

EFFECTS OF PRUNING AND BARK RINGING ON TOTAL NONSTRUCTURAL CARBOHYDRATES IN CRABAPPLE

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Abstract. To assess the effects of pruning and bark ringing (girdling) on total nonstructural carbohydrates, Sargent crabapple (*Malus sargentii*) seedlings were subjected to six pruning and/or bark ringing treatments as follows: 50% top (stem) pruning, 50% top pruning plus bark ringing (girdling), 50% root pruning, 50% root pruning plus bark ringing, bark ringing alone and controls. All pruning was performed by length (root-stem collar to terminal bud) and the ringing conducted by removal of a 5 mm strip of bark from the root-stem collar. During the 38 day growth period, seedlings were assayed for total nonstructural carbohydrates in the stems, leaves and roots. Roots in bark ringed seedlings were lower in carbohydrates than in non-bark-ringed seedlings.

Total nonstructural carbohydrates are an essential source of reserve energy in trees and other perennial plants. They can then be mobilized for metabolism or translocated to other plant organs. The concentration and localization of total nonstructural carbohydrates such as sugars, starches and fructosans within plants will vary with temperature, moisture, light and time of planting (1, 8, 9, 17, 18). Carbohydrate allocation is complex and affected by a number of factors (2) as indicated by a review on the subject (10, 11).

Bark ringing has been used effectively to study the translocation of total nonstructural carbohydrates. It often creates an accumulation of carbohydrates above the ring (4) indicating that basipetal translocation of photosynthates is impeded.

Philipson (5) investigated the effect of new root and shoot growth and its effect on regrowth after dormancy in Sitka spruce (*Picea sitchensis*) and Douglas fir (*Pseudotsuga menziesii*). Despite bark ringing at the root-stem collar which severed the phloem, new roots emerged in both species. When

carbohydrates were assayed in new root growth, the content was found to be insignificant indicating new roots were nourished from preexisting roots. However, Van den Driessche (15) reported that with Douglas-fir (*P. menziesii*), girdling prevented new root growth. Apparently plant species vary in regard to the role stored carbohydrates and/or new photoassimilates play in growth resumption.

Physiological consequences of pruning trees remains misunderstood, particularly regarding total nonstructural carbohydrate allocation. Arborists currently prune trees according to guidelines that do not account for optimizing this energy resource. Trees are sometimes pruned with disregard for seasonal effects on carbohydrate levels; the arborists' workload and overall convenience dictate time of pruning. Even though some research has been reported, the complex relationships between root and shoot systems of trees are still not totally understood (7). The objective of this study was to determine the effect of root and/or stem pruning treatments on total nonstructural carbohydrate status of greenhouse-grown crabapple seedlings. By disrupting the phloem with bark ringing, new shoot and root growth may be observed to be a result of reserve carbohydrates and/or current photosynthates.

Materials and Methods

One-year-old, dormant, unbranched bare-root seedlings of Sargent crabapple (*Malus sargentii*), 20 - 30 cm tall were used in this research. There were six treatments, all applied prior to planting on

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June 1 (Expt. 1) and June 8 (Expt. 2). The six treatments included: 1) 50% stem pruning, 2) 50% stem pruning plus bark ringing, 3) 50% root pruning, 4) 50% root pruning plus bark ringing, 5) bark ringing alone and 6) control - no pruning or ringing. All pruning was performed by length, which was defined as 50% of the length from the shoot apex to the root-stem collar and 50% of the length from the root-stem collar to the longest root (shoot and root pruning, respectively). Bark ringing was done directly above the root-stem collar making two circumferential cuts 5 mm apart. Trees were nicked initially until the bark would slip to indicate how deep to cut. A scalpel was used to make a third cut to allow the bark (periderm and phloem) to be peeled away (5).

Seven trees for each treatment were planted in a peat-perlite mixture (1:1, v:v) in one gallon containers. The plants were placed under intermittent mist during the first week to prevent desiccation of the new foliage. Trees were grown in a greenhouse at approximately 27°C day/21°C night and watered as needed. Water soluble fertilizer was applied with each irrigation at 200 mg/liter of 20 N-4.3 P-16.6 K. Plants were harvested on three dates beginning 18 days after all ringing/pruning treatments were applied. Seven trees from each pruning treatment were harvested 18, 28, and 38 days after the experiment was initiated. A factorial design was utilized (12) and the experiment was repeated approximately one week later. Plants were again removed from cold storage, treated (bark ringed and/or pruned) and planted the same day.

Upon each of the three harvest dates, nonstructural carbohydrates were assayed for from the stems, leaves and roots of the seedlings. All leaves were removed, and shoots severed at the soil line. Roots were removed from the containers and the media washed away. Plant tissues were dried at 80°C for 48 hours. Dried tissue was ground utilizing a Wiley mill with a 40 mesh screen, placed in 25 ml vials, and refrigerated at 3.5°C until assays were performed for total nonstructural carbohydrates. Samples were analyzed within two weeks of tissue collection.

The assay chosen was modified by the procedure outlined by Smith (11). Colimetric procedures were substituted for titration since errors are less likely to occur than with titration. Tissue samples were placed

in solution, brought to a boil, and then cooled to ambient temperature. The tissue was then digested by a 5.0% alpha-amylase solution, derived from the fungus *Aspergillus oryzae*. Upon digestion and filtering of the solutions, samples were analyzed by use of a Varian 635 UV-visible spectrophotometer. Absorbance was read at 520 nm with a fixed wavelength. Total nonstructural carbohydrates were calculated by using the absorbance of the samples against glucose standards of 25 to 125 mg forming a standard curve. Data are presented as nonstructural carbohydrate as a percent of total tissue dry weight. Data were analyzed by an analysis of variance followed by mean separations utilizing Newman-Keuls test at $p = 0.05$ (12). Coefficients of correlation were determined for each plant tissue assayed over time to determine carbohydrate gains or losses for total nonstructural carbohydrates.

Results and Discussion

When the seedlings were sampled for total nonstructural carbohydrates prior to treatments and planting, stems and roots were similar in reserve carbohydrate content. This was expected since *Malus* spp. have no specialized perennial storage organs and equal distribution of reserves often occurs throughout the tree as a result (13).

After 18 days no significant differences were seen in total nonstructural carbohydrates among any of the treatments for leaves, stems or roots (Table 1). Stem and root total nonstructural carbohydrate was similar to initial values. Leaf total nonstructural carbohydrate levels were about 50% of stem or root levels for Sargent crabapple 18 days after planting.

At the second harvest (28 days), leaf carbohydrates showed a slight increase from most treatments over the first harvest, with shoot total nonstructural carbohydrate decreasing slightly from the first harvest (Table 1). Nonstructural carbohydrate in stems steadily decreased with the onset of new growth in trees that were not subjected to bark ringing. However, when bark ringing was performed, stem carbohydrates steadily increased over time. The three bark ringing treatments produced a significant decrease in total nonstructural carbohydrate within the bark-ringed seedlings for root and stems by the second harvest date.

Leaf carbohydrate levels were increased for most treatments at the second harvest date. However, there were no significant differences among the treatments and harvest dates for leaf carbohydrates. Stem carbohydrate levels generally decreased for most treatments at the second harvest date. Stems were being slowly depleted of carbohydrates indicating a movement of carbohydrate from stems into breaking buds. The stem may have been serving as a source of energy for the newly emerging foliage. Root carbohydrate levels for all treatments were lower than for the

first harvest date.

At the third harvest, total nonstructural carbohydrates of roots were lower with the treatments which involved bark ringing when compared to those where the phloem was not interrupted (no bark-ringing). Stem total nonstructural carbohydrate was significantly higher when assayed after the third harvest for the bark ringed treatments. Root total nonstructural carbohydrates decreased at the third harvest for the bark-ringed treatments.

Potter et al (6) reported that total nonstructural carbohydrates in prickly pear roots declined in the

Table 1. Total nonstructural carbohydrate levels for *Malus sargentii* after six pruning and/or bark ringing treatments applied prior to planting for two experiments.

Experiment 1	Total Nonstructural Carbohydrate (%) ¹								
	6-28-89			7-8-89			7-18-89		
	Harvest 1 (18 days)			Harvest 2 (28 days)			Harvest 3 (38 days)		
	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root
1) 50% S ²	11.2a ⁵	25.1a	22.7a	11.8a	23.1a	20.8a	12.9a	21.5a	16.5a
2) 50% S + BR ³	13.1a	24.3a	24.3a	14.4a	27.2b	16.8b	14.7a	28.8b	11.5b
3) 50% R ⁴	12.8a	25.9a	25.5a	12.5a	23.8a	21.2a	13.6a	20.6a	17.8a
4) 50% R + BR	10.9a	23.8a	23.9a	11.7a	26.3b	16.5b	13.9a	27.5b	10.6b
5) BR	12.6a	26.4a	25.5a	13.3a	25.7a	18.6b	15.0a	28.4b	12.3b
6) Control	11.5a	25.4a	24.0a	12.2a	23.6a	22.1a	14.8a	21.8a	19.2a
Standard dev.	2.8	3.1	2.5	2.1	4.3	2.9	2.2	3.7	2.4

Experiment 2	Total Nonstructural Carbohydrate (%) ¹								
	7-3-89			7-13-89			7-23-89		
	Harvest 1 (18 days)			Harvest 2 (28 days)			Harvest 3 (38 days)		
	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root
1) 50% S ²	12.1a ⁵	23.5a	24.1a	12.3a	21.1a	22.6a	13.1a	19.8a	19.7a
2) 50% S + BR ³	10.8a	26.1a	22.7a	11.1a	28.4b	18.0b	11.6a	29.7b	13.5b
3) 50% R ⁴	12.6a	24.4a	23.3a	12.5a	22.2a	21.7a	12.9a	22.1a	18.6a
4) 50% R + BR	11.4a	23.2a	23.8a	11.7a	27.0b	16.6b	12.2a	26.8b	11.3b
5) BR	11.7a	25.0a	24.6a	11.6a	24.6a	17.9b	11.9a	26.1b	12.8b
6) Control	12.5a	25.6a	22.0a	12.4a	23.2a	22.4a	13.4a	20.4a	21.0a
Standard dev.	1.7	2.8	3.3	1.9	2.5	3.0	4.1	3.2	3.7

¹ Total nonstructural carbohydrates based on a plant dry weight percentage of seven replications/ treatment/harvest.

² S = Shoot or root pruning which was based on length.

³ BR represents bark ringing with a 5.0 mm strip of bark removed at the root-stem collar.

⁴ R = Root pruning which was based on length.

⁵ Values followed by like letters by columns are not significantly different utilizing Newman-Keuls at p=0.05.

spring due to upward translocation. Since root carbohydrates steadily decreased in our research, this suggests that new root growth made use of existing root-stored-reserves and photosynthates from non bark-ringed trees. Bark ringing was apparently effective in blocking phloem translocation as revealed by the low carbohydrate levels in roots of plants with bark ringing. Root carbohydrates in plants without bark ringing was much higher than for bark-ringed plants. However, roots were never totally depleted of carbohydrates even after the third and final harvest date.

Pruning treatments utilized in these studies decreased carbohydrate supply to seedling shoots. Yamashita (16) with mulberry stated that pruning enhanced conversion of sucrose to starch in the stem, resulting in a larger accumulation of new carbohydrates. Fishler (4) reported that bark ringing resulted in accumulated carbohydrates above the bark ring, as in our study. Tschaplinski and Blake (14), found shoot decapitation in poplar (*Populus maximowiczii* x *nigra*) severely depleted starch reserves over a several week period. The plants were invigorated by pruning and an increase in photosynthetic rate resulted. From our experiments it is unclear if pruning stimulated net photosynthesis. Even though leaf carbohydrates steadily increased, stem carbohydrates equally decreased. Therefore, it is impossible to determine if pruning stimulated photosynthate production and the foliage demands were too high to be met without stem reserves.

Relevance to the industry. Physiological consequences of current landscape management practices are largely misunderstood. One example is the effect of shoot or root pruning on overall growth of trees. Although differences between treatments in this study were not always significant, it is clear that control trees (those not pruned) were consistently higher in total nonstructural carbohydrates. Therefore, severe pruning (50% shoot and/or root removal) is deleterious to the overall growth and vigor of ornamental trees. Additional research is needed to make recommendations to arborists regarding the proper timing and severity of pruning to optimize carbohydrate relationships of the root and shoot systems of trees.

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Resumé. Pour évaluer les effets de la taille et de l'étranglement (anneler) de l'écorce sur le total d'hydrates de carbone non structuraux, des semis de pommier de Sargent (*Malus sargentii*) étaient soumis à six traitements: 1) taille de 50% de la cime, 2) taille de 50% de la cime avec étranglement de l'écorce, 3) taille de 50% des racines, 4) taille de 50% des racines avec étranglement de l'écorce, 5) étranglement seul de l'écorce et 6) aucun traitement (groupe-contrôle). L'étranglement consistait à retirer une bande de 5 mm d'écorce du collet (racines-tronc) de l'arbre. Durant une période de 38 jours de croissance, les semis étaient analysés sur le total en hydrates de carbone non structuraux dans les tiges, les feuilles et les racines. Les racines des semis à écorce annelée étaient faibles en hydrates de carbone comparativement aux semis à écorce non annelée. Les taux en hydrates de carbone racinaires augmentaient, avec le temps, avec l'accroissement en hydrates de carbone des tiges. Les réserves des tiges et des racines, tout comme la photosynthèse courante, fournissaient l'énergie nécessaire pour de nouvelles racines et feuilles.

Zusammenfassung. Um die Auswirkung des Beschneidens von Trieb und Wurzel sowie das Ringeln der Rinde auf den Gehalt an niedermolekularen Kohlehydraten in Gehölzpflanzen einschätzen zu können, wurden Sämlinge von Holzapfelbäumen "Sargent crabapple" (*Malus sargentii*) auf sechs verschiedene Arten beschnitten und/oder geringelt (jeweils Prozent der Länge: 1) 50% von Trieb, 2) 50% von Trieb plus Ringelung, 3) 50% der Wurzeln, 4) 50% der Wurzeln plus Ringelung, 5) nur Ringelung 6) unbehandelte Kontrolle. Beim Ringeln wurde aus dem Entfernen eines 5 mm breiter Rindenstreifen am Wurzelhals entfernt. Im Laufe einer 38tägigen Wachstumszeit wurden die Triebe, Blättner und Wurzeln der Sämlinge auf den Gehalt an niedermolekularen Kohlehydraten untersucht. Die Wurzeln von geringelten Sämlingen hatten geringere Kohlehydratgehalte als die von nicht geringelten Pflanzen. Der Kohlehydratgehalt der Wurzeln nimmt bei gleichzeitigem Verlust von Kohlehydraten im Stamm zu. Reserven in Wurzeln und Trieb ebenso wie gerade synthetisierte Photosyntheseprodukte liefern die Energie für neues Blattwerk und Wurzeln.