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ABSTRACT

The experimental plantation was established in the territory of the Fruit-Growing Institute in Plovdiv, with geographic coordinates of 42° 9' N latitude, 24° 45' E longitude and 160 meters altitude. The study was carried out during the period 2013-2016, i.e. third-sixth vegetation of the trees, covering the first four fruiting seasons. The aim of the present study was to investigate the effect of the training systems Slender spindle, Solen and Vertical axis on growth and fruiting characteristics of the apple cultivar'Braebutn' and 'Granny Smith', grafted on M9 rootstock and grown under the conditions of Bulgaria. The results obtained show that the average and cumulative yields per ha were higher when Vertical axis training method was used compared to Slender spindle and Solen training systems. That was due to the better reproductive habits of trees in that variant, as well as to the larger number of trees per ha. Under the conditions of our country, tree training to Vertical axis method is recommended for 'Braeburn' and 'Granny Smith' apple cultivar grafted on M9 rootstocks.

Keywords: apple, *Malus domestica* (Borkh), training and pruning system.

Introduction

According to Hampson et al. (2002) training of fruit trees to a certain system is a method of modelling canopy architecture with the aim of improving light interception and distribution and optimizing yield quantity and quality. Over the past two or three decades many new training systems for intensive apple plantations have been developed in the world. The common feature in all of them is the desire of researchers to develop a training system, which is cost effective, enables the trees to enter the fruit-bearing stage quickly and provides high yields of good quality (Gandev and Dzhuvinov, 2014).

Various training systems have been used in the different fruit-growing countries, suitable for their soil and climatic conditions and the grown cultivars. In Bulgaria Slender spindle training system, developed by Wertheim (1978), is still the most popular for apple production in intensive plantations. Meanwhile, there are announcements in scientific literature about the development of the training systems Vertical axis (Lespinasse and Delort, 1986) and Solen (Lespinasse, 1989). A number of literaturedata (Lauri and Lespinasse, 1998; Hampson et al., 2002; Mitre et al., 2011; Ozkan et al., 2012) confirm that the use of those two training systems leads to obtaining high apple fruit yields of good quality.

The aim of the experiment was to study the effect of the training systems Slender spindle, Solen and Vertical axis on growth and fruiting of the apple cultivars ‘Braeburn’ and ‘Granny Smith’, grafted on M9 rootstock and grown under the soil and climatic conditions in Bulgaria.

Materials and Methods

The experimental plantation was established in the spring of 2011 on the territory of the Fruit-Growing Institute in the city of Plovdiv, at 42°9’ N latitude, 24°45’ E longitude and an altitude of 160m. Planting material without lateral shoots of ‘Braeburn’ and ‘Granny Smith’ cultivars, grafted on M9 rootstock was used in the study. The rows are north-south oriented. The soil is alluvial-meadow, neural in reaction. Drip irrigation installation is constructed for fertilization and irrigation, applied according to tree needs. The soil in the experimental plantation is maintained as black fallow.

The study was carried out in the period 2013-2016, i.e. third-sixth vegetation, covering the first four fruiting seasons of the apple trees.

Due to the heavy fruit setting in 2015 and 2016, chemical thinning was carried out with the product Dirager, the active substance of which is Alfa-Naphtyl-aceticacid (3.3%). The applied rate was 30 ml per da.

Three training systems were studied, forming the separate variants of the experiment. Variants:

1. Slender spindle
2. Solen
3. Vertical axis.

Slender Spindle

Tree pruning was done following the adopted classical method of training the trees to that system (Wertheim, 1978). At planting the trees were cut to 90 cm above the soil surface. During the first two vegetations shoots were horizontally bended for the formation of the future skeletal branches. The leader was annually changed with its competitor. Pruning practices for fruit-bearing included cutting off the vigorous, growing straight up shoots and retaining those of moderate to weak growth. During the fourth winter pruning the trees were cut to 2.5 m above the soil surface.

Solen

The trees were trained as described by Lespinasse (1989). During the pruning after planting the trees were cut to 1.2 m above the soil surface. At the beginning of vegetation two shoots were selected, which at a later period, in August, were tied horizontally to a wire construction along the row line. Pruning for fruit-bearing was done following the long pruning method.

Vertical Axis

Tree pruning was done according to the pruning practices recommended by Lespinasse and Delord (1986). When training the trees, the leader was not cut off or replaced with its competitor. During the third and the forth winter pruning, the shoulders with thickness close to that of the leader were removed. Fruiting shoots were annually cut off at the curve formed after the natural bending under the fruit weight.

The trees of Variant 1 and Variant 2 were planted at a distance of 4 × 2 m (1250 trees per ha) and those of Variant 3 – 4 × 1.5 m (1667 trees per ha). The following characteristics were reported: trunk cross-sectional area /HCC/ in (cm^2); canopy volume (m^3); yield per tree (kg); cumulative yield per tree (kg); mean fruit weight (g); yield per ha and cumulative yield per ha.

Five trees randomly located in the plantation, were included in each variant and each tree represented a separate replication. Statistical processing was done following Duncan's test (Steele and Torrie, 1980).

Results and Discussion

Data presented in Table 1 show that the studied apple tree training systems manifested the same tendency for the effect on the growth habits of the trees of 'Braeburn' and 'Granny Smith' cultivars. It should be mentioned that in both studied cultivars, in all the four reporting years, the stem cross-sectional area was smaller when applying Solen training system (Var. 2) compared to Slender spindle (Var. 1) and Vertical axis (Var. 3). The smallest canopy volume - 2.1 m^3 in 'Braeburn' cv. and 2.7 m^3 in 'Granny Smith' cv. Was reported for the

variant with the smallest stem cross-sectional area (Var. 2). Although the values of the stem cross-sectional area of the trees in Var. 1 and Var. 3 were similar in both cultivars, the canopy volume of the trees in Var. 3 was significantly larger compared to the trees in Var. 1. That is due to the specific technique of the Slender spindle training system (Var. 1), according to which the trees are cut to a height of 2.5 m above the soil surface during the fourth winter pruning, which leads to a reduction of the canopy volume in that variant. Such pruning practices are not applied in the Vertical axis training system (Var. 3). What is more, when training the trees to that system, it is mandatory to leave the leader uncut.

Table 1. *Effect of the Training Systems on the Trunk Cross-Sectional Area and the Canopy Volume in the Apple Cultivars 'Braeburn' and 'Granny Smith', Grafted on M9 Rootstock*

Training system	***Trunkcross-sectional area (TCA), cm²***				***Canopy volume, m³***
	2013	**2014**	**2015**	**2016**	**2016**
'Braeburn'					
Slender spindle	19.5 a	23.5 a	30.2 a	39.2ab	2.8 b
Solen	13.0 b	15.2 b	24.6 b	33.4 b	2.1 c
Vertical axis	18.4 a	23.4a	31.6 a	44.5 a	4.0 a
'Granny Smith'					
Slender spindle	18.9 a	24.0 a	28.7 ab	42.0 b	4.0 b
Solen	12.5 b	16.5 b	19.2 b	36.7 c	2.7 c
Vertical axis	20.0 a	25.0 a	32.8 a	47.4 a	4.9 a

Significantat P = 5%.

Table 2 shows that in the first fruit-bearing season of the trees of 'Braeburn' cv. (2013) there is not a significant difference in the average yield per tree among the separate variants of the experiment. However, the results in the next experimental years did not show the same tendency. In 2014, as well as in 2015, the average yield per tree in Var. 2 waslowercompared to that of Var. 1 and Var. 3.In 2016, the yield in Var. 2 was 19.8 kg and it was close in value to that in Var. 1, which was 21.7 kg. In both variants, the yield per tree was lower than that in Var. 3, which was 24.6 kg.

When reporting the cumulative yield in 'Braeburn' cv. (Table 2), it was established that the yield from the trees in Var. 2 (35.0kg) was significantly lower than that in Var. 1 (42.6 kg) and Var. 3 (49.4 kg). Obviously Solen training system (Var. 2) leads to obtaining lower cumulative yield per tree, compared to Slender spindle (Var. 1) and Vertical axis (Var. 3) training systems.

Data in the same table (Table 2) also show that in 2013 there was not a difference in the average yield per tree among the separate variants of 'Granny Smith' cultivar. But the results in the next experimental years did not show

such tendency. Both in 2014 and in 2015 the yield per tree in Var. 3 was significantly higher than that in Var. 1 and Var. 2.

When reporting the cumulative yield in 'Granny Smith' cv. (Table 2), it was established that the yield from the trees in Var. 3 was 55.5kg versus 42.3 kg in Var. 1 and 36.7 kg in Var. 2, respectively. Obviously Vertical axis training system (Var. 3) used in that cultivar, leads to obtaining higher cumulative yield per tree, compared to Slender spindle (Var. 1) and Solen (Var. 2) training systems.

Table 2 also shows that the average fruit weight of 'Braeburn' and 'Granny Smith' cultivars decreased with the increase of the fruit yield per tree, but it did not lead to worsening of production quality. In both cultivars 'Braeburn' (Milatović and Durovic, 2012) and 'Granny Smith' (Iliev et al., 1984), the values of the average fruit weight were similar to those commonly accepted for the given cultivar.

Table 2. *Effect of the Training Systems on the Yield, Fruit Weight and Cumulative Yield in the Apple Cultivars 'Braeburn' and 'Granny Smith' Grafted on M9 Rootstock*

Training system	***Yield and mean fruit weight (kg/tree), g***								***Cumulative yield (kg/tree)***
	2013		***2014***		***2015***		***2016***		
	yield	**fruit weight**	**yield**	**fruit weight**	**yield**	**fruit weight**	**yield**	**fruit weight**	
'Braeburn'									
Slender spindle	1.09 a	203.3 a	5.4 ab	180.0 b	14.4 ab	200.0 a	21.7 b	180.0 a	42.6 b
Solen	0.85 a	182.3 a	2.9 b	197.0 a	11.5 b	209.0 a	19.8 b	182.0 a	35.0 c
Vertical axis	1.19 a	190.0 a	6.5 a	176.1 b	17.1 a	178.0 b	24.6 a	178.0 a	49.4 a
'Granny Smith'									
Slender spindle	1.8 a	222.0 a	4.9 b	186.6 a	13.1 b	185.0 a	22.5b	178.0 a	42.3 b
Solen	1.00 a	214.0 a	4.2 b	200.5 a	11.0 b	190.0 a	20.5 b	175.0 a	36.7 b
Vertical axis	1.6 a	197.5 a	6.7 a	188.3 b	20.2 a	171.6 b	27.0 a	170.0 a	55.5 a

Significantat P = 5%.

Yield differences between the variants with different training systems used in the cultivars 'Braeburn' and 'Granny Smith' are still more marked when calculating the average and the cumulative yield per ha (Table 3). That is due to the fact that in Var. 1 and Var. 2 the number of trees per ha is 1250, while in Var. 3 it is 1667, i.e. 33.36% higher. It is known (Robinson, 1992) that the first yields are a function of the number of trees per ha and by increasing the density of the plantation the yield also increases. In our experiment the larger number of trees per ha resulted in obtaining a higher cumulative yield in both studied cultivars. The obtained cumulative yield of 'Braeburn' cultivar in Var. 3 was 49.40 t/ha versus 42.60 t/ha in Var. 1 and 35.05 t/hain Var. 2, respectively. Similar results were reported for 'Granny Smith' cultivar. Again the larger number of trees per ha led to obtaining a higher yield – 92.50 t/ha in Var. 3 versus 52.86 t/ha in Var. 1 and 45.87 t/ha in Var. 2, respectively.

Table 3. *Effect of the Training Systems on the Yield per ha and the Cumulative Yield in the Apple Cultivars 'Braeburn' and Granny Smith' Grafted on M9 Rootstock*

Training system	***Number tree per ha***	***Yield, t/ha***				***Cumulative yield, t/ha***
		2013	***2014***	***2015***	***2016***	
'Braeburn'						
Slender spindle	1250	1.36 b	6.87 b	18.00 b	27.12 b	42.60 b
Solen	1250	1.06 b	3.62 c	14.37 c	24.75 b	35.05 c
Vertical axis	1667	1.98 a	10.83 a	28.50 a	41.00 a	49.40 a
'Granny Smith'						
Slender spindle	1250	2.25 ab	6.12 b	16.37 b	28.12 b	52.86 b
Solen	1250	1.25 b	5.25 b	13.75 b	25.62 b	45.87 b
Vertical axis	1667	2.66 a	11.17 a	33.67 a	45.00 a	92.50 a

Significantat P = 5%.

Conclusions

- Growth habits of the treesof 'Braeburn' and 'Granny Smith' cultivars grafted on M9 rootstock are affected by the choice of the training system. Slender spindle and Vertical axis training systems induce more vigorous growth compared to Solen;
- The cumulative yield perha of the cultivars 'Braeburn' and 'Granny Smith' on M9 rootstock, trained to Vertical axis, is higher compared to that obtained when using Slender spindle and Solen training systems;
- In agricultural practice, it is recommended to use Vertical Axis training system for 'Braeburn' and 'Granny Smith' cultivars, grafted on M9 rootstock.

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