POSSIBILITY FOR SPINDLE AND SOLAXE TREES APPLE BREEDING

Vasiliy Dzhuvinov[1], Stafan Gandev[1]

Abstract: The second stage of intensification of apple industry in Europe started during the early of 1970`s with Dutch `Slender spindle` training system for high density plantations. Other systems such as `Verical axis', V and Y - shaped system,`Tatura trellis`,`Solen`, `Solaxe`, `Cone` etc. were developed in different countries of the world.

Apple breeding for resistance to major diseases and for spindle and Solaxe tree architecture aims to significantly lower the total cost of fruit production. At our breeding program for resistance to scab, mildew and the aphids *Dysaphis plantaginea* Pass. and *Aphis pomi* De Geer, we selected hybrids with naturally attained spindle and Solaxe trees. In the progenies of cultivars 'Enterprise', 'Freedom', 'Avrora', 'Generos', 'Paulared', 'Prima', 'Tavria', 'Pionier' o.p. and 'Akane' ('Primrouge') × 'Krimskoe', 'Akane' × 'Florina', and 'McIntosh Wijcik' × 'Paradox', we found trees with a habit resembling the characteristics of the spindle training system. Plants with a weeping habit were selected from crosses of 'Paradox' × 'Prima' and 'Elize Rathke' × 'Florina', and between those hybrids a further set was selected which exhibited a natural Solaxe, the modern system for training and pruning in apple orchards.

Key words: *Malus domestica* (Borkh), training systems, breeding, spindle and Solaxe trees

Introduction

The evolution of apple industry in different countries from 1950 to 1970, apple training and pruning have resulted in good fruit production in terms of yield and fruit quality. Tree forms used are not always appropriate to the branching and fruiting type of the cultivar. Keeping tree low in height by pruning causes a state of imbalance and rapid aging of the production zone.

There are three factors in orchard management of concern to the fruit grower:

- reduction in the time needed for pruning and harvesting;
- the rapid attainment of a commercial production;
- an annual production and better quality fruit which requires a balance between fruiting and vegetation vigor.

It is therefore of major importance to develop training concepts that optimally combine training and management systems at the orchard scale and training methods at the tree scale (pruning, bending). At both levels, an accurate knowledge of growth, branching and flowering processes within the tree canopy, i.e. tree architecture, is thus required to optimize tree manipulation adapted to the plant material (Costes et al., 2006).

Architecture breeding in fruit crops has not been given much attention, due to the established practice of training and pruning to overcome the natural habit of upright

[1]Fruit Growing Institute, 4004 Plovdiv, Bulgaria.

growth. This area of breeding may become more important as the cost of labor rises (Way et al., 1983).

Laurens (1999) noted that many apple breeders were involved in habit studies aimed at obtaining productive trees with regular cropping. Fideghelli et al. (2003) explained that, for centuries, orchardists have controlled the size and shape of fruit trees mainly through training and pruning. Costes et al. (2004, 2006) learned about a French breeding program where the regular bearing behavior, as well as the reduction of tree training by introducing architectural traits to control tree size and form, has been considered. Later all aspects of fruit tree architecture in relation to tree training, orchard management and fruit production have been analyzed. One of the main purposes of intensive orchards is to manage the tree shape and fruit load with minimal pruning, by taking advantage of the natural trends of the cultivar and thereby reducing the cost of this manual operation.

`SLENDER SPINDLE` is the first new training system developed by Wertheim (1978) for high-density plantings during second half of the last century and very fast has been introduced in many countries in the world. The reason for this change was the need to achieve early cropping, regular high yields and low labor requirements i.e. low costs of production. In the 1950-1977 period, the average yield from an apple orchard increased from 16 to 38 tons per hectare and the man-hours required per hectare for cultural practices (excluding picking) decreased from 550 to 175.

`VERTICAL AXIS` was developed by J-M. Lespinasse (1977, 1980). The tree is made up of a vertical trunk, along which fruiting branches are regularly distributed. The tree shape tends to be conical and tree fruiting zones exist in fruiting limb. `Zone A` (from 0-30^{o} from vertical) is characterized by the best light interception. `Zone B` which is below the former between 30^{o} and 120^{o} from the vertical, is the prime fruiting zone, with good light distribution and moderate shoot growth. `Zone C` underneath the first two zones, does not allow good fruit production because of the deleterious effect of within-tree shading on fruit quality. This training system aims to develop limbs in `Zone B`, which produce the best fruit quality.

`V and Y` - SHAPED SYSTEMS. V-shaped fruit trees were popularized for commercial orchards by Chalmers and van den Ende (1975) as the `Tatura trellis`. A number of variations of the Tatura trellis were developed which include the Mini - Tatura trellis and Y-trellis (Robinson, 2000), the Mikado system (Widmer and Krebs, 1997), the Drilling (Triplet) system (Widmer and Krebs, 1997), the V-Slender spindle and the V-Super spindle. With all V systems the objective has been to improve yield by light interception, the fruit quality by light penetration to the center of the canopy. The optimum angle for fruit size was around 60^{o} while fruit color was best on the most vertical angles and the best yield efficiency was at intermediate angles of around 60^{o} i.e. the best balance of vegetative growth and cropping (Robinson, 2000).

`TATURA TRELLIS` is a Y-shaped system with arms of the trellis at 60^{o} above the horizontal. This system was originally developed for peaches to increase yields and to allow mechanical harvesting, but was later adapted for apples. Each tree has 2 main scafold arms and secondary branches are trained as a palmette. Secondary branches are trained about 45^{o} from the leader and are attached to the wires (Chalmers and van den Ende, 1975).

`SOLEN` is a training system developed by J-M. Lespinasse during the 1980`s. It is good system for cultivars from fruiting type III and IV like Golden Delicious, Gala, Granny Smith, Fuji etc. All branches are bended like weeping position (Monney and Evequoz, 2000).

`SOLAXE` is a combination between `Solen` + `Vertical axe`. It involved combining the bending of the central axis and the fruiting branches from the `Solen` and developing free growing fruiting branches and removing the competing vegetative branches on this fruiting branch from the `Vertical axis` (Lespinasse, 1986).

The main stem is attached to a support system. The best balance between vegetative and fruiting on mature Solaxe tree is obtained with 12 to 16 fruiting branches spirally arranged along the trunk (Lauri and Lespinasse, 2000).

`CONE` as a system for training and pruning has been developed by Gandev (2009), because under Bulgarian conditions the MM.106 was the main rootstock in apple orchards when the fruit growers use predominantly spur type cultivars during the 1970-1980`s. Nowadays after planting apple cultivars `Granny Smith`, `Melrose`, `Jonagold`, `Fuji`, `Florina` etc. on MM.106, faced some difficulties for control of vigor and regular yield of the cultivars, because for new orchards needs lot of investments for individual sticks on M.9 rootstock. The `Cone` system is suitable for moderate and vigorous cultivars on MM.106 rootstock without support systems and wires.

Material and methods

Seeds from open pollination were obtained from the apple scab resistant 'Prima', 'Priscilla', 'Redfree', 'Freedom', 'Dayton', and 'Enterprise' from the USA, 'Nova Easygro' and 'Moira' from Canada, 'Florina' from France, and 'Generos' and 'Pionier' from Romania.

The open-pollinated (o.p.) seedlings originated from the low-susceptible to scab (Djouvinov and Penev, 2000) 'Paulared', 'Krimskoe' and from moderate-susceptible 'Tavria' and 'Avrora'. The seeds were collected from the columnar 'McIntosh Wijcik' and 'Telamon' and weeping 'Paradox' and 'Elise Rathke'.

The hybrids from crosses 'Akane' × 'Krimskoe', 'Akane' × 'Florina', 'McIntosh Wijcik' × 'Paradox', 'Paradox' × 'Prima', 'Elise Rathke' × 'Prima' and 'Elise Rathke' × 'Florina' were grafted on M.26 rootstock and planted in the same orchard. The open-pollinated seedlings and hybrids after planting were grown without training and pruning and without pesticide control. After the second growing season, the angles of the first three skeleton branches of each tree were measured from the base toward the vertical axis.

Results and discussion

According to the studies of Lespinasse (1977), the size of apple fruits on upright branches between 0 and 30° is heterogeneous, because of the dominant tree vigor. In the range from 30 to 120°, the fruit size is relatively homogeneous. When the angle is greater than 120°, the fruit quality is poor, due to insufficient light penetration. Depending on the angle, the hybrids were separated into four groups: 0-30°, 30-45°, 45-90°, and >90° from the vertical axis.

Table 1. Frequency of distribution of progenies per angle range.

Open-pollinated apple cultivars	Number of seedlings	0-30° (%)	30-45° (%)	45-90° (%)	> 90° (%)
1. Scab-resistant					
Prima	63	23.8	28.6	47.6	0.0
Priscilla	54	37.0	27.8	35.2	0.0
Redfree	66	24.2	33.3	42.5	0.0
Dayton	47	29.8	21.3	48.9	0.0
Freedom	55	12.7	30.9	56.4	0.0
Enterprise	38	31.6	26.3	42.1	0.0
Nova Easygrow	33	24.2	45.4	30.4	0.0
Moira	37	37.8	24.3	37.9	0.0
Fiorina	46	34.8	32.6	32.6	0.0
Generos	48	10.4	20.8	68.8	0.0
Pionier	45	22.2	26.7	51.1	0.0
2. Low-susceptible to scab					
Tavria	77	19.5	37.7	40.2	2.6
Avrora	42	16.7	28.5	54.8	0.0
Krimskoe	39	15.4	46.1	38.5	0.0
Paulared	34	20.6	26.5	52.9	0.0
3. Columnar					
McIntosh Wijcik	81	32.1	42.0	25.9	0.0
Telamon	27	33.3	40.7	26.0	0.0
4. Weeping					
Paradox	40	15.0	32.5	30.0	22.5
Elise Rathke	27	14.8	22.2	51.9	11.1

Figure 1. 'Tavria' o.p. Solaxe tree (a) and 'Paradox' × 'Prima' Solaxe tree (b).

From the progenies 'Akane' × 'Krimskoe' and 'Akane' × 'Florina', we received a good percentage of natural spindle trees, about 40% (Table 2). The results of 'McIntosh Wijcik' × 'Paradox' were close to the former two crosses, and a small percentage

exhibited the weeping habit. Very promising were the crossings 'Elise Rathke' × 'Prima' and 'Elise Rathke'× 'Florina', because 10-15% of the hybrids show a natural Solaxe. In the progeny of 'Elise Rathke' × 'Florina', we obtained weeping trees like the mother parent 'Elise Rathke', with a height of about 80 cm. We need to note that, as o.p. and as crosses with other cultivars, the progenies of weeping cultivars form trees that vary from upright to weeping.

Table 2. Frequency of distribution of progenies per angle range.

Progenies	No. of plants	0-30° (%)	30-45° (%)	45-90° (%)	> 90° (%)
Akane **x** Krimskoe	48	31.1	32.3	36.6	0.0
Akane **x** Fiorina	57	31.9	27.8	40.3	0.0
McIntosh Wijcik **x** Paradox	41	47.3	11.8	33.2	7.7
Paradox **x** Prima	54	10.9	39.3	40.7	9.1
Elise Rathke **x** Prima	46	14.8	33.2	34.7	17.3
Elise Rathke **x** Fiorina	63	23.3	34.9	30.1	11.7

Conclusion

The results of our apple breeding program for tree architecture, natural spindle and Solaxe, appear very promising, as they combine the results of our breeding program for scab and mildew resistance (showing 'McIntosh Wijcik' × 'Florina' (Figure 2a) and showing 'Generos' o.p. (Figure 2b). The next step of our program is to improve the fruit quality of some natural Solaxe trees and to study the inheritance of this growth habit.

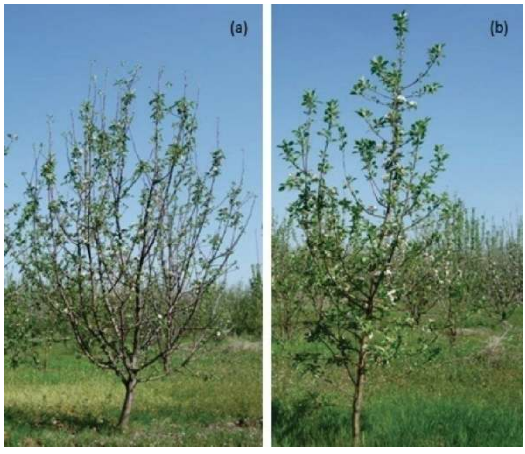

Figure 2. 'McIntosh Wijcik' × 'Florina' spindle tree (a) and 'Generos' o.p. spindle tree (b).

These positive results provide a direction for further breeding toward helping to reduce investment in new apple orchards as well as labor costs for bending, tying, and pruning.

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