

The Response of 'Montmorency' Tart Cherry to Renewal Pruning Strategies in a High Density System

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Abstract

Tart cherry (*Prunus cerasus*) production in the U.S. is based on low-density plantings designed to accommodate large trunk-shake mechanical harvesters. Availability of canopy-shake harvesters adapted to smaller trees could facilitate transitioning to high-density (HD) precocious systems, based on continuous fruiting walls that are highly efficient at light capture. HD systems would require specialized pruning techniques to maintain long-term productivity while maximizing the efficiency of a limited labor supply. Experimental HD orchards with multiple rootstocks, training systems and tree densities were used for investigating renewal pruning strategies. Pruning cuts of predetermined lengths ranging from 0 cm to 25 cm were made on branches of differing size (0.6 cm to 4.7 cm diameter), and renewal growth was monitored for shoot number and length. The minimum stub length for generating at least one renewal shoot was approximately 10 cm. However, this differed somewhat with rootstock and diameter of the cut branch, where the critical length was shorter for larger diameter branches and on the more vigorous rootstock. Results provide guidelines on pruning of HD plantings to renew fruiting wood and maintain productivity.

In many temperate fruit tree species, renewal pruning is used to replace large, rigid branches with smaller, flexible branches with healthy, young spurs and fruiting shoots. In apples and peaches, renewal pruning often involves leaving short, 2 cm long bevel cut stubs, referred to as Dutch or stub cuts. From this short stub, a bud will break, typically on the underside of the stub. The resulting shoot will grow with a wide crotch angle and at a flatter angle, effectively replacing or renewing the cut branch (Robinson, 2003). Renewal pruning is an important practice aiding in improvement of light penetration and air-flow in the canopy and helps to maintain the health of the tree (Cain, 1972).

It has been well documented in multiple fruit crops, that dry matter production, fruit size, color, soluble solids concentration and total fruit yield are directly related to the amount of sunlight intercepted in the tree (Campbell and Marini, 1992; Flore and Layne, 1999; Palmer, 1997; Wünsche and

Lakso, 2000). As light filters through the canopy, a gradient of light interception is established that contributes to both whole tree light interception and light microenvironment around the fruiting spur. By selectively renewing the largest branches in the canopy, light penetration may be increased. This increased light in the canopy promotes tree health, increased flower bud formation, and the development of quality fruit.

Renewal pruning for improved light distribution can increase air circulation and improve spray penetration through the canopy (Sutton and Unrath, 1984; Ferree and Hall, 1980). Tart cherry is susceptible to a host of fungal infections, such as powdery mildew (*Podosphaera clandestine*), as well as arthropod pests that thrive in dense canopies where air circulation is poor. Selective renewal pruning can improve air circulation, decrease canopy humidity, decrease the prevalence of disease, and at the same time may make crop protectant applications more effective by in-

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creasing distribution uniformity through the canopy. Hedging is being used to efficiently prune and reduce labor costs in the orchard, but this practice can create a denser outer canopy in the trees (Nugent, 2002). Renewal pruning may be needed in conjunction with hedging to maintain appropriate canopy density. It has been suggested that one-fifth of the largest branches in tart cherry trees be renewed annually to keep wood small, flexible, and fruitful (Crandall, 1979). Maintaining flexible fruiting wood may also be important for over-the-row harvesters that remove fruit from the plant by shaking the canopy instead of the tree trunk. These canopy shake harvesters are commonly used in grapes, raspberries, blueberries, olives, and some nut crops.

Fruiting in tart cherries occurs primarily on spurs on two-year-old and older wood, but in certain circumstances, may also occur at the base of one-year-old wood, which can result in blind wood after the first fruiting year. In contrast, vegetative buds formed on one-year-old wood result in spurs that will fruit for several years (Perry et al., 1998). Any management practice that promotes more precocious fruiting, potentially risks excessive flower bud formation on one-year-old wood, further contributing to the amount of blind wood in the canopy. This can be managed with the application of gibberellic acid (Anderson et al., 1996) which suppresses flower bud formation in favor of vegetative bud formation, resulting in less blind wood formation in the canopy. However, renewal pruning is also required to replace blind wood with spur-bearing branches by removing unfruitful wood and encouraging new potentially fruitful growth in its place.

Although apples and peaches respond best to cutting branches to at least 2 cm stubs (Robinson, 2003), the stub length for tart cherry branch renewal is a topic that has not been well researched. Preliminary results indicate that cherries respond to short renewal cuts differently than apples and peaches, where cherries appear to need longer stub

lengths to regrow fruiting wood. Long stub lengths (>15 cm from the base) in sweet cherries have been found to increase the number of flower buds and lateral shoots (Guimond et al., 1998). Nugent (2002) recommended 10 to 15 cm long stubs to promote renewal growth in 'Montmorency' tart cherry, but did not cite data from which this recommendation was based.

The objective of this research was to find the minimum stub length to generate at least one new shoot on 'Montmorency' tart cherry in a high density orchard, and to determine whether this critical length was affected by rootstock vigor. Our hypothesis was that tart cherry requires 10 cm long stubs to generate a renewal shoot.

Materials and Methods

Renewal pruning strategies were applied to a high density (HD) tart cherry orchard planted in 2010 at the Utah Agricultural Experiment Station research farm in Kaysville, Utah (41°01'16"N latitude, 1328 m elevation, 165 freeze-free days). The orchard consists of combinations of 3 rootstocks and 3 training systems with 'Montmorency' tart cherry as the scion cultivar. Rootstocks included the dwarfing Gisela® 3 (Gi.3) and Gisela® 5 (Gi.5), and the commercial standard 'Mahaleb'. Tree training included a single leader, a double leader, and a quad leader, with leaders oriented in line with the row to facilitate machine harvest. Annual dormant pruning was based on a columnarized system with renewal cuts made back to the leaders in a 3-4 year cycle, patterned after protocols for tall spindle apples (Robinson et al., 2006). Briefly, annual dormant pruning involved renewal cuts to 2 to 3 of the largest branches of each tree. The targeted result was 1, 2 or 4 permanent leaders with weaker fruiting lateral shoots that are frequently replaced. Row orientation was approximately northeast to southwest corresponding to the slope of the field to improve air drainage. Each rootstock-training system combination was replicated in ~9 m long plots. Orchard soil

was a Kidman fine sandy loam with 0 to 1 percent slope. Fertilizer application rates differed between years, with nitrogen application rates of $55 \text{ kg} \cdot \text{ha}^{-1}$ in 2015 and $25 \text{ kg} \cdot \text{ha}^{-1}$ in 2016 banded within the tree row.

For the purposes of this study, branches identified for renewal during the 2015 and 2016 dormant pruning seasons were cut to ~25 cm long. Selected branches represented a range of locations within the tree, height in the canopy and orientation. The diameter of each cut branch was measured at the base of the branch using hand held calipers, categorized by diameter class (small <1.5 cm, medium 1.5 to 2.5 cm, and large >2.5 cm), flagged, numbered and the diameter recorded. Approximately equal numbers of flagged branches representing each diameter class, rootstock and training system combination were then randomly assigned to a stub length treatment. Stub length treatments varied slightly between 2015 and 2016. In 2015, target stub lengths were 0, 10, 18, and 25 cm. In order to better determine optimum stub length, the number of treatments in 2016 was increased to include target lengths of 0, 5, 10, 15, 20, and 25 cm. Branches were cut to the assigned stub length on 23-27 March 2015 and 11-15 April 2016 and assessed for growth in early September in both years. Growth was evaluated by number and length of new shoots.

Overall pruning severity (the number of branch cuts per tree) was relatively consistent across training system and rootstock treatments for both years, with the exception of the single-leader trees in 2016. In order to accommodate the interior space in the over-the-row harvester, tree height had to be reduced in the single leader system between the 2015 and 2016 seasons, resulting in more severe pruning compared to the multi-leader systems.

Data for the number and length of regrowth were analyzed as a completely randomized design with 3 branch diameter \times 5 branch length \times 3 rootstock \times 3 training system factorial treatment structure, using the

GLM procedure in SAS statistical analysis software, version 9.4 (Cary, NC). Data for each year were analyzed separately. Means separations were determined using the pdiff option in the LS-Means statement of SAS. Quadratic regression were calculated using the estimate option in the GLM procedure.

Results

Shoot number

The amount of renewal growth, as determined by the number of new shoots originating from a stub cut, was affected by both the length and the diameter of the cut branch in both 2015 and 2016. In 2016, the tree training system and rootstock also affected new shoot number. Except for a marginally significant interaction ($P < 0.075$) between rootstock and stub diameter in 2016, there were no significant interactions ($P < 0.10$) among any factors, and the data are presented as main effects for each factor.

In both study years, the number of new shoots per renewal cut was linearly related to the length of the remaining stub (Fig. 1), where the 25 cm stub lengths resulted in more than 2.5 times more new shoots per cut stub than the 0 cm length. Stub cuts approximately 10 cm in length resulted in an average of one new shoot per renewal cut. The number of new shoots was also related to branch diameter in both study years. However, the magnitude of this diameter effect depended somewhat on the rootstock, where the largest diameter cuts on 'Mahaleb' rootstock had disproportionately more new shoots when compared to large diameter cuts on the dwarfing rootstocks (Fig. 2). Another way to visualize this effect is in comparing the stub length that is required for regrowth of an average of one branch per renewal cut. Linear regression was used to calculate this critical stub length for each rootstock and branch diameter combination (Table 1). To regrow a single renewal shoot, smaller diameter stubs on Gi.3 rootstocks required 14 cm stub length as compared to Gi.3 large diameter stubs that required 8 cm. In contrast, large diameter

Table 1. Critical stub length required to regrow one shoot for each rootstock and branch diameter category. Linear regressions were calculated for each combination. Asterisks indicate the R2 of the regression.

Rootstock	Stub Diameter		
	Small (<1.5 cm)	Medium (1.5-2.5 cm)	Large (>2.5 cm)
Length of stub cut (cm)			
Gi.3	14.1**	10.6***	7.8**
Gi.5	11.5***	10.2***	8.4***
Mahaleb	10.2**	8.6*	5.1***

*R² = 0.80-0.89, **R² = 0.90-0.94, ***R² = 0.95-1.00
P value for all regressions were <0.0001

stubs on ‘Mahaleb’ could be as short as 5 cm and regrow an average of one shoot per cut. A significant effect of training system on number of new shoots was found in 2016, but not 2015. Mean number of shoots per stub in the single leader system in 2016 was 1.45 shoots, compared to 1.02 shoots per stub in the double leader system, and 1.26 shoots

per stub in the quad leader system (data not shown).

Shoot length

The average length of new shoots is another way to quantify renewal growth response. Average shoot length was affected by rootstock, diameter, and stub length in both 2015 and 2016. There were significant interactions between training system and stub length (*P* = 0.001) and between training system and branch diameter (*P* = 0.038) in 2016, but no significant interaction in 2015 (*P* > 0.10).

The effects of training system and stub length on shoot number is shown in Fig. 3. In general, average new shoot length increased with stub length up to 10 cm, with minimal increase with stubs longer than 10 cm (Fig. 3). In 2016 for example, average new shoot length in the 4-leader system increased from 5.9 cm to 38.6 cm as stub length increased from 0 to 10 cm, but was only 41.9 cm for 25 cm stub lengths. The interaction between training system and stub length observed in

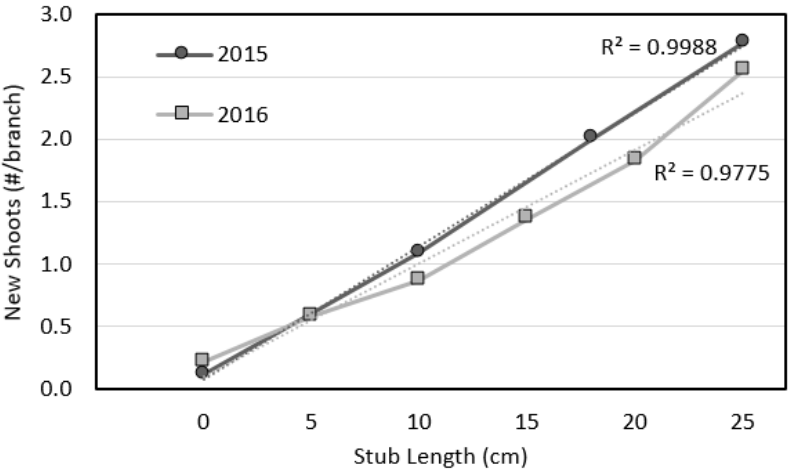


Figure 1. The effect of stub length on regrowth as determined by the number of new shoots formed per branch cut. Values are averaged across rootstock, training system and stub diameter to show general trends so that each value represents the mean of at least 200 and 100 observed renewal stubs in 2015 and 2016, respectively. R² values are for a linear regression model. Within the various treatment combinations, the relationship between stub length and new shoot number remained linear. *P* values are <0.0001 for both 2015 and 2016.

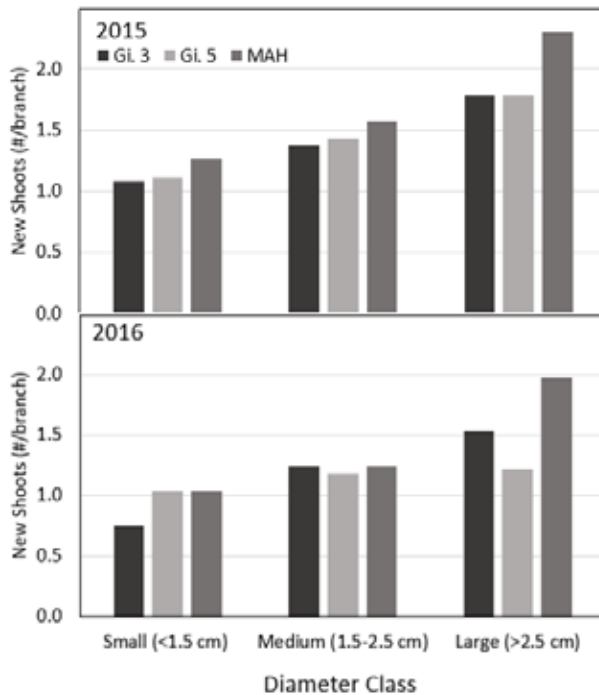


Figure 2. The effect of rootstock and branch diameter on regrowth as determined by the number of new shoots formed per cut branch in 2015 (A) and 2016 (B). Values are averaged across training system and stub length, and represent the means of at least 80 and 50 stubs per branch diameter and rootstock combination in 2015 and 2016, respectively.

2016 appears to be the result of disproportionately longer new shoots originating in the single-leader system, particularly at intermediate (5 cm and 15 cm) stub lengths. The interaction between training system and branch diameter is illustrated in Fig. 4. In this interaction, the single leader training system results in disproportionately longer new shoots, but only for the large diameter branches. Both of these interactions may be due to the more intense pruning severity required in the single-leader system.

The effect of rootstock on new shoot length differed slightly between years, but was generally related to overall rootstock vigor. The effect of rootstock and branch diameter are shown in Fig. 5. In general, the more vigorous ‘Mahaleb’ rootstock had longer shoots than the less vigorous rootstock, although

this effect was less pronounced in 2016 for the larger diameter branches.

Discussion

The objective of this study was to determine the minimum length of renewal stub cuts needed to regenerate branches in high density ‘Montmorency’ tart cherry. It is well known that short stub cuts lead to renewal growth in apple and peach. Critical length of renewal pruning cuts for tart cherry is not well documented. Nugent (2002) recommended that renewal stub lengths be left between 10 and 14 cm for tart cherry, but this recommendation did not reference any published data. A study with sweet cherry found that long renewal stub lengths (>15 cm) resulted in greater shoot and flower formation (Guimond et al., 1998). Our results confirm

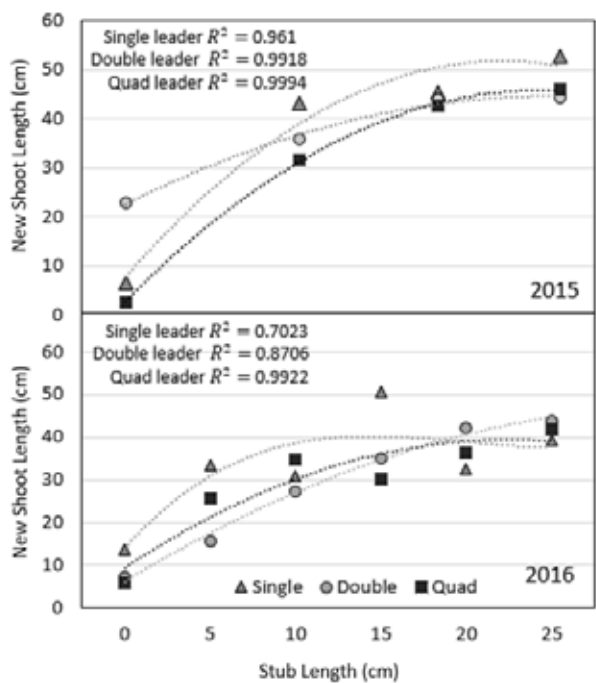


Figure 3. The effect of branch stub length and training system on renewal growth as measured by the average length of new shoots. Values are averaged across rootstock and stub diameter and represent the means of at least 70 and 30 renewal stubs observed per treatment in 2015 and 2016, respectively. Values of R^2 are for a quadratic regression model, where all regressions were significant at P values <0.0004 .

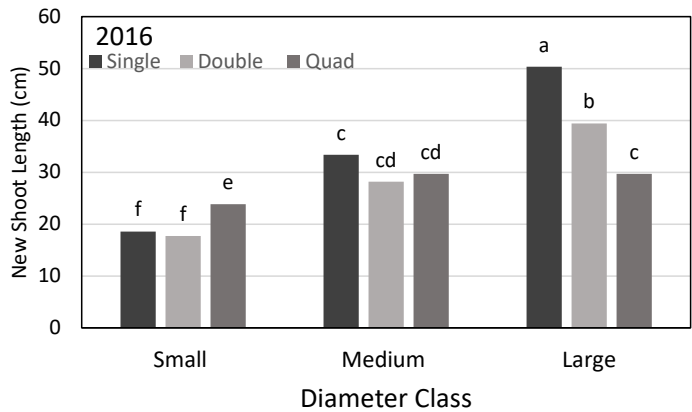


Figure 4. The effect of branch diameter and training system on the average length of new shoots in 2016. Letters denote significant differences ($P < 0.05$) using the pdiff options from the LSMeans statement in SAS.

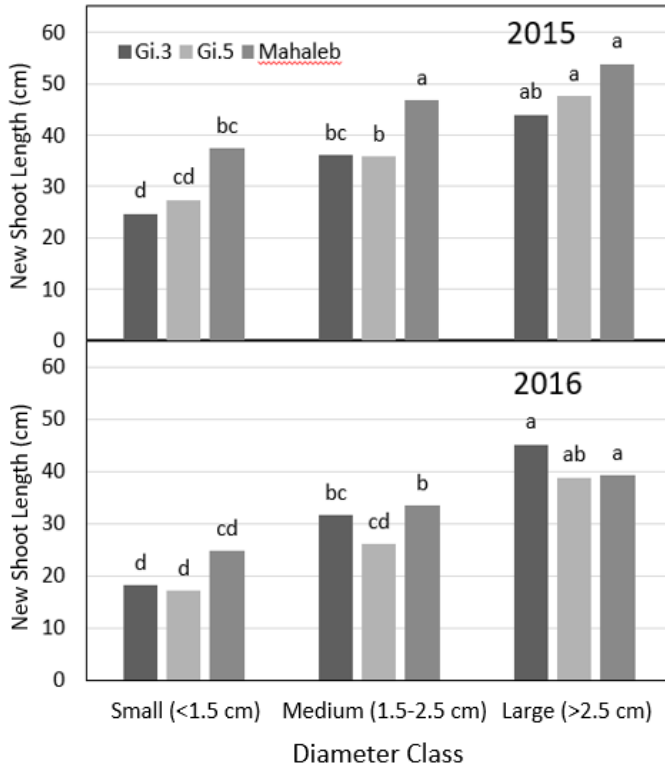


Figure 5. The effect of rootstock and diameter on regrowth, as measured by the average length of shoots formed per renewal cut. Branch diameter was classified into small (<1.5 cm), medium (1.5-2.5 cm) and large (>2.5 cm) categories. Values are the means of at least 105 (2015) and 61 (2016) renewal stubs observed per rootstocks. Letters denote significant differences (P values < 0.05) using the pdiff option from the LS-Means statement in SAS.

the recommendation by Nugent (2002) that lengths greater than 10 cm generally produced at least one new renewal shoot per cut in the season following pruning. However, this critical length is influenced somewhat by rootstock and branch diameter. Previous recommendations were for conventionally grown ‘Montmorency’ on ‘Mahaleb’ rootstock. ‘Mahaleb’ is the most vigorous rootstock included here, producing large trees that are 90% of full sized seeding Mazzard trees when grafted to a sweet cherry scion (Long and Kaiser, 2010). Gi.3 and Gi.5 produce trees less than 50% of the size of full-size trees when grafted to sweet cherry scion

(Long et al., 2014). Under Utah conditions, ‘Montmorency’ tart cherry on Gi.3 and Gi.5 are 32% and 33% the size of ‘Mahaleb’ trees, respectively (Roper et al., unpublished). These dwarfing, more precocious rootstocks are more appropriate to a high-density system, and data here indicate that these trees need longer renewal cuts to ensure regeneration of fruiting wood.

Training system also affected regrowth, but only in 2016. This orchard is harvested using a prototype over-the-row canopy shake harvester (BEI International, South Haven, MI), with a design based on a commercial blueberry harvester. This harvester design al-

lows tree heights no greater than 3.4 m. Trees in all systems were pruned to fit through this predetermined space. After the 2015 season, some trees required more severe pruning to maintain appropriate height, and this was more common in the single leader training treatments. Otherwise, pruning protocols followed typical spindle pruning developed for apples with 2 to 4 of the largest limbs being renewed annually. This renewal pruning strategy, coupled with the height reduction cuts contributed to an overall higher severity of dormant pruning in the single leader trees. Schupp et al. (2017) found that severity of whole-tree pruning had an effect on the number of new renewal shoots in apple, with greater numbers of new shoots in more heavily pruned trees. They recommend a pruning severity index to compare severity across management treatments. The objectives of the present study did not include a comparison of pruning severity, and data were not collected to compare severity among treatments. However, the results of this study may suggest that the overall pruning severity of the tree could influence the critical renewal cut length in tart cherry.

In addition to pruning severity, renewal growth can be influenced by the orientation of the renewed branch, and the height and localized shading within the canopy. Branches were selected for renewal based on the overall strategy of spindle pruning, and primarily consisted of larger, more upright branches in the middle portion of the canopy (typically 0.76 m to 1.8 m above the ground). We did not record specific information on canopy height or location for each observed branch and so the relative influence on canopy position could not be compared. Further, renewal growth was only observed at the end of the first growing season. Ideally, tart cherry renewal growth should produce primarily vegetative buds during the first growing season, so that future fruiting is on spurs to minimize blind nodes resulting from first-year flower buds.

In conventional low-density tart cherry production systems where trunk shake har-

vesters are used, branch growth habit can influence machine harvest efficiency, where fruit removal is often less efficient on more pendant branches. However, we have observed that this is less of an issue when using canopy shake technology. With canopy shake harvesters, fruit removal is usually less complete in the center of the row, regardless of branch orientation. Future research should focus on the long-term productivity of renewed shoots, and whether or not the growth habit of these shoots lend themselves to canopy shake harvest.

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