EFFECTS OF 3 TRUNK SUPPORT SYSTEMS ON GROWTH OF YOUNG *PYRUS CALLERYANA* TREES

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Abstract. Trunk support of newly planted *Pyrus calleryana* saplings (from 57-L [15-gal] containers, 280 cm [9 ft] tall) for 2 years with 2 stakes was compared with the TreeSaver™ Tree Anchoring System (3 rubber support straps anchoring each tree) and with a prototype of Bio-Tie (single-stake system holding each tree in an upright position with a flexible cord allowing for multidirectional movement of each tree). During the first year after installation, the double-staked trees grew taller than those supported with Tree Saver or Bio-Tie systems ($P < 0.05$). After the trunk supports were removed and the trees were allowed to sway normally in the third year, the differences in growth increase disappeared. The Bio-Tie-supported tree trunks developed significantly more taper than either Tree Saver or the 2 stakes and remained more tapered after the stem supports were removed.

Key Words. Stakes; *Pyrus calleryana*; tree planting and maintenance.

As early as 1678, Evelyn recommended use of artificial supports for trunk of trees grown in nurseries and planted in cultivated soils (Patch 1987). Since then, protection of replanted trees from prevailing winds with 1 or "too many" stakes and some "twine" has been broadly recommended (Harris et al. 1978). Opinions about the influence of staking on height and stem growth, taper, root system growth, stress, and damage originated from the series of experiments by Jacobs (1954) and by Leiser and Kemper (1968, 1973). These investigators reported that free movement of the tree trunk and crown affected height growth.

In Northern California, pressure-treated lodgepole pine stakes (Figure 1) are widely used for supporting stems of balled-and-burlapped or bare-root saplings in containers. How many, where, and when stakes are driven into the ground and how and where they are tied to the tree trunk vary greatly (Harris 1992).

Harris et al. (1978) recommended that stakes and position of ties should be no higher than necessary to hold a tree upright, while allowing the top to move freely in the wind. A common procedure to find the correct height for the stem attachment to a stake is to grasp the trunk with one hand and bend the treetop. If the top returns to its upright position when released, the trunk is tied to stakes at the grasped height (Hickman and Švihra 1994).

This paper compares the effects of a commonly used double-stake stem support system with 2 new designs, Bio-Tie (Vitech Technologies, Inc.) and Tree Saver™ (Lawson & Lawson, Inc.), on the growth of *Pyrus calleryana* after replanting from 57-L (15-gal) containers into California landscape conditions. Because these trees were unable to stand upright without the stake support, the objective of this study was to evaluate the effect of these methods on shoot and caliper growth.

Figure 1. Double-stake (DS) support system.

MATERIALS AND METHODS

Thirty-three uniform *Pyrus calleryana* trees grown in 57-L (15-gal) containers, averaging 280 cm (9 ft) in height were planted 5 m (16.5 ft) apart on January 12 and 13, 1994, in rows in moderately drained heavy clay (disturbed urban soil) in Novato, California. An 80-cm (2.5-ft) diameter hole (about 30 cm [1 ft] wider than the container) with adequate depth for the container was dug for each tree by a power auger. The bottom and side of each hole was then scored with a spade (Smith 1977). To prevent root girdling, the exterior of each root ball was cut with a sharp knife by 4 vertical cuts equally spaced around the ball circumference, and the cut roots were then roughened with a trowel. A randomly selected tree was set in the center of each hole with the tree stem in an upright position. Two lodgepole pine stakes placed in line with prevailing north-south directional winds were hammered approximately 25 cm (10 in.) into undisturbed soil at the bottom of the hole adjacent to the root ball. Unamended backfill soil was firmly packed around the root ball and stakes. Each root ball received 1 irrigation of 15 L (4 gal) of water. Stakes were cut uniformly to 175 cm [5.75 ft] above the ground, slightly higher than the height at which the tree crown was held upright by the ties. At a height corresponding to the top of the stakes, the tree stem was connected with 2 beltlike rubber straps nailed to the stakes, thus holding the trunk firmly while allowing the crown to sway in the wind (Figure 1).

Experimental Design

On February 10, 1994, all 33 trees were assigned staking treatments in groups of 3. Within each group of trees, the following 3 treatments were randomly assigned:

1. DS—Double stake (Figure1): Trees that had been staked 1 month earlier.
2. BT—Bio-Tie (prototype, Figure 2): A single-stake system holding each tree in an upright position with a flexible cord allowing for free movement of each tree. The holding tube was firmly screwed to the top of a single stake positioned on the windward (northern) side. The flexing guy was attached to a rubber strap tightened to the stem. The internal side of the strap was lined with foam rubber to decrease the risk of mechanical injury.
3. TS—Tree Saver™ Anchoring System, with 3 rubber support straps anchoring each tree (Figure 3): Three rubber support straps were attached by loops in the upper middle portion of the stem and spaced at 120-degree angles. The straps were anchored to metal hooks driven into the ground at right angles to pull lines.

All supports were removed on February 11, 1996. The trees were not fertilized but were drip irrigated over a 3-year period once a week, each receiving about 38 L (10 gal) of water. Tree survival was 100%.

Measurements and Data Collection

Over a 3-year period (February 10, 1994, to February 13, 1997) a Pentax stick was used to measure tree height and height to the first lateral branch; stem diameter was measured at 3 stem locations: 30 cm (1 ft) above the ground (bottom diameter), 30 cm below the lowest lateral branch (top diameter), and midway between (center diameter). Stem diameter measurements were made with a microcaliper at 2 right-angle directions. Mean diameters were calculated for the 3 stem positions. Stem taper was calculated by subtracting the top diameter (cm) from the bottom diameter

Figure 2. Bio-Tie (BT) support provided freedom for stems to sway in the wind.

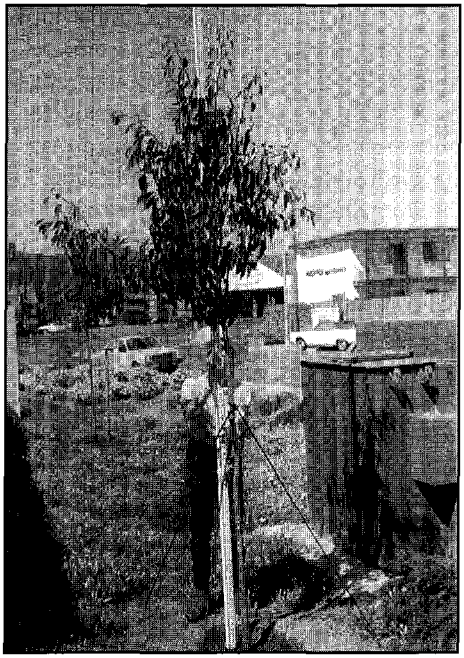

Figure 3. Height measurement with Pentax stick of *Pyrus calleryana* supported with the Tree Saver Tree Anchoring System (TS).

(cm) divided by the distance between the 2 measurements (in cm), and multiplying by 10 to convert to mm/cm.

Statistical Analysis

Two sets of measurements were analyzed: 1) growth data for trees with supports installed (4 and 8 measurements respectively), and 2) growth data after supports were removed (4 measurements). The experimental design was a randomized block with 3 blocks and 11 replications per block. Differences between initial and final tree height growth, diameter, and stem taper were subjected to analysis of covariance (covariants were the initial height and diameter) followed by a means separation test (the Scheffe multiple comparison procedure) of the SAS software (SAS Institute Inc., Cary, NC). All analyses were conducted at the 5% significance level.

RESULTS AND DISCUSSION

Initial measurement of tree height (average, 286.5 cm [113 in.]) and diameters (average, 2.4 cm [0.9 in.]) did not differ significantly among the 3 treatments groups. During the first year after treatment, the height of DS trees increased significantly faster than that of those supported with TS or BT systems ($P < 0.05$). In the second year (Table 1), the growth increase of DS trees differed only from those supported with the TS system. After the stem supports were removed, there were no differences in height growth. Jacobs (1954) and Leiser et al. (1972) reported increases in height growth of staked trees. In a glasshouse experiment with *Liquidambar styraciflua*, Neel and Harris (1971) demonstrated that moderate shaking of trunks for 30 seconds daily significantly reduced height growth over that of unshaken trees. When Larson (1965) prevented *Larix occidentalis* from swaying, the rate of height growth increased.

Although the tops of trees supported with the BT system moved more freely in the wind than those of DS and TS (Figure 2), their height growth—while significantly reduced in the first year—was only slightly less than that of DS trees by the end of the second growing season. Why trees supported with the TS system were consistently shorter is not clear (Figure 4).

Data recorded by the California Irrigation Management Information System (CIMIS) Novato Weather Station #63, located 3.5 km (2 mi) from the site, showed that the experimental trees were subjected to wind from 2 directions (Figure 5). Winds prevailed from the north for 484 days and from the south for 409 days. Only 39 days were calm; during the remaining 100 days the winds varied and prevailed

Table 1. The 2-year effect (February 1994 to February 1996) of 3 stem supports on height, diameter, and stem taper of *Pyrus calleryana*.

	Height increase (cm)		Top diameter increase (cm)		Center diameter increase (cm)		Bottom diameter increase (cm)		Trunk taper (mm/cm)	
Treatment	Support	Nonsupport	Support	Nonsupport	Support	Nonsupport	Support	Nonsupport	Support	Nonsupport
Double-stake	82.3 a*	24.4 a	2.44 a	1.73 a	2.08 a	2.06 a	2.26 b	2.36 a	0.092 b	0.146 ab
Bio-Tie	79.3 ab	15.2 a	2.44 a	1.54 a	2.38 a	1.68 a	2.87 a	2.00 a	0.137 a	0.177 a
Tree Saver	61.0 b	12.2 a	1.54 a	1.19 a	1.75 a	1.35 a	2.44 b	1.62 a	0.091 b	0.129 b

*Means in the same column followed by a different letter are significantly different at $\alpha \leq .05$ using the Scheffe multiple comparison procedure.

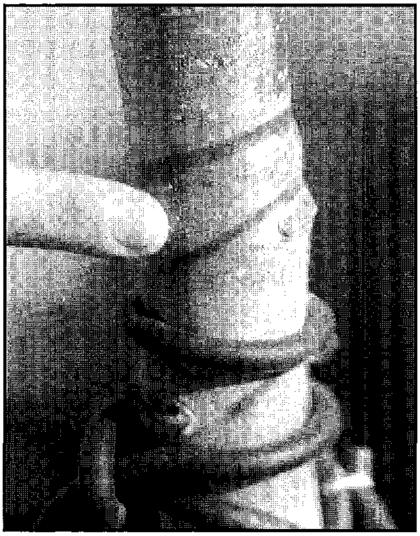

Figure 4. Injury to tree stem by Tree Saver Tree Anchoring straps. Stems of soft-wooded species might be girdled and perhaps affected in their growth when exposed to windy conditions, such as these were.

from northeast, northwest, southwest, east, and southeast directions. Therefore, the deflection of stems by wind was 2-directional, which may have affected not only growth in height and stem diameter, but also stem taper. The degree of stem deflection by wind depended on wind speed, resistance of the stem supports, and the season. The experimental site was visited more than 90 times when high winds were forecast, to observe the performance of supports when crowns and stems swayed in the wind. Lateral movement of crowns and stems during the growing season began when the wind speed reached approximately 2.5 m/sec [8 ft], and such wind speeds developed in 68 days (Figure 5). In contrast, wind speeds of the same velocity barely moved the crowns and stems of leafless trees.

Top and center diameters were similar for trees of all 3 treatments, but those of TS–supported trees tended to be lowest (Table 1). In contrast, the bottom diameters significantly increased in trees supported with the BT system, but this difference disappeared after the stem supports were removed (Table 1). Freer lateral movement of tree stems supported with the BT system was associated with increased diameter growth at the lowest stem portion ($P < 0.05$). In addition, the BT system stimulated growth of sprout and sucker shoots near the stem bases. DS- and TS-supported trees produced no or very few sprouts and suckers near the ground. After the stem supports were removed, watersprouts and suckers tended to proliferate near the ground on trees of all treatment groups. The swaying of crowns had a marked effect on loosening of double stakes near the ground, wearing out the straps and even breaking some of the BT-flexing guys. As the trees leafed out, resistance of the stem supports to winds decreased progressively and deflection of both stems and tree crowns increased. After the second growing season, movement of stakes markedly increased (Figure 6) and appeared to affect appreciably both diameter and height growth of DS trees (lat-

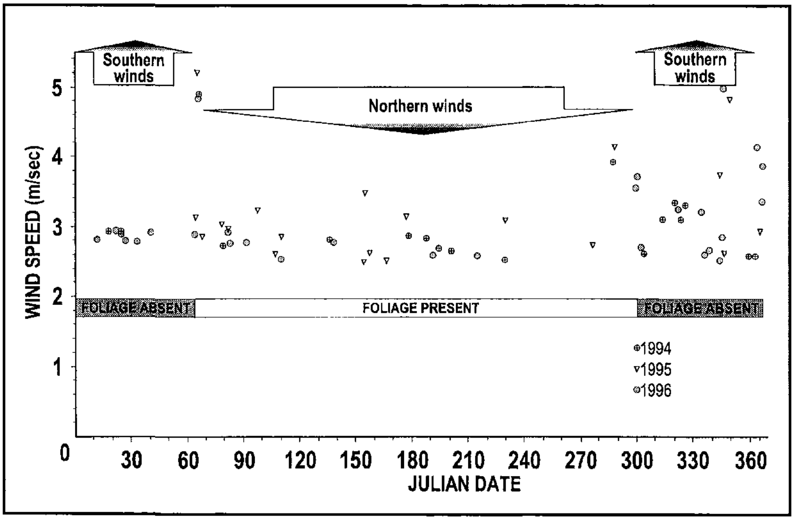

Figure 5. Diagram of frequency of days during which wind speed exceeded 2.5 m/sec in relation to wind direction and vegetative growth. Data obtained from the California Irrigation Management Information System (CIMIS) Novato Weather Station # 63 about 3.5 km (2 mi) from the experimental site.

eral movements of their crowns became similar to those supported by TS and BT systems). All 3 support systems held tree stems at a single point in our experiment, which differed from the studies by Larson (1965), Leiser and Kemper (1973), and Patch (1985) in which the stems were restrained at more than 1 point; perhaps this is another reason why our results are less dramatic and both height and diameter growth of *P. calleryana* were only slightly modified by the tested support systems.

The BT-supported stems, which were observed to sway in the wind more freely than those of TS or DS trees (as demonstrated in Figure 2), had the greatest stem taper. Prevention of stem swaying of *Pinus taeda* reduced stem taper (Burton and Smith 1972). The BT-supported *Pyrus* trees retained highest taper even after the supports were removed and all trees swayed normally. Interestingly, after the stem supports were removed, stem taper of DS-trees increased most (Table 1), as would be expected.

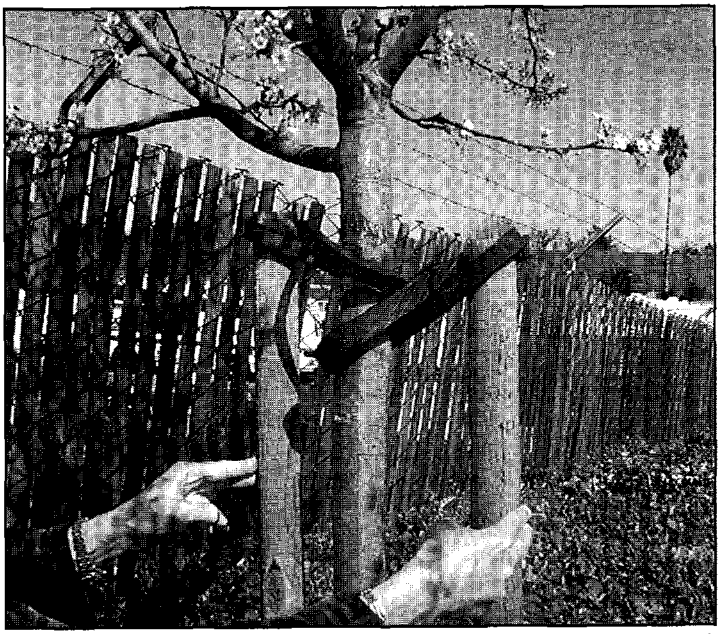

Figure 6. Slight lateral pressure with fingers moved (bent) stakes more than 15 cm (6 in.) after 1 year of continuous stem and crown movement by wind. This photograph demonstrates that even "rigid" double stakes stiffened with 2 ties to the stem could only partially oppose sideways stem deflection after 1 year.

CONCLUSIONS

DS and TS systems prevented or strongly reduced stem swaying by wind and trunk taper but did not have a lasting effect. The BT-supported stems had the greatest stem taper. Our experiments suggest that double staking when the tree trunk is supported near the place that allows free crown sway may not appreciably inhibit tree growth.

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Résumé. La qualité de support de jeunes *Pyrus calleryana* nouvellement plantés par deux tuteurs conventionnels a été comparée pendant deux ans à celle du système d'ancrage Tree-Saver[MC] (trois colliers de caoutchouc entourant le tronc et ancrés au sol) ainsi qu'à celle d'un prototype de Bio-Tie (système à tuteur simple retenant l'arbre dans une position verticale au moyen d'une corde flexible permettant un nouvement multidirectionnel de l'arbre). Au cours de la première année suivant l'installation, les arbres attachés à deux tuteurs ont poussé plus vite que ceux attachés avec les systèmes Tree-Saver[MC] ou Bio-Tie (P<0,05). Après que les différents systèmes de supports furent enlevés la troisième année et que les arbres purent se balancer normalement, les différences dans le taux de croissance ont disparu. Le système de support Bio-Tie a permis un développement plus fort du tronc en diamètre et il en est demeuré ainsi après le système fut retiré.

Zusammenfassung. Der Stammschutz durch zwei Baumpfähle bei frisch gepflanzten *Pyrus calleryana* Heistern (aus 60 l Containern, 250 cm hoch) wurde verglichen mit: 1. Tree Saver- Baumverankerungssystem (drei elastische Gummistrapse halten den Baum) und 2. Prototyp von Bio-Tie (ein System mit einem Baumpfahl, der den Baum mit einem flexiblen Band in einer aufrechten Stellung hält und so ein Wachstum in alle Richtungen erlaubt). Während des ersten Jahres nach der Installierung wuchsen die Bäume mit den zwei Baumpfählen höher als die Bäume unter den anderen Systemen (P < 0.05). Nachdem die Wachstumshilfen entfernt wurden und die Bäume frei wuchsen konnten, verschwanden die Unterschiede im dritten Jahr. Die Stämme, die mit dem Bio-Tie unterstützt wurden, entwickelten sich deutlich mehr spitz zulaufend und blieben auch so, nachdem die Hilfen entfernt wurden.

Resumen. El sostén del tronco de árboles jóvenes de *Pyrus calleryna* recientemente plantados, con dos estacas, fue comparado por dos años con el Sistema de Anclaje de los Árboles Tree-Saver™ (tres correas de soporte de hule anclando cada árbol), y con un prototipo de Bio-Tie (sistema de una estaca sosteniendo cada árbol en la posición vertical con una cuerda flexible permitiendo un movimiento multidireccional de cada árbol). Durante el primer año después de la instalación, los árboles doblemente estacados crecieron más altos que aquellos sostenidos con los sistemas Tree-Saver o Bio-Tie (P<0.05). Después que fueron removidos los soportes del tronco y se permitió el movimiento libre de los árboles en el tercer año, las diferencias en crecimiento desaparecieron. Los troncos de los árboles sostenidos con el Bio-Tie desarrollaron significativamente más ahusamiento y permanecieron más ahusados después que los soportes fueron removidos.