African Journal of Biotechnology Vol. 10(24), pp. 4901-4906, 6 June, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB10.278
ISSN 1684–5315 © 2011 Academic Journals

Full Length Research Paper

Growth and yield of the sweet cherry (*Prunus avium* L.) as affected by training system

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Accepted 9 March, 2011

Modern intensive production of sweet cherry (*Prunus avium* L.) tends to planting of high quality cultivars on the dwarfing rootstocks in high density orchards. The most productive training system is used, providing an ideal condition for undisturbed growth and yield. The main objective of this study was to determine the best training system of sweet cherry, considering regular and high yields and fruit quality. The three-year study was carried out on a 4-years old sweet cherry orchard with cultivar summit grafted on the dwarfing rootstock Tabel ® Edabriz. Three different training systems (Spanish bush, Spindle bush and "V") were compared. The smaller vegetative growth, expressed as trunk cross-sectional area (TCSA) was recorded in Spanish bush (34.68 cm^2) when compared to Spindle bush (40.11 cm^2) and "V" (40.82 cm^2). The largest cumulative yield per hectare was gotten by the training system "V" (41.65 t/ha), followed by Spindle bush (21.12 t/ha) and Spanish bush (11.30 t/ha). Yield efficiency (YE) (kg/cm^2) of Spanish bush (0.19 kg/cm^2) was significantly lower than that of Spindle bush (0.32 kg/cm^2) and "V" (0.28 kg/cm^2). Yield per unit land area (YA) (kg/m^2) differed in all training systems and the highest was recorded on "V", while the smallest was in Spanish bush. Training system and density did not affect the fruit weight. Results showed that the training system significantly affected the growth and yield of sweet cherry.

Key words: Rootstock, trunk cross-sectional area (TCSA), training system.

INTRODUCTION

Intensive production of sweet cherry requires an economically sustainable training system which induces early, regular and high yield, and high fruit quality and efficient harvest. For this purpose, less vigorous trees are needed which could be grown at high density, using the most productive training system, and providing satisfactory conditions for undisturbed growth and yield.

Rootstock has a significant influence on tree vigor, yield and fruit quality in a number of fruit species, especially apple (*Malus domestica* Borkh.) (Fallahi et al., 2002) and peach (*Prunus persica* L.) (Kappel and Bouthillier, 1995). Dwarfing rootstocks have a large effect on precocious fruiting and tendency of high tree productivity of sweet cherry, which makes them more suited to high planting density. Apart from their early fruit production, such orchards allow an easier application of cultivation procedures, harvest and protection from rainfall and birds during fruit ripening (Weber, 2001).

Gisela 5 (*Prunus cerasus x Prunus canescens*), Gisela 10 (*Prunus fruticosa* x *P. cerasus*), Tabel ® Edabriz (*P. cerasus* L.) and GM 9 (*Prunus incisia x Prunus serrulata*) stimulate early transition to reproductive age (De Salvador et al., 2005) and allow the control of the height and volume of the canopy. Rootstocks like Gisela 5 or Tabel® Edabriz stimulate the formation of a large number of spurs on shoots, which is of a particular importance for light distribution of high yielding cultivars such as Tieton or Regina (Lang, 2001).

Tabel® Edabriz is one of the first dwarfing rootstock selected in France (Chalton et al., 2005). The vigor of trees on Tabel® Edabriz could be 20 to 25% lower in the tenth year when compared to trees on F12/1 (*Prunus avium*), even though the soil and site are also of

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importance (Edin, 1993; Edin et al., 1996). It was also shown that their vigor was 30 to 45% lower than of MaxMa 14 (*P. avium x Prunus mahaleb*) (Chartlon et al., 2005). Tabel® Edabriz initiates an earlier flower bud differentiation, and initial bearing already in the third or fourth year after planting (Lang, 2001) reaching full yield potential in the seventh year (Charlton et al., 2005). The specific yield efficiency is three to four folds higher when compared with Colt (*P. avium x Prunus pseudocerasus*) and up to ten fold higher than F/12 (Edin, 1989). Fruit size could be slightly reduced (Callesen, 1998), but there are results where Tabel® Edabriz produces acceptable fruit size when compared to both F 12/1 and MaxMa 14 (Edin, 1993).

Tree canopy size may be regulated by many cultivation measures such as: Planting density, deficit irrigation (water stress), root restriction or root pruning, bending of branches, summer pruning and/or plant growth regulator application (Lang, 2001). An optimum orchard density is inevitable for flower bud differentiation, which in turn affects better yield and fruit colour. It is determined by the rootstock, cultivar, training system and prevailing ecological conditions (Balmer, 2001).

Sweet cherry has distinctive acrotonic growth with few lateral shoots which make it difficult to establish training systems. Therefore, it is recommended to use the feathered nursery trees. Appropriate training system will allow an early initial bearing, regular and high yield of an excellent quality, while reducing the number of agro-technical and pomotechnical management strategies (Haberlein, 1990).

Several training systems have been developed for high density sweet cherry plantations (Long, 2001). In the mid-seventies, the sweet cherry grafting on Mazzard and Colt rootstocks was intensified, focusing on the retaining of fruit quality under Spindle bush production systems and improvement of light distribution within the canopy (Zahn, 1994). At the beginning of eighties, Spanish bush training system was developed on vigorous *Prunus mahaleb* rootstock in Spain and "V" system in Australia. Both proved very successful in respective climatic conditions. Even though its planting density is very high, "V" system is characterised with a very high yield and light interception (Chalmers et al., 1978), but it is rather expensive with very high labour costs (Boucher and Adams, 1995). Training systems are strongly related to planting density. The main objective of this study was to determine the best training system, considering regular high yields and fruit quality.

MATERIALS AND METHODS

This study was carried out on a 4-years old sweet cherry orchard in Kaštela (43°33' N and 16°21' E) at 20 m height above sea level in the period from 1999 to 2001. Average precipitation quantity in area amounts to 1010.9 mm. During the course of the experiment, an annual absolute temperature maximum was 37.4°C and absolute minimum was -3.3°C. Orchard soil is deep with sufficient level of total carbonates (19.4%) and 4.4% of active lime and pH 6.65.

The orchard was established in spring in 1995, with one year old nursery trees of Summit cultivar grafted on the dwarfing rootstock Tabel® Edabriz (*P. cerasus* L.). Drip irrigation was applied during vegetation period according to crop demand. Three training systems were developed: Spanish bush (1.5 x 3.8 m; 1754 trees/ha); Spindle bush (1.5 x 3.8 m; 1754 trees/ha) and “V” (0.7 x 3.8 m; 3759 trees/ha). The experiment was set up by random design with 15 repetitions (trees) for each training system.

Development of training systems

Spanish bush

Trees were headed after planting at about 25 cm above the graft union. In spring following planting, when shoots have already reached 50 to 60 cm length, green pruning was carried out, and shoots were headed to about 20 cm length. In year 2 (about mid-March), the entire one-year-old shoots were headed to 25 cm and excessive thinning was performed. In May, when new shoots have reached 25 cm, those protruding into the canopy were thinned to keep adequate light inside the tree. At the end of the second year, all the trees had developed canopy. In the third year, after upper branches have been pruned, as well as those in the top of the tree, this provided good light exposure at the bottom part of the canopy (Oromi et al., 1994).

Spindle bush

This was developed after Zahn (Zahn, 1994). Feathered nursery trees were used so that the basic shape would be formed and post planting heading was not necessary. Lateral branches were bent down at an angle of 90° and tied to the first wire. Short shoots along the leader were obtained by its banding down. At the dormant period, the leader was returned into vertical position and tied to the second wire. Tip isolation took place just before vegetative period started. Pruning was minimized and branches in undesirable position were removed. Trees were also cleared and water-sprouts and all the lateral branches with the diameter thicker than half of the central leader were cut back to 20 to 30 cm stubs (Zahn, 1992). Pruning was accompanied with regular branch banding by 70° to 90° during the first two years to stimulate faster differentiation of flower buds.

"V" system

This training system was formed by a metal construction of "V" shape. Sweet cherry trees were planted following the two alternating rows planting pattern at 0.7 m within the row, directed outward (by means of bamboo sticks) at an angle of 30° and the 60° angle between the trees. Feathered nursery trees are not headed at planting. Two shoots were bent to the first wire. Branch management during the first three years is limited to heading shoots during springs and summers. This refers mainly to banding and pruning. In some cases, this also includes notching above the buds at the end of winter in trees with undesirable branch distribution or blind wood. The tree height was maintained at less than 2.5 m. To prevent over density of the canopy, the lush branches were pruned and banded horizontally.

Growth and yield measurements

Trunk cross-sectional area (TCSA) was calculated from the trunk diameter, measured at 15 cm height above the graft union during

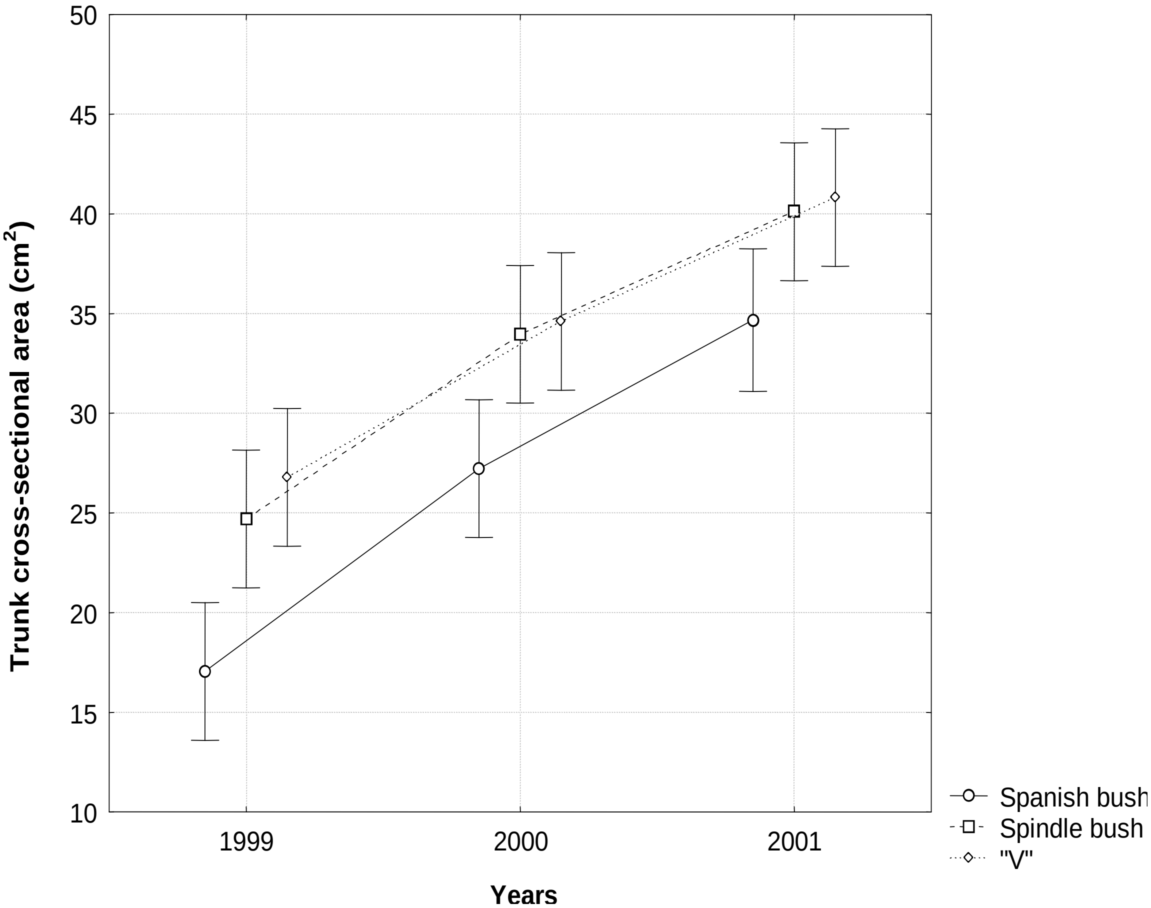

Figure 1. The effect of training system (Spanish bush, Spindle bush and 'V' system) on the trunk cross-sectional area (cm^2) of sweet cherry cv. summit during 1999 to 2001 year. Vertical bar indicates mean ±1 SE (n = 15).

dormant period in each study year with a digital calliper. Trunk vegetative growth (cm^2) was obtained from the difference in TCSA between study years.

Yield per tree (kg) was calculated as the average weight of harvested fruit. Yield per hectare (t/ha) was obtained by multiplying the yield per tree and tree density (trees/ha). Yield efficiency (YE, kg/cm^2) is the relationship between the yield per tree (kg)/TCSA (cm^2) and cumulative yield efficiency (kg/cm^2) from the relation of cumulative yield per tree (kg)/TCSA of the latest year (cm^2). Yield per unit land area (YA, kg/m^2) was calculated from the relationship between YE (kg/cm^2) x TCSA/tree/orchard density (m^2). Fruit weight (g) was obtained as the average of fruit weight of the total of 100 fruits from each tree. Fruits were picked by random selection from all canopy parts at the optimal stage of maturity. The difference between training systems for all growth and yield measurements were tested by the analysis of variance (ANOVA). Turkey multiple comparison test was applied to the main effects (training system, years) which were shown significant (at $P \leq 0.05$). All the data were analysed using SAS 6.12 software (SAS Inc. 1989).

RESULTS AND DISCUSSION

Vegetative growth

Significant difference in vegetative growth, expressed as trunk cross-sectional area (TCSA) cm^2, was recorded between all the training systems (Figure 1). Annual vegetative growth reduced with time after planting. The highest total vegetative growth (TCSA) cm^2 in the period of 1999 to 2001 was recorded for Spanish bush (18 cm^2), and the lowest was recorded for the "V" system (14 cm^2). Seven years after planting (2001), Spanish bush training system showed smaller trunk cross-sectional area (34.7 cm^2) when compared to Spindle bush (40.1 cm^2) and "V" system (40.8 cm^2). Whiting et al. (2005) reported significantly smaller TCSA in Spanish bush during the first four years upon planting when compared to Central leader, Palmetta and Y systems. Intensified pruning, particularly during summer, accounts for the differences during the first two years upon planting (Oromi et al., 1994). Total increase in the size of canopy, trunk and roots is higher in non-pruned trees, because severe pruning during canopy formation depress the tree growth (Bargioni, 1990). The present study did not record differences in TSCA between Spindle bush and "V" system. Pruning was minimised at canopy formation in Spindle bush and "V" systems, and bending were intensified. Bending reduces the vegetative growth of

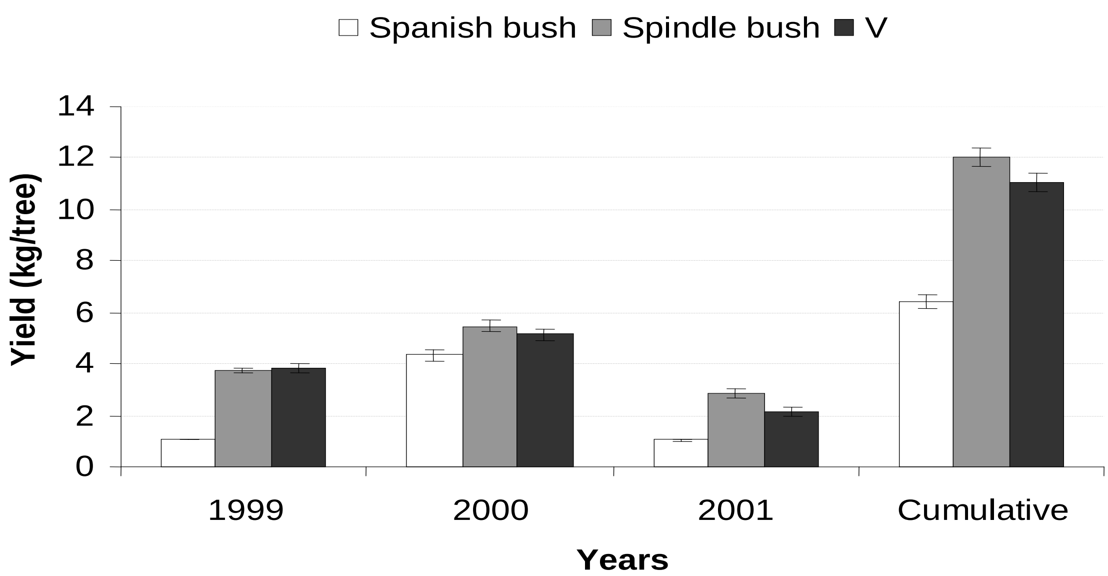

Figure 2. The effect of training system (Spanish bush, Spindle bush and 'V' system) on yield per tree (kg/tree) of sweet cherry cv. summit during 1999 to 2001. Vertical bar indicates mean ±1 SE (n = 15).

leader and lateral long shoots and spurs, and enhances flowering and fruit bearing (Lauri et al., 1998).

Vegetative tree growth is affected by climatic conditions, soil type and vigour of the rootstock and cultivar as well as pruning intensity. In eight year after planting, sweet cherry cultivated in "V" system on Tabel® Edabriz rootstock had 22.6 to 53.7 cm^2 TCSA dependently on the cultivar (Sansavini et al., 2001).

Yield

Yield per tree differed significantly from one study year to another and between training systems (Figure 2). The results indicate that year (environmental conditions) plays an important role in productivity of sweet cherry, although in the first two successive years, yield per tree showed significant increase in all the systems. Comparing the yields in 1999 and 2000, Spanish bush had the highest growth yield in 2000. In 2001, a significant reduction in yield per tree was recorded for all three training systems. Unfavourable climatic conditions during blossom in April 2001, particularly long rainfall period accompanied with the strong dry northern wind, adversely affected both the pollination and fertilization.

Spanish bush yielded less per tree than Spindle bush and "V" system. Intensive pruning at the formation of canopy in Spanish bush improved shoot growth, delayed fruit bud differentiation and fruit production. Spindle bush and "V" system showed earlier and greater fruit bearing potential, because banding of one-year-old shoots reduces vegetative growth and enhances flowering and fruit bearing (Lauri et al., 1998).

Yield per hectare (t/ha) significantly differed between training systems (Table 1). The "V" system yielded most and Spanish bush had the least yield in all years. The cumulative yield per hectare of "V" system amounted up to 41.65 t/ha (Table 1). Greater yield of the "V" training system was due to higher density of orchard for this system (3759 trees/ha) compared to Spanish bush and Spindle bush systems (1754 trees/ha). However, different orchard density did not significantly affect yield per tree between Spindle bush and "V" system. The yield of sweet cherry for "V" system was 17.69 t/ha in the 5th vegetation, 18 t/ha in 6th vegetation and 13.9 t/ha in 7th vegetation (Balmer, 2001). This makes a cumulative yield of 49.59 t/ha at 3333 trees/ha orchard density. Cumulative yield efficiency kg/cm^2 of "V" system and Spindle bush did not differ and exceeded the cumulative yield efficiency of Spanish bush (Table 1). Sansavini et al. (2001) reported cumulative yield efficiency of 0.32 kg/cm^2 in the 8th year for "V" system (1670 trees/ha) with the 3.24 kg/tree in the seventh to eight year.

All the trees showed significant yield per unit land area (kg/m^2) increment during the first two years of the study; however, yield was reduced in the third year (data not shown). The significant differences in YA were found between the training systems (Table 1). The highest YA (1.4 kg/m^2) were recorded for the "V" system and the lowest one for Spanish bush (0.4 kg/m^2). "V" system utilizes the best production site. It has the greatest tree density, only 2.66 m^2 of available production area per tree, and its fruit yield and weight equalled those of Spindle bush which had 5.7 m^2 available production site.

Training system did not play an important role in fruit weight (Figure 3). Year of bearing affected fruit weight more and the lowest fruit weight was recorded in 2000 (6.7 g) and the greatest in 1999 (10.8 g). Orchard density

Table 1. The effect of training system (Spanish bush, Spindle bush and 'V' system) on the yield per hectare (t/ha), cumulative yield per hectare (t/ha), cumulative yield efficiency (kg/cm^2) and cumulative yield per unit land area (kg/m^2) of sweet cherry cv. summit during 1999 to 2001 year.

Training system	Tree density tree/ha	Yield per hectare (t/ha)			Cumulative yield per hectare (t/ha)	Cumulative yield efficiency (kg/cm^2)	Cumulative yield per unit land area (kg/m^2)
		1999 (5 year)	2000 (6 year)	2001 (7 year)			
Spanish bush	1754	1.98 c*	7.60 c	1.81 c	11.30 c	0.19 b	1.15 c
Spindle bush	1754	6.54 b	9.59 b	4.98 b	21.12 b	0.32 a	1.93 b
"V"	3759	14.32 a	19.32 a	8.00 a	41.65 a	0.28 a	3.64 a

*Means within column followed by different letters are significantly different at P ≤ 0.05 by Tukey test.

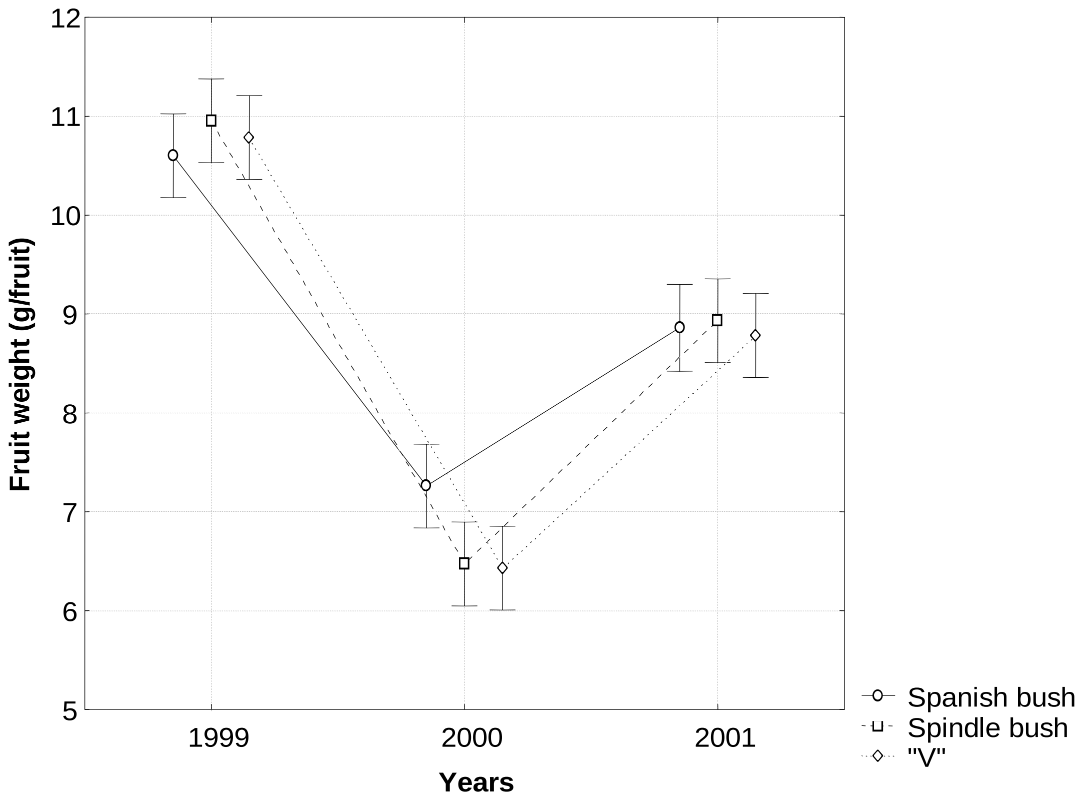

Figure 3. The effect of training system (Spanish bush, Spindle bush and 'V' system) on fruit weight (g/fruit) of sweet cherry cv. summit during 1999 to 2001. Vertical bar indicates mean ±1 SE (n = 100).

and yield per tree did not affect the fruit weight. In 2000 and 2001, fruit weight was significantly smaller than standard of 10 to 12 g (Lugli et al., 1995). Sansavini et al. (2001) reported an adverse effect of the Tabel® Edabriz rootstock on fruit weight at yield increment. Smaller fruit size was taken to be due to the decreased leaf area: fruit ratio (Callesen, 1998). Whiting and Lang (2004) reported negative relationship between the sweet cherry canopy fruit: leaf area ratio and fruit quality on dwarfing rootstocks. However, Meland (1998) stated that the training system and orchard density of sweet cherry cultivars on Damil rootstock did not strongly influence fruit weight and soluble solids content. Moreno et al. (1998) found higher sweet cherry yield efficiency but lower fruit quality with Palmetta and Marchand training systems when compared to the multiple leader vase system.

Conclusion

The results of the three-year study, in intensive orchard of high tree densities on the Tabel® Edabriz rootstock, confirmed the significant influence of training system on an early fruit bearing, vegetative growth, initial cropping and dynamics. Spindle bush and "V" system were better systems for fasted initial cropping when compared to Spanish bush. At Spindle bush, sweet cherry had the highest yield per tree (kg) and yield efficiency (kg/cm^2), whereas for Spanish bush, the yield per tree was the lowest. "V" system had the best yield per unit area (t/ha), followed by Spindle bush and Spanish bush. This study found no effect of training system on fruit weight. According to these results, growth and fruit bearing of sweet cherry are strongly related to training system and the best results in this study were obtained with Spindle bush.

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