the following project is to make such assessments. Specifically, we will determine the impact of that harvest pruning ‘Thompson Seedless’ grapevines may have on:

- 1). Over-wintering soluble sugar and starch levels in canes, trunk, and roots.
- 2). Canopy size and leaf photosynthesis.
- 3). Vine fruitfulness, fruit quality, and yield.
- 4). Root growth, and soil respiration as an indicator of root physiological activity.

### **Experimental Procedures to Accomplish Objectives:**

*Experimental design and data analysis.* The experiment will consist of a single factor (HP or non-HP), randomized, complete block design with eight single vine replicates. Data will be subjected to statistical analysis with the SAS system (SAS Inc., Cary, N.C.).

*Plant material.* The experiment is being conducted on forty-year-old ‘Thompson Seedless’ grapevines on their own roots. Vines are spaced 2 m within rows and 3.6 m between rows. All vines are head-trained, cane pruned, and supported with a single-wire trellis. The vines are pruned to 6 canes of 15 nodes per cane.

*Plant dry mass and carbohydrate partitioning.* Six uniform, non-experimental vines of the same age, variety, training method, and trellis were harvested on 10 March. The vines were separated into roots, trunk, and canes. Each organ was oven-dried, weighed, and ground into a fine powder. Soluble sugars were extracted from ground tissue with hot deionized water and analyzed by HPLC with refractive index detection (Johansen et al., 1996). After soluble sugars were extracted, the tissue was subjected to a solution of amylase and amyloglucosidase to digest starch and convert it to free glucose that was detected by HPLC (Smith, 1969).

*Cane severance.* Fruiting canes were severed (HP), or fruit harvested (non-HP), when average soluble solids levels of fruit were about 20 °Brix. Fruit maturity was assessed weekly, beginning in July, by sampling berries. Each sample consisted of 3 berries collected from each of about 33 clusters (one berry from the top, middle, and bottom of each cluster) from the North side of each vine. Samples were weighed, and average berry weight calculated. The berries were then homogenized in a blender, and the soluble solids of filtered juice determined with a hand-held, temperature compensating, digital refractometer (Palette 101, Atago, Farmingdale, NY). Fruit of vines from both treatments was harvested green, the fruit were weighed, soluble solids determined, drying ratio estimated according to Christensen (2000), and raisin mass estimated.

*Leaf area.* Total canopy leaf area, and the proportion of the canopy removed by HP, was determined by defoliating six uniform, non-experimental vines of the same age, variety, training method and trellis. Leaves from fruiting and renewal canes were harvested separately from each vine, and their areas measured with a Li-Cor 3100 leaf area meter (Li-Cor Inc., Lincoln, NE, USA).

*Leaf chlorophyll content and gas exchange.* Before cane severance, three healthy, recently expanded exterior leaves on renewal canes of each vine were selected for chlorophyll

content and gas exchange measurements. A Minolta SPAD meter was used for non-destructive measurements that estimate chlorophyll content (Chlorophyll meter SPAD-502, Minolta, Osaka). Measurements were made with a Li-Cor 6400 portable photosynthesis system (Li-Cor Inc., Lincoln, NE, USA). Measurements were made approximately weekly, between 0900 and 1100 HR, on dates that bracketed cane severance, and continued until leaf fall. The same leaves were used for each measurement.

*Soil Respiration.* We have found that soil respiration in intensively cultivated vineyards more strongly reflects root respiration than it does decomposition of senesced roots or organic matter (Smart & Carlisle, 2003). We believe this occurs because older lignified roots of grapevine are recalcitrant to decomposition, and that senescent new roots decompose quickly during the warm season. Thus, soil respiratory measurements in intensively cultivated vineyards can integrate root activity over larger volumes of soil; whereas, minirhizotron tubes provide point source correlative information concerning birth and death rates of new roots. Soil respiration measurements commenced on 1 August, and were made bimonthly. Our previous experience shows this approach works well in characterizing short term rainfall events.

*Root Activity:* On 9 June, we installed 16, 1.5 meter long clear plastic minirhizotron tubes at a 30° angle beginning 1 m from the trunk. The tubes were capped to prevent water entry and covered with radiation shields. Beginning on June, we shall acquire images at each 1.4 cm of depth down the tubes using fiber optics and digital imaging. The activity of roots was determined by scrutinizing each of the 1,680 images acquired each session for new root birth, senescence and longevity. We are currently undertaking root imaging in Napa (Smart laboratory) and used that venue during 2002 to resolve several issues related to the collection of these images and processing thereof.

*Water potential.* On days where gas exchange was measured, a pressure bomb (Soil Moisture Equipment Co., Santa Barbra, CA) was used to determine leaf water potential mid-day.

*Pruning weights.* In the winter, vines were pruned to six canes, with 15 nodes per cane. Prunings of fruiting and renewal canes were oven dried, to compensate for water lost from severed fruiting canes (Scholefield et al., 1977), and comparisons were based on dry mass.

### **Summary of Major Research Accomplishments and Results:**

#### 1). Over-wintering soluble sugar and starch levels in canes, trunk, and roots.

The dry mass of vines harvested on 10 March, just before budbreak, averaged about 14 kg (Table 1). Of the total vine dry mass, about 68% was trunk, about 30% was roots, and about 2% was canes. Starch was the primary CHO, and dried trunk, roots and canes each had about 6% starch. Sucrose was the next most abundant CHO, and roots, trunk, and canes averaged 2%, 1.5%, and 1% sucrose, respectively. The concentrations of fructose and glucose were  $\leq 0.3\%$  in roots and about 1% in trunk and canes. Because of its relatively large mass, the trunk was the major CHO storage organ.

#### 2). Canopy size and leaf photosynthesis.

At the end of August, when vines would be subjected to HP, canopy leaf area was about 21.6 m<sup>2</sup> (Table 2). More than 60% of the leaf area was from fruiting canes and thus would be removed by HP. Generally, retention of 50% of the canopy leaf area, post harvest, is considered necessary to maintain yield in warm climates (Mandell et al., 2001; Scholefield et al., 1977; Smith, 2003).

Leaf chlorophyll content, as estimated with a Minolta SPAD meter, declined between 19 August and 22 October (Figure 1). Net CO<sub>2</sub> assimilation rate of leaves on renewal shoots also decreased, but remained positive, between 8 August and 31 October. Harvest pruning did not affect A on an individual leaf basis (Figure 2), so HP must have substantially reduced the vines' photosynthetic capacity. Leaf water potential measurements made at mid-day were generally  $\geq -1.2$  MPa, and were not affected by HP (data not shown).

### 3). Vine fruitfulness, fruit composition, and yield.

Vines of both treatments had similar number of clusters (fruitfulness), and berries were of similar size and composition. These similarities were expected because treatments were not applied until harvest, and 2003 was the first year of the study; thus, the vines should be identical at least through harvest. However, the vines were not equivalent with respect to yield. The harvest pruned vines had lower fruit weight, and thus also lower estimated raisin weight than the non-harvest pruned vines. Because berry size and cluster number were similar between treatments, the harvest-pruned vines must have produced smaller clusters. Differences in cluster weight cannot be attributed to treatments in 2003, but we will consider these differences in future yield analyses, possibly exploiting them as a covariate. There were no differences in pruning weights.

### 4). Root growth, and soil respiration as an indicator of root physiological activity.

We imaged each minirhizotron tube 12 times between June 2003 and January 2004, but data are still being analyzed. Grapevine roots have been viewed at all but two tubes, so we consider the installation successful. All vines initiated a pronounced root flush after Julian day 210 (Figures 3 and 4), about a month before harvest pruning. This is earlier than the post harvest root flush observed in South Africa (Van Zyl, 1984). However, data collected in the first months following minirhizotron installation must be interpreted with caution as the disturbed soil surrounding the tubes can encourage abnormal root growth. Moreover, it might take several months or longer for the roots of some vines to grow past the tubes. Even so, the relatively uniform root growth observed so far indicates that the roots of all vines are responding similarly to any disturbance caused by installing the tubes. The surface of most roots developed a brown color within 14 d (Figure 3). Most brown-colored roots were alive as evidenced by new roots that emerged from them and by lateral thickening of the roots (Fidelibus, pers. obs.).

Soil respiration was highly variable but, in general, it seemed to decrease from summer to winter, probably in response to lower soil temperatures (Figure 5). This is in contrast to root activity which seemed to increase over the same period (Figure 4). Thus, soil respiration might not be useful for indicating root activity.

### **Outside Presentations of Research:**

This experiment was showcased at the Kearney Agricultural Center Grape Day, 12 August 2003, and a synopsis of the research was published in the meeting's proceedings. A discussion of the research was published as an interview in the October 2003 issue of American Vineyard magazine. An abstract of this research was also submitted to the American Society for Horticultural Science for consideration as a poster presentation at their 2004 annual meeting.

**Research Success Statements:**

We showed that harvest pruning removes about 60% of the canopy leaf area, and that the remaining leaves do not compensate by increasing their photosynthetic capacity, suggesting that effects on vine growth, carbohydrate reserves, or both, should be observed in forthcoming seasons. Minirhizotron installation was successful, and most tubes are already colonized by roots. Extensive root growth was observed in 2003, suggesting that a fall root flush does occur in the San Joaquin Valley. Thus we are well positioned to document any effects of harvest pruning on vine capacity.

**Funds status:**

All of the funds awarded in 2003 have been spent.

**Literature cited:**

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Table 1. Dry mass of roots, trunk and canes of ‘Thompson Seedless’ grapevines, and the concentration and content of fructose, glucose, sucrose, and starch in those organs, Parlier, CA, 2003. Plants were harvested on 10 March, just before budbreak.

Organ	Dry mass (kg)	Fructose		Glucose		Sucrose		Starch	
		Concentration (% dry mass)	Content (kg)	Concentration (% dry mass)	Content (kg)	Concentration (% dry mass)	Content (kg)	Concentration (% dry mass)	Content (kg)
Roots	4.13 <sup>z</sup>	0.3 ± 0.03	0.012 ±	0.22 ± 0.02	0.008 ±	2.0 ± 0.2	0.083 ±	6.2 ± 0.3	0.256 ±
Trunk	9.48	1.0 ± 0.09	0.095 ±	0.91 ± 0.12	0.085 ±	1.5 ± 0.2	0.142 ±	6.1 ± 0.7	0.578 ±
Canes	0.28	1.3 ± 0.07	0.004 ±	0.83 ± 0.04	0.002 ±	1.0 ± 0.2	0.003 ±	6.3 ± 0.1	0.018 ±

<sup>z</sup>Values are treatment means ± SE, n = 6.

Table 2. Leaf area partitioned to fruiting wood and renewal shoots, and the percent leaf area removed by harvest pruning, of 40-year-old ‘Thompson Seedless’ grapevines, 2 September 2003, Parlier, CA. Vines were head trained, cane pruned, and supported by a single-wire trellis.

Leaf area (m <sup>2</sup> )		
Fruiting	Renewal	Percent fruiting
12.6 ± 1.3 <sup>z</sup>	9.0 ± 1.6	0.60 ± 0.02

<sup>z</sup>Values are treatment means ± SE, n = 6.

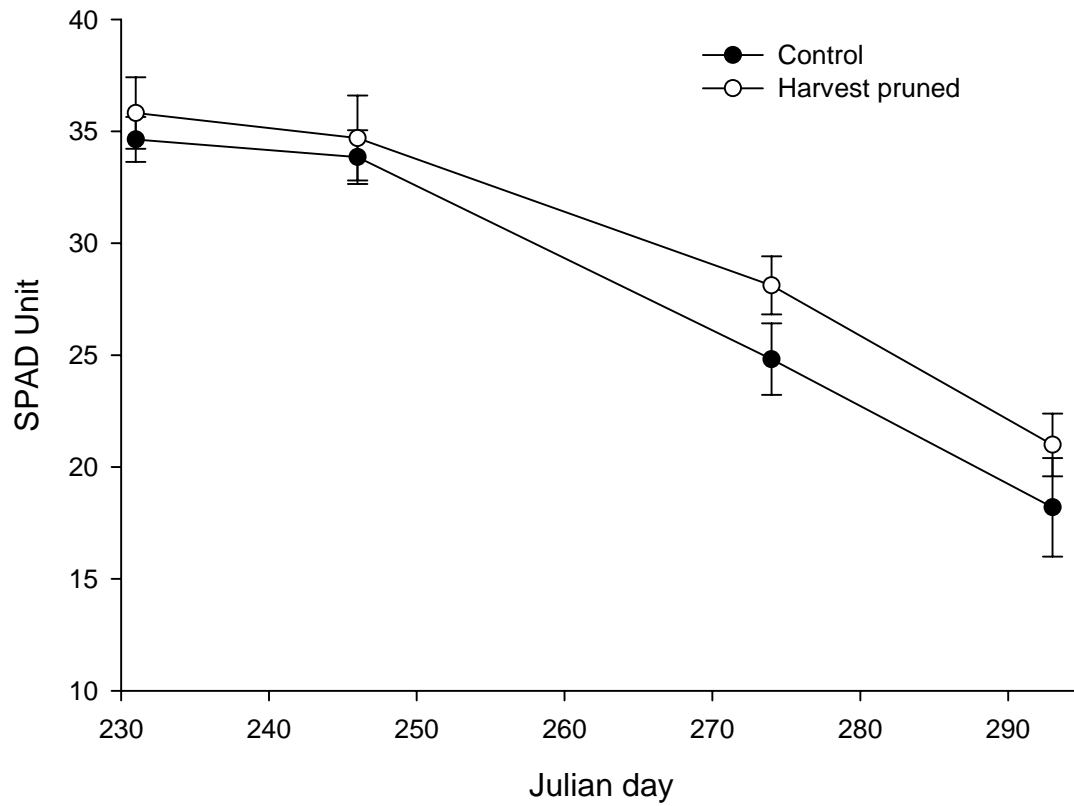


Figure 1. SPAD units, a measure of relative chlorophyll content, of mature leaves on renewal shoots of 'Thompson Seedless' grapevines harvest pruned on day 245, or non-harvest pruned (control). Data are the average of six treatment replicates; each treatment replicate was the average value of three leaves, and the same leaves were measured on each date.

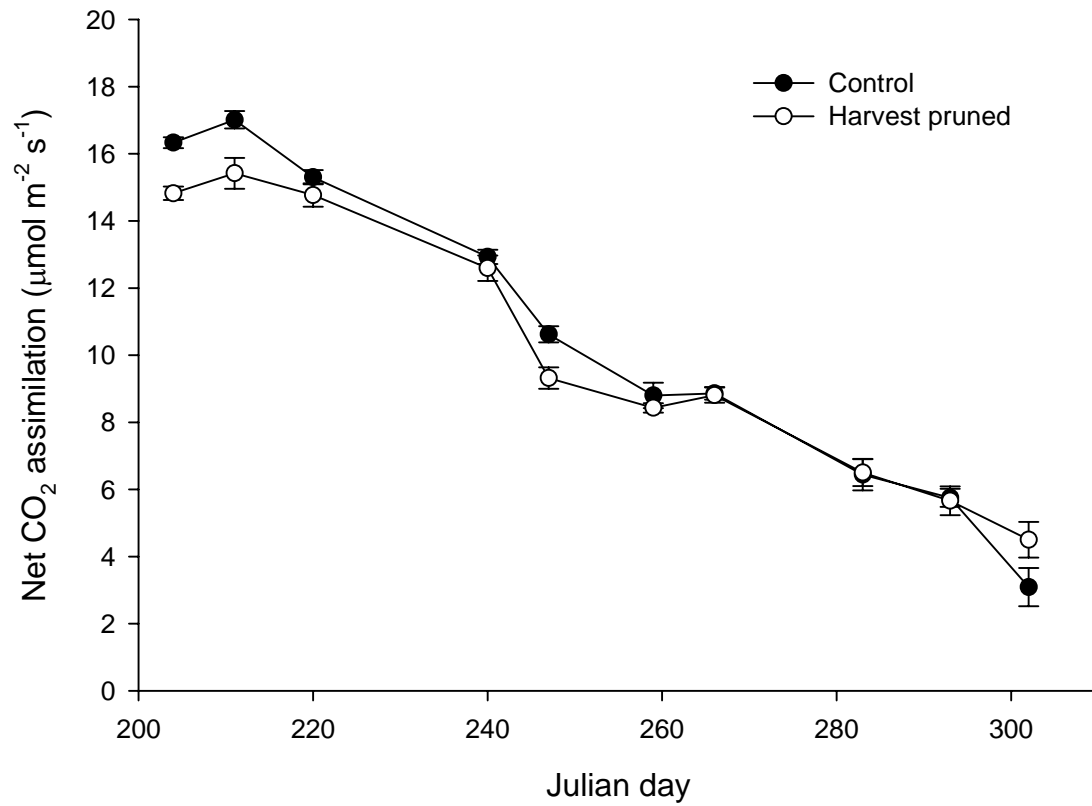


Figure 2. Net CO<sub>2</sub> assimilation of 'Thompson Seedless' grapevine leaves, Parlier, CA, 2003. Data are the average of six treatment replicates; each treatment replicate was the average value of three leaves of renewal shoots, and the same leaves were measured on each date. The canes of harvest pruned vines were severed on day 245.

Table 3. Berry weight, soluble solids, titratable acidity, fruit weight, estimated raisin weight, and pruning dry weight of ‘Thompson Seedless’ grapevines subjected to harvest pruning, or not harvest pruned (control), 2003, Parlier, CA.

Treatment	Number of Clusters	Berry weight (g)	Soluble solids (°Brix)	Titratable acidity (g • 100ml <sup>-1</sup> )	Fruit weight (kg)	Estimated raisin weight (kg)	Pruning dry weight (kg)
Harvest prune	38	2.0 <sup>z</sup>	21.1	0.48	21.7	5.5	1.7
Control	34	2.0	20.1	0.48	26.5	6.4	2.5
Significance <sup>y</sup>	0.31	0.44	0.36	0.53	0.015	0.03	0.11

<sup>z</sup>Values are treatment means, n = 8.

<sup>y</sup>P<F, as determined by a t-test within columns.

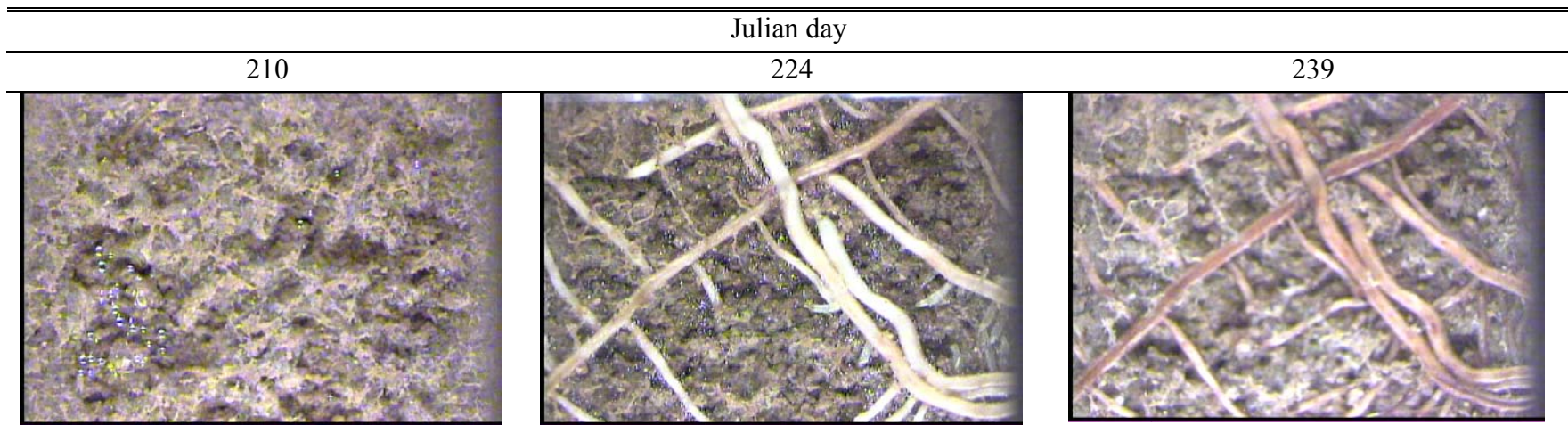


Figure 3. Typical root development of 'Thompson Seedless' grapevines, Parlier, CA, 2003. Most vines produced roots in periodic flushes, beginning after Julian day 210. The color of root surfaces generally changed from white to brown within 14 d.

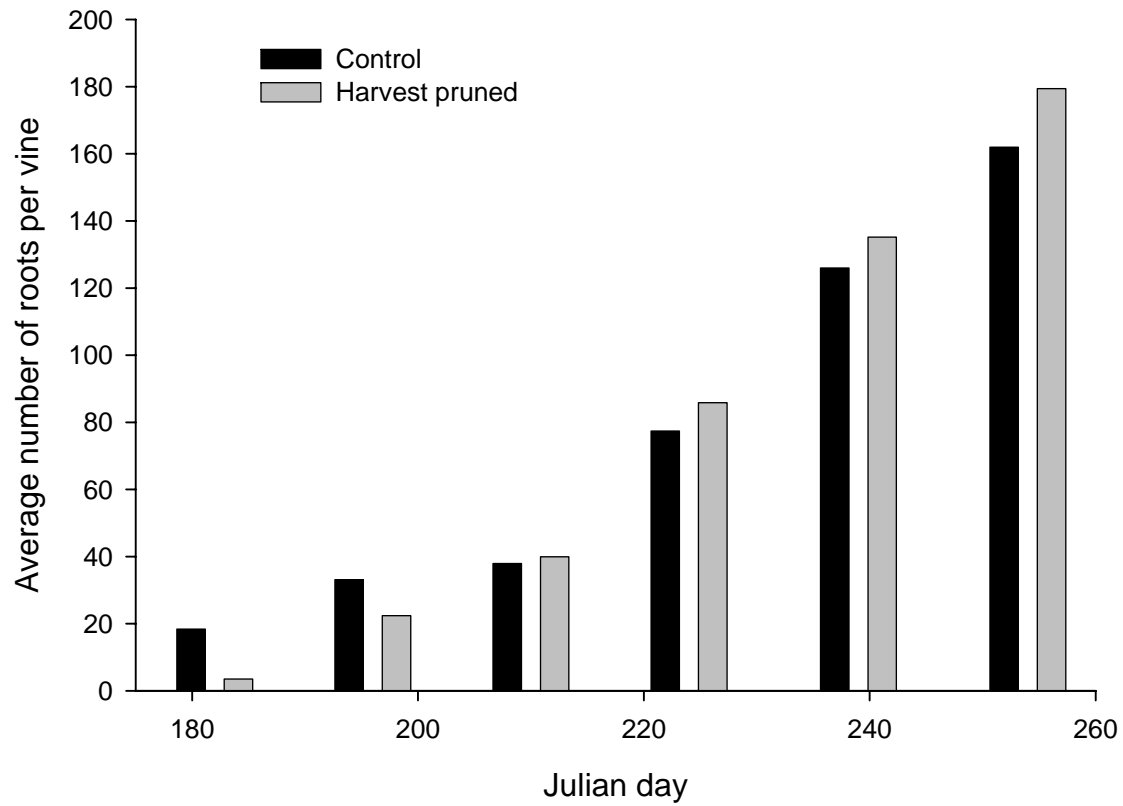


Figure 4. Average number of roots accumulated by 'Thompson Seedless' grapevines harvest pruned on day 245, or non harvest pruned (control), Parlier, CA, 2003.

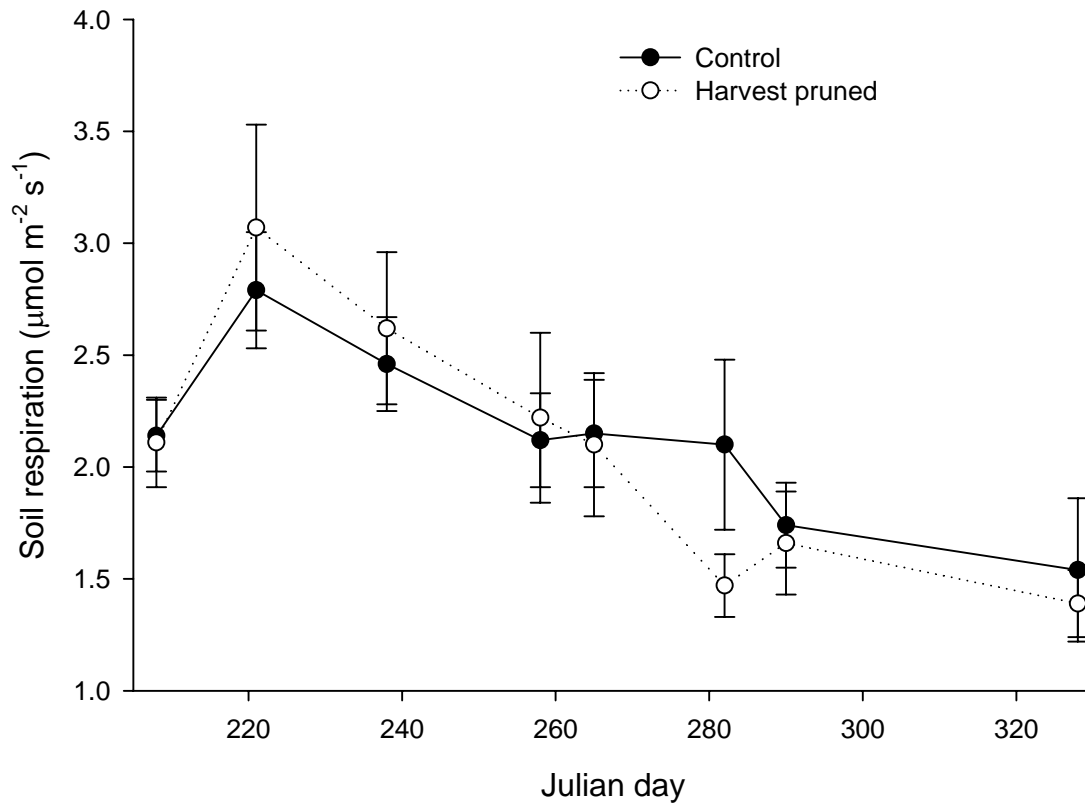


Figure 5. Soil respiration, measured about 20 cm from the trunk, of ‘Thompson Seedless’ grapevines subjected to harvest pruning, or non-harvest pruned. Data are the average of six treatment replicates; each treatment replicate was the average value of three leaves of renewal shoots, and the same leaves were measured on each date. The canes of harvest pruned vines were severed on day 245.