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Bud management affects fruit wood, growth, and precocity of cherry trees

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Abstract: As the production benefits of pruning fruit trees have been realized, growers have begun pruning periodically and, accordingly, various canopy training systems have begun to be developed. Following the genetic development of dwarfing rootstocks, interest has grown in the creation of modern training systems for smaller, more efficient orchards. During the formation of these training systems, it became apparent that branches of a certain size can alter the partitioning of growth resources (nutrients and carbohydrates) within the tree, delaying the formation of the target canopy structure as well as fruit bearing. In recent years, studies have focused on management of the buds related to branch development. Bud management describes such practices as debudding and selection of specific buds to promote the growth of the tree to achieve its most productive, efficient structure. This study determined the effectiveness of bud management for sweet cherry trees. The variety/rootstock combinations of 0900 Ziraat / M × M 60, Sweetheart / M × M 60, 0900 Ziraat / Gisela 5, and Regina / Gisela 6 were studied using bud management techniques, with the Vogel Central Leader training system as a control. The study was carried out in Samsun, Turkey, between 2010 and 2014. In the experiment, phenological observations (such as bud burst, first and full bloom, and harvest date) and tree values (such as shoot diameter and height; diameter, height, and number of the first branches from the trunk, amount of pruned branch mass; diameter and height of a 1-year-old shoot; number of 2-year-old or older shoots; volume of the tree canopy; and production values) were determined. Bud management resulted in homogeneous branching along the leader, less empty space in the canopy, healthy canopy formation in a shorter period, shorter and more uniform branches, an increase in 2-year-old shoots that could yield fruit, and trees that reached maximum productivity earlier.

Key words: Bud management, bud selection, pruning, training, phenology, sweet cherry

1. Introduction

The benefits of pruning sweet cherry trees have been increasingly recognized. A number of modern training systems have been developed specifically to utilize dwarfing rootstocks that have recently become available (Perry, 1999; Long, 2001, 2007; Robinson et al., 2007, 2008; Robinson and Hoying, 2014). A key focus of pruning is the removal or prevention of unnecessary shoot growth during the process of giving shape to the tree canopy by bending, twisting, and/or removing the unwanted shoots in the summer season, and the time for bearing is shortened. When these processes are done for shoots that have already formed, it delays bearing due to inefficient allocation of energy and resources for the growth of the tree.

In recent years, sweet cherry training concepts have been proposed to create orchards that begin bearing fruits after 3 years old and that maintain a tree size for which cultural processes can be conducted by hand easily when adopting dwarfing rootstocks and new training systems. These new concepts focus on precise canopy development by managing the buds that will develop into the shoots that will bear fruit. In this sense, managing the buds rather than the shoots becomes more important. The decisions regarding bud management strategies to optimize pruning, crop load, and fruit size can ensure better use of growth sources (light, mineral nutrition, photosynthesis products, water) for the development of canopy and fruit quality (Lang et al., 2007b). Bud management can be summarized briefly as retaining the buds from which future shoots are desired, or removing the buds from which unnecessary shoots might be produced. In other words, to optimize the development of the desired canopy structure of the tree, the buds at locations where the shoots should be formed are retained by minimizing pruning cuts as much as possible, and the buds that have the potential to form shoots that

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would be unwanted are removed in the spring before bud break. With bud management, the aim is to ensure that the tree develops its shape as quickly as possible and begins bearing fruit to best utilize available plant growth resources (water, nutrition, carbohydrates) only for the necessary canopy structure (Lang et al., 2007a). Such a tree development strategy reduces the need for both future summer and winter pruning. This research was carried out to determine the effect of bud management on sweet cherry tree shape, canopy growth, and fruit-bearing precocity.

2. Materials and methods

2.1. Materials

This study was performed from 2010 to 2014. The experimental site elevation is 4 m above sea level and is located at 41°17′N, 36°17′E. The location has a climate that is mild in winter and not overly hot in summer. The hottest months are July (mean temperature of 23.3 °C) and August (mean temperature of 23.5 °C), and the coldest months are January (mean temperature of 9.3 °C) and February (mean temperature of 7.2 °C) (Turkish State Meteorological Service, 2015). The soil structure is clay-loam and pH is 6.86, with 2.07% organic matter content.

2.2. Methods

The young trees in the spring of 2010 were planted with spacing of 4 × 3 m. The experiment was arranged in a randomized complete block design with two central leader canopy training treatments (with and without bud management) and four scion / rootstock combinations, namely 0900 Ziraat / M × M 60, Sweetheart / M × M 60, 0900 Ziraat / Gisela 5, and Regina / Gisela 6. There were five replicated blocks, four scion / rootstock plots per block, and 6 plants per plot. Central leader canopy development using bud management was compared with Vogel Central Leader canopy development as the control. Statistical comparisons were performed with the t-test.

Tree canopy training with bud management or Vogel Central Leader canopy development was done according to the protocols below. Phenological observations were made in the experiment, and the effects of the canopy training treatments on growth, development, and early cropping of the trees were determined as explained below.

2.2.1. Bud management

In this study, bud management was used to develop a central leader tree shape. Bud management was imposed during bud swell, and the nursery tree was not headed. Specific buds were selected and retained for potential development into new lateral shoots, and the other buds were removed. Wide branch angles for new shoots were established with the use of such apparatuses as clips or toothpicks when the shoots arising from the selected buds reached 10–15 cm in length. These processes were continued until the tree reached its target shape, i.e. through the fourth growth season (Lang et al., 2007a, 2007b).

In the process of bud management, first a single terminal leader bud is left, and the subtending side buds within 7.5–12.5 cm of that bud are removed. This is done either without heading or by leaving the bud that is left at the top as the new terminal if the tree was already headed. Second, after removing the buds that are within 7.5–12.5 cm, bud selection continues basipetally down the central leader, with one bud left for every 2–5 buds starting from the first bud, with the aim of spiral distribution of the buds under the terminal bud down the length of the nursery tree leader. Third, at 30–45 cm from the ground, all remaining subtending buds below the last selected bud are removed. Thus, bud selection establishes the specific growing points for potential formation of canopy shoots that are lined up spirally from the top to the bottom of the leader.

2.2.2. Vogel Central Leader

The Vogel Central Leader training system (described by Long, 2001) was used for the control. When the orchard was being established, a support system was used for trees on Gisela 5 and Gisela 6 rootstocks, while the support system was not used for trees on M × M 60.

The supported young trees were attached to concrete poles of 3 m in length and 10 cm in diameter after planting. Trees were irrigated and fertilized (fertigated) as needed, and weeds were controlled with tillage and using herbicide.

2.2.3. Phenological observations

1) Bud burst: The time when the buds start to burst.
2) First bloom: The time when 10% of the flowers bloom (Christensen, 1974).
3) Full bloom: The time when 90% of the flowers bloom (Demirsoy and Demirsoy, 2003).
4) Harvest date: The time when the fruits reach the desired skin color, eating quality, and fruit flesh texture, depending on genotype (Demirsoy and Demirsoy, 2003).

2.2.4. Tree measurements

1) Each year, measurements were recorded for tree diameter at 10 cm above the budding point, the height before pruning, the diameter of primary shoots at 5 cm away from the leader, and the heights and numbers of branches determined by digital compass.
2) Number of primary shoots on the leader (after pruning) and the amount of wood removed via pruning (kg per tree) were determined.
3) The diameter (5 cm away from the connection point) and height of annual shoots were measured.
4) Canopy volume (m^3) was calculated with the formula of canopy volume = $\pi r^2 h/3$ by measuring the radius of the tree canopy and the height of the tree canopy (Wocior, 2008).

5) Tree volume (m^3) was calculated with the formula of tree volume = $[(L+W)/4]^2\pi H/2$ by using the width of the tree crown (W), height of the tree (H), and length of the tree crown (L) (Stehr, 2005).
6) Precocity: The numbers of branches of 2 years old or older were taken to determine priority of bearing.

3. Results and discussion

3.1. Phenological observations

Bud burst began at the end of March and beginning of April for Sweetheart / M × M 60 and at the first week of April for 0900 Ziraat / M × M 60, 0900 Ziraat / Gisela 5, and Regina / Gisela 6. First bloom occurred earliest for Sweetheart / M × M 60 at the end of March to the middle of April, and it occurred the second week of the April for 0900 Ziraat / M × M 60, 0900 Ziraat / Gisela 5, and Regina / Gisela 6. Full bloom occurred earliest and longest between the first and third weeks of April for Sweetheart / M × M 60, and around the third week of April for 0900 Ziraat / M × M 60, 0900 Ziraat / Gisela 5, and Regina / Gisela 6. While the times of bud burst, first bloom, and full bloom were similar for 0900 Ziraat and Regina, they were 8–10 days earlier for Sweetheart. Harvest occurred the second week of June for 0900 Ziraat / M × M 60 and 0900 Ziraat / Gisela 5, and the second and third weeks of June for Sweetheart / M × M 60 and Regina / Gisela 6. The bloom and harvest times were similar to those reported from other studies in Turkey (Akçay et al., 2014).

When the bud management was compared with the control in this research, it had no effect on the dates of bud burst, first bloom, full bloom, and harvest date.

3.2. Tree measurements

Initial measurements made just after planting are given in Table 1. The diameter and height values of the trunk before the 2nd and 3rd season (2011 and 2012) growth began are given in Table 2.

Table 1. Tree measurements after planting.

Combination	Treatment	Trunk diameter (cm)	Tree height (cm)
0900 Ziraat / M × M 60	Bud management	14.1	66.4
	Control	14.8	64.2
Sweetheart / M × M 60	Bud management	14.2	66.7
	Control	13.9	61.7
0900 Ziraat / Gisela 5	Bud management	14.2	140.0
	Control	14.2	70.5
Regina / Gisela 6	Bud management	15.0	136.3
	Control	16.2	68.5

Table 2. Effects of bud management on trunk diameter and tree height (2011 and 2012).

Combination	Treatment	Trunk diameter (cm)		Tree height (m)	
		2011	2012	2011	2012
0900 Ziraat / M × M 60	Bud manag.	2.9	4.3	2.0	2.6
	Control	2.8	4.2	2.1	2.3
Sweetheart / M × M 60	Bud manag.	2.8	4.1	2.0	2.6
	Control	2.8	4.3	2.0	2.6
0900 Ziraat / Gisela 5	Bud manag.	2.5	3.6	2.0	2.4[a]
	Control	2.5	3.5	1.9	1.9
Regina / Gisela 6	Bud manag.	2.4	3.7	2.3[a]	2.5[a]
	Control	2.5	3.5	1.9	1.9

[a] $P \leq 0.01$, Bud manag.: Bud management.

Tree height was higher with bud management; differences were significant for Regina / Gisela 6 in 2011 ($P < 0.01$) and 0900 Ziraat / Gisela 5 and Regina / Gisela 6 in 2012 ($P < 0.01$) (Table 2).

The diameters, lengths, and numbers of branches formed on the tree leader before the 2nd and 3rd growth seasons (2011 and 2012) are shown in Table 3. While the number of the primary branches on the leader was similar for bud management and the control in 2011, there were significant differences for some combination such as Sweetheart / M × M 60 and Regina / Gisela 6 in 2012. Generally, values were higher for bud management, and the differences were significant statistically ($P < 0.01$) for Sweetheart / M × M 60 and Regina / Gisela 6 (Table 3).

The trunk diameter, the primary shoot diameters and numbers, and the amount of mass pruned before growth began in the 4th and 5th growth seasons in 2013 to 2014 are shown in Table 4. Generally, the number of primary shoots on the leader in the bud management applications exceeded that of the controls in 2013 and 2014. Statistically, in 2013, the number of primary shoots on the leader with bud management was greater for all combinations, and in 2014 it was greater for all except Regina / Gisela 6 ($P < 0.01$).

A sufficient number of evenly distributed lateral shoots on the leader is very important for sweet cherry canopy development and productivity. Various tree training strategies affect the number of lateral shoots that form

Table 3. Effects of bud management on diameter, length, and numbers of primary shoots on the leader (2011 and 2012).

Combination	Treatment	Primary shoots on leader					
		Diameter (mm)		Length (cm)		Number	
		2011	2012	2011	2012	2011	2012
0900 Ziraat / M × M 60	Bud manag.	10.4	13.6[a]	86.9	87.1[b]	2.9	9.3
	Control	9.8	16.4	72.8	102.3	3.6	6.8
Sweetheart / M × M 60	Bud manag.	9.4	13.0[a]	74.0	91.6[b]	2.8	8.0[a]
	Control	10.2	17.0	91.8	120.0	2.9	5.4
0900 Ziraat / Gisela 5	Bud manag.	9.0	11.3	41.8	58.0	3.2	10.5
	Control	8.9	11.9	42.0	62.4	3.2	8.3
Regina / Gisela 6	Bud manag.	8.6	9.1[a]	67.1[a]	49.6	3.2	13.8[a]
	Control	8.5	11.2	50.9	58.0	3.2	8.1

[a] $P \leq 0.01$, [b] $P \leq 0.05$, Bud manag.: Bud management.

Table 4. Effects of bud management on tree trunk diameter, diameter, and numbers of primary shoots and amount of removed wood by pruning from tree (2013 and 2014).

Combination	Treatment	Trunk diameter (cm)		Primary shoots on leader				Removed wood (kg/tree)	
				Diameter (mm)		Number			
		2013	2014	2013	2014	2013	2014	2013	2014
0900 Ziraat / M × M60	Bud manag.	6.6	7.6	16.9	18.5	15.9[a]	18.8[a]	0.8	1.2
	Control	6.1	7.9	19.4	18.5	9.8	12.2	0.6	1.2
Sweetheart / M × M 60	Bud manag.	6.6	7.0	15.9[b]	18.9	13.8[a]	14.7[b]	0.7	0.9
	Control	6.4	7.4	20.7	23.7[a]	7.4	10.6	0.7	1.6
0900 Ziraat / Gisela 5	Bud manag.	4.5	6.0	13.4	16.0	16.3[b]	18.4[a]	0.2	0.6
	Control	4.9	5.6	13.5	13.6[b]	12.1	12.3	0.3	0.6
Regina / Gisela 6	Bud manag.	4.6	5.3	11.6	13.1	19.4[a]	18.7	0.3	0.4
	Control	4.5	4.9	12.2	12.6	12.8	14.6	0.3	0.4

[a] $P \leq 0.01$, [b] $P \leq 0.05$, Bud manag.: Bud management.

on the leader (Hoying et al., 2001; Jacyna and Puchała, 2004; Elfving and Visser, 2007; Savini et al., 2007; Jacyna and Lipa, 2008; Moghadam and Zamanipour, 2013; Stanisavljević et al., 2015). In this research, the number of primary lateral shoots on the leader developed with bud management was larger than the number for the control (Tables 3 and 4). The main branches that constituted the canopy grew faster and were more numerous because they were not cut during pruning. This achieved a canopy structure in a shorter time compared to the control and ensured earlier bearing of fruit.

Statistical differences were not found between the treatments in terms of amount of pruned mass (Table 4). However, with bud management, branch number was more than that of the control. This was important for developing earlier fruiting capacity without heading cuts to create shoots and thereby reducing the pruning workload.

Tree heights, canopy volume, and tree volume before the 4th and 5th growing seasons are shown in Table 5. Tree height was generally higher with bud management. These differences were only statistically significant for 0900 Ziraat / M × M 60 in 2013 ($P < 0.05$) and 0900 Ziraat / Gisela 5 in 2014 ($P < 0.01$) (Table 5).

Canopy and tree volume were calculated, as well. While there were no differences between treatments in terms of canopy volume, tree volumes were larger with bud management for 0900 Ziraat / M × M 60 in 2013 ($P < 0.01$) and for 0900 Ziraat / Gisela 5 in 2014 ($P < 0.01$) (Table 5).

Tree height, canopy volume, and tree volume were greater with bud management compared to the control (Table 5). The greater tree volumes were an important factor for earlier formation of the tree canopy and fruiting capacity. The earlier canopy formation was closely related to tree height, as well. Other research has shown that some canopy training treatments affect tree height (Jacyna and Lipa, 2008; Moghadam and Zamanipour, 2013).

Tree canopy volume with bud management was similar to that of the control. However, the distribution of the primary shoots that formed the canopy was more homogeneous with bud management and they increased in number after 2011 (Tables 2 and 3). This greater number improved the fullness of the inner part of the tree canopy to which the bud management had been applied. This increased the potential fruiting capacity for earlier and greater tree productivity. Earlier and higher fruiting and improved quality are key goals of training systems throughout the world (Meland, 1998; Moreno et al., 1998; Weber, 1998; Lang, 2005; Robinson et al., 2007; Grandi and Lugli, 2013; Lang, 2013a, 2013b).

Annual shoot diameters, lengths, and standard deviations prior to 4th and 5th season growth are shown in Table 6. In general, annual shoot diameter and length were less with bud management. This difference in shoot diameter was statistically significant for 0900 Ziraat / M × M 60 and Regina / Gisela 6 in 2013 and for Sweetheart / M × M 60 in 2014, and shoot length was statistically significant for 0900 Ziraat / M × M 60 in 2013. The standard deviations for shoot diameter and length were less with bud management, indicating more uniform growth among the shoots (Table 6).

Previous studies have shown that treatments to promote lateral shoot formation on cherry trees can affect shoot length, as well (Elfving and Visser, 2006; Jacyna and Lipa, 2008; Moghadam and Zamanipour, 2013). In our study, the standard deviation values indicate that shoot diameters and lengths were more homogeneous with bud management (Table 5). The best quality fruits on sweet

Table 5. Effects of bud management on tree length and canopy and tree volume (2013 and 2014).

Combination	Treatment	Tree height (m)		Canopy volume (m^3)		Tree volume (m^3)	
		2013	2014	2013	2014	2013	2014
0900 Ziraat / M × M 60	Bud manag.	3.1^{b}	3.6	1.75	2.81	5.44^{b}	8.92
	Control	2.8	3.5	1.32	2.83	4.07	8.38
Sweetheart / M × M 60	Bud manag.	3.1	3.7	1.75	3.92	5.34	10.48
	Control	2.8	3.4	1.61	3.08	4.41	8.37
0900 Ziraat / Gisela 5	Bud manag.	2.5	3.2^{a}	0.88	1.81	2.90	5.68^{a}
	Control	2.4	2.7	1.05	1.49	2.65	3.72
Regina / Gisela 6	Bud manag.	2.6	4.2	0.84	2.05	2.74	5.60
	Control	2.3	2.7	0.96	1.20	2.27	3.56

^{a} $P \leq 0.01$, ^{b} $P \leq 0.05$, Bud manag.: Bud management.

Table 6. Effects of bud management on annual shoot diameter and length (2013 and 2014).

Combination	Treatment	Shoot diameter (mm)		Shoot length (cm)	
		2013	2014	2013	2014
0900 Ziraat / M × M 60	Bud manag.	7.2 ± 2.0[b]	7.4 ± 2.4	50.6 ± 15.[b]	42.8 ± 19.6
	Control	7.7 ± 3.3	7.9 ± 2.6	58.5 ± 20.2	45.7 ± 23.0
Sweetheart / M × M 60	Bud manag.	7.5 ± 2.0	7.8 ± 2.3[a]	52.4 ± 16.5	47.9 ± 17.6
	Control	8.2 ± 2.1	8.9 ± 2.8	58.5 ± 19.2	57.0 ± 25.8
0900 Ziraat / Gisela 5	Bud manag.	6.8 ± 2.5	5.4 ± 1.5	33.2 ± 12.1	23.6 ± 7.7
	Control	6.8 ± 2.0	5.6 ± 1.6	36.8 ± 12.5	24.9 ± 8.9
Regina / Gisela 6	Bud manag.	6.3 ± 1.6[b]	5.0 ± 1.3	37.2 ± 13.4	23.0 ± 8.0
	Control	6.5 ± 1.6	5.5 ± 1.4	41.0 ± 13.7	27.2 ± 8.0

[a] $P \leq 0.01$, [b] $P \leq 0.05$, Bud manag.: Bud management.

cherry trees are borne on shoots of moderate length and diameter that have angles from 45° to 60°. Lower quality fruits tend to be borne on pendant shoots and shoots that grow strongly upwards tend to be less productive. Shoots that are too long tend to develop unproductive blind sections, requiring heading cuts to initiate replacement shoots. Thus, bud management created a more balanced and productive canopy and had a better impact on pruning labor. Weber (1998) similarly reported that some training systems and pruning methods can reduce pruning requirements.

The number of 2-year-old and older shoots counted before 4th and 5th season growth is shown in Table 7. In general, the number of 2-year-old and older shoots was higher with bud management, and the differences between treatments became important statistically for 0900 Ziraat / M × M 60 and Regina / Gisela 6 ($P < 0.01$) in 2013 and for all combinations in 2014 (Table 7).

The fruits on sweet cherry trees are obtained from flower buds at the base of the previous season's annual shoot growth and the spurs on shoots of 2 years old or older. The lifespan of a cherry spur is around 10 years, but spurs should not be more 5 years old for high quality fruits (Long, 2007). Thus, when considering potential productivity, the number of shoots within the canopy that are 2 years old or older is important. In this study, the number of 2-year-old and older shoots in the bud management treatment was greater than that for the control (Table 5). These values

Table 7. Effects of bud management on number of 2-year-old and older shoots (2013 and 2014).

Combination	Treatment	Number of 2-year-old and older shoots	
		2013	2014
0900 Ziraat / M × M 60	Bud manag.	15.6[a]	38.5[a]
	Control	10.7	28.1
Sweetheart / M × M 60	Bud manag.	12.9	35.2[a]
	Control	9.6	24.1
0900 Ziraat / Gisela 5	Bud manag.	18.1	47.0[a]
	Control	12.9	31.3
Regina / Gisela 6	Bud manag.	17.4	32.4[a]
	Control	10.8[a]	20.6

[a] $P \leq 0.01$, [b] $P \leq 0.05$, Bud manag.: Bud management.

demonstrated that bud management provided greater and earlier fruiting potential in the first years of the orchard.

This research found that bud management caused branching in all directions and homogeneously throughout the leader, formed shoots that yielded more fruits, and completed canopy formation earlier. Thus, bud management made the tree more productive in a shorter time with a lot of fruit-bearing shoots. Moderately sized lateral shoots formed a greater and more homogeneous proportion of the canopy, and bud management reduced blind wood formation. Thus, this research showed that bud management can be beneficial as a canopy development strategy for new cherry training systems. The time spent imposing bud management should not be thought of as extra work or lost time. Likewise, bud management will help prevent formation of unnecessary shoots and reduce the need for remedial pruning.

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