Scientific Papers. Series B, Horticulture. Vol. LXIII, No. 2, 2019
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

NEW TENDENCIES IN FRUIT TREES TRAINING AND ORCHARD PLANTING SYSTEMS

Florin STĂNICĂ

University of Agronomic Sciences and Veterinary Medicine of Bucharest,
59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: flstanica@yahoo.co.uk

Abstract

In the last 40 years there was a continuous struggle to increase the orchard productivity specially by increasing the fruit trees planting density. The availability of low or medium vigour rootstocks in most fruit species created the possibility of raising the planting densities in apple and pear. The general tendency is to create canopies with vertical axes garnished with non-permanent, renewable fruit branches. The number of axes varies from one to three per canopy: more vigorous is the tree, more axes are formed and the total vigour is split on more growing directions. The main concern is to ensure a sufficient productive canopy volume per hectare and a high light interception in order to obtain high quality fruits and high and constant yield. The paper presents some new ideas on rootstocks use and alternative methods to control the tree vigour, new planting systems and discussions on actual canopies as Vertical axe, Bi-Baum®, Parallel V and Trident. New pruning techniques to balance the tree growth and fruiting capacity are explained.

Key words*: rootstocks, canopy, trellis systems, light efficiency, tree growth, productivity.*

INTRODUCTION

In the last 40 years there was a continuous struggle to increase the orchard productivity specially by increasing the fruit trees planting density especially in apple and pear (Wertheim et al., 2001) and recently, in sweet cherry and peach and other stone fruits.

The availability of low or medium vigour rootstocks in most fruit species created the possibility of raising the planting densities in apple and pear, to more than 4,000 trees per hectare and in stone fruits, to over 2,000 trees per hectare. This new approach was possible by the introduction of low vigour rootstocks like M9, P16, M27 for apple (Stehr, 2011), quince for pear (Wertheim, 2002) and Gisela 5 for sweet cherry (Franken-Bembenek, 2005).

The used of feathered planting material, launched by Fleuren nursery in Netherlands at the beginning of ’90, with side fruit branches, took the advantage of early fruiting.

In parallel, a constant reduction of the tree permanent structure and simplification of the canopy occurred with a correspondent reduction of the man work costs for tree training and pruning.

A large number of publications presented results on testing high and very high planting densities, the new proposed planting systems, reaching densities from 2,500 trees/ha to 6,000, or even more than 8,000 trees/ha.

Many of the high-density planting systems were promoted by different nurserymen, being characterized by high initial investment costs, rapid fruit bearing, short orchard life, early replacement (Hoying et al., 2012).

All these means an obvious increase of the planting material quantity per hectare and an early return to the nursery for buying new trees. Not all the farmers were happy with those ideas and there was a counter tendency on finding alternative solutions.

As a reaction to the initial tendency of the increase in tree density to very high numbers, researchers and farmers tried to keep the orchard density below 2,500-3,300 trees/ha in order reduce the orchard investment costs.

New canopies were designed, by increasing the number of tree axes to two in Bibaum® (Musacchi, 2008), Bi-Axis (Dorigoni et al., 2011), Tatura trellis, Parallel Y, etc. or to three axes in Drilling (Widmer & Krebs, 1997; 2001; Stănică & Platon, 2011), Candlestick (Chandelier) (Vercammen, 2011), 3 - Leader system (Elkins & DeJong, 2011), Parallel trident (Stănică & Eremia, 2012; Stănică et al., 2014a; 2014b), or even four axes in Mikado

(Widmer & Krebs, 1997; 2001; Stănică & Platon, 2011).
Besides the reduction of the number of planted trees, the multiple axes canopies, were also suitable for more vigorous species like peach (Caruso et al., 1997), apricot (Stănică & Eremia, 2012), plum (Meland, 2001) and sweet cherry (Stănică et al., 2014) or, for apple cultivar grafted on medium vigour rootstocks.
Nowadays, the general tendency for all fruit species is to create canopies with vertical axes garnished with non-permanent, renewable fruit branches.
Starting from simplified canopies like Vertical axis, Tall spindle (Robinson et al., 2011; Robison & Dominguez, 2015), Super spindle, Solaxe (Lauri & Lespinasse, 2000) etc., the tree management, pruning techniques and the orchard "philosophy" and technology changed radically.
The number of axes varies from one to three per canopy: more vigorous is the tree, more axes are formed and the total vigour is split on more growing directions.
The main concern is to ensure a sufficient productive canopy volume per hectare and a high light interception in order to obtain high quality fruits and high and constant yield.
Recently, at the Faculty of Horticulture in Bucharest, several planting systems and canopies designs are evaluated in different species in order to find efficient solutions for the new fruit orchards.

MATERIALS AND METHODS

The paper presents some new ideas on rootstocks use and alternative methods to control the tree vigour, new planting systems and discussions on actual canopies as Vertical axe, Bibaum®, Parallel V and Trident.
New pruning techniques to balance the tree growth and fruiting capacity are explained.

RESULTS AND DISCUSSIONS

Rootstock use

In the last years the breeding programs in different countries created medium and low vigour rootstock for the most important fruit species. Generally, the low vigour rootstocks transfer to the grafted tree: reduced vegetative growth, precocity, high productivity, high quality fruits (Ghena et al., 2004). Reducing vigour opened the way to increase the planting densities and to imagine simplified canopies and planting systems. But because of reduced root volume, most of the low rootstock need trellis systems.
In apple, M 9 rootstock was generalized in most of the modern orchards. Even M 9 has the above-mentioned advantages, it showed to have also some important problems as: high susceptibility to woolly apple aphid, to fire blight (*Erwinia amylovora*), to *Phytophtora cactorum*, to replant diseases, etc. There are no results yet regarding the resistance to deep frost in the Romanian conditions, especially when the soil is not covered with snow.
Taking in consideration the necessity of new plantings within the Romanian Rural Development Sub Program for the Fruit Industry, the new orchards will be planted in areas with multiple risks regarding the fire blight, drought, replanting diseases, deep winter frost, high summer temperatures etc.
In this situation, a new range of rootstocks has to be tested in order to avoid the mentioned challenges. Promising new apple rootstocks have been recently released by American, Polish and Russian breeding programs.
The Geneva Apple Rootstock Breeding and Development Program started at Cornell University in 1968 by Dr. James Cummins and Herb Aldwinckle. From 1998 to present the program continues in cooperation with USDA having as leaders Dr. Gennaro Fazio, Herb Aldwinckle and Terence Robinson. Several Geneva® released rootstocks appear to have tolerance/resistance to apple replant disease, fire blight and *Phytophtora*: G.41, G.214, G.935, G.202 and G.210. The resistance may be due to the initial screening for *Phytophtora* disease which may also have selected for tolerance to other soil microorganisms (Robinson et al., 2013).
Resistant rootstocks offer better performance in organic orchards too. A few selections of Geneva® rootstocks are available in Europe since 2013 for large scale testing.
In Poland at Skiernievice the apple rootstock breeding program. Lewandowski et al., 2012 tested the susceptibility of selected apple rootstocks to fire blight caused by *Erwinia amylovora*.

From the Russian breeding program initiated by Budagowski, B 9 seems to be extremely promising and interesting for Romanian conditions, for its low vigour, productivity, high resistance to fire blight and frost. For M9 rootstock vigour, the planting distances for apple have been generalized at 3.2-3.5 x 0.7-1.0 m.
For pear, besides the quince rootstocks that have a vigour reducing effect, some pear rootstocks as Farold 40 or 60 are used, giving a much higher tree vigour and three axis canopies as Trident, are recommended (Cean & Stănică, 2013). The *in vitro* propagation of some pear varieties and their cultivation without grafting can be used with good results (Stănică et al., 2002).
For sweet cherry, Gisela 5 is already spread in most of the high-density orchards (Asănică et al., 2013) and recently, while lower vigour rootstock, Gisela 3 started to be tested. However, in more difficult conditions and soils, Gisela 6 gives better results even the tree vigour is superior to the previous ones.
For peach, plum and apricot, besides some specific rootstocks as GF 677, plum and apricot seedlings, there at least three clonal rootstocks that are quite commonly used: Myrobalan 29C (high vigour), Saint Julien A and Ishtara (medium vigour).

Planting systems and canopies
Vertical axe is a popular canopy nowadays for most of the temperate fruit trees species. Being introduced initially at apple, it was then used for pear (Figure 1) and lately it was introduced also to more vigorous species as sweet cherry, peach, apricot and plum. It has few import features that makes it so popular:
- it is close to the natural growing tendency of the fruit trees, besides the axis vertical training;
- it doesn't need complicated and labour-intensive trellising;
- it allows a good illumination of the canopy and a periodical renewal of the fruiting branches.
The main principles for Vertical axe training and pruning are:
- the axe is the leader and it has to be kept vertical and stimulated to grow annually;
- all the lateral fruiting branches are disposed in spiral on the main axe, their vigour decreasing from base to top;
- each fruiting branch has its own growing space and a single growing direction;
- a diameter ratio of 1: 3 has to be maintained between the axe and the lateral branches and between the main and the secondary branches.

a b
Fig. 1. Vertical axe at apple (a) and pear (b)

The Vertical axe can be used equally for low vigour trees at stone fruits. The planting distances are slightly increased taking in consideration the general higher vigour of the tree (Table 1).

Table 1. Planting distances and trees density for the Vertical axe canopy

Species	Planting distances (m)	Planting density (trees/ha)
Apple, pear	3.2-3.5 x 0.6-1.0	2,857 - 5,208
Sweet cherry, peach, plum, apricot	4.0-5.0 x 1.5	1,333 - 1,666

In some special conditions (low fertility soils, slopes,) sweet cherry can be planted at 3.5 x 0.5 m, on very high density (5,714 trees/ha).
It is a typical approach on Trento region in Italy (Figure 2).
Generally, sweet cheery need to be planted for Vertical axe at 4.0-4.5 x 1.5 m (Figure 3).
Vertical axe trees at different stone fruit species are presented in the Figure 4.
For peach, 3-4 short skeleton branches can be formed at the canopy base, while on the axe, only mixed fruiting branches and 2-3 buds short pruned replacing branches are kept.

Fig. 2. Very high-density planting at sweet cherry in Trento region (3.5 x 0.5 m)

Fig. 3. Vertical axe in high density planting at sweet cherry in Însurăței, Brăila (4.5 x 1.5 m)

a b

Fig. 4. Vertical axe at peach (a) and plum (b) in Însurăței, Brăila (4.5 x 1.5 m)

Parallel U and Bi Baum® are two different canopies that in principle aim to create two parallel axes oriented on the row in order to divide/reduce the tree growing vigour. Designed by the Italian nursery Mazzoni, Bi Baum® is created in the nursery by budding two opposite scion buds on the rootstock. By the competition for resources between the "twin shoots", a reduction of the vigour and a balanced growth of the axes is obtained. The technique was firstly proposed for vigorous scion/rootstock combination in apples and pears (ex. Fuji/M9, Florina/M9, other varieties/M26) (Figure 5). Even the tree cost is higher, there are some other advantages regarding the lower number of trees per ha, limited vegetative growth, reduction of the central axe dominance (especially in some pear cultivar) etc.

a b

Fig. 5. Bi Baum® at apple, first leaf (a) and pear, second leaf (b)

Recently, the double budding method was introduced to sweet cherry too in order to produce Bi Baum® trees (Figure 6).

Fig. 6. Bi Baum® sweet cherry trees in high density planting at INRA Balandran, France

Besides the double budding, the trees for Parallel U, can be produced in nursery by early

scion tipping and by selection of two successive shoots. The last solution is to prune the tree after planting at 30-40 cm from the ground and to choose two successive and opposite shoots for the two axes. In all cases, the axes has to be trained and treated in order to have the same vigour (Figure 7).

a b

Fig. 7. Parallel U at peach (a) and apricot (b), second leaf

The training and pruning principles of Parallel U and Bi Baum® canopy, are:
- two axes as leaders;
- balanced vigour of axes;
- each axe has a high conical shape;
- the lateral shoots - to respect the 1: 3 ratio;
- fruiting shoots distributed in spiral along the axes;
- mixed shoots kept 2-3 years in apricot and plum, 1-2 years in peach;
- unnecessary shoots cut in stubs.

The planting distances and the trees densities for the two canopies are presented in Table 2.

Table 2. Planting distances and trees density for the Parallel U and Bi Baum® canopies

Species	Planting distances (m)	Planting density (trees/ha)
Apple, pear	3.5-4.0 x 1.2-1.5	1,666 - 2,380
Sweet cherry, peach, plum, apricot	4.0-5.0 x 2.0-2.5	800 - 1,250

Trident or Chandelier is a canopy that has been introduced recently for medium and high vigour trees in stone fruits, in order to distribute the growing vigour on three vertical axes. In this case, the total height of the tree is reduced and each vertical axe is managed respecting the principles already presented before. The trees can be pre formed in the nursery with three vertical shoots, preferably obtained from successive buds after the main scion shoot tipping. Another possibility is the formation of the tree shoots after planting following the scion pruning (Figure 8).

Fig. 8. Formation of Trident canopy at peach by pruning the scion after planting (beginning of second leaf)

The recommended planting distances, are influenced by the specie and variety/rootstock vigour. As one can see in the Table 3, the distance between row is correlated with the final tree height, while the one between trees on the row, needs to offer enough space for the growth of the vertical axes (Figure 9).

Table 3. Planting distances and trees density for the Trident canopy

Species	Planting distances (m)	Planting density (trees/ha)
Apple, pear	3.5-4.0 x 1.5-2.5	1,000-1,904
Sweet cherry, peach, plum, apricot	4.0-5.0 x 2.5-3.0	666-1,250

Fig. 9. Trident canopy at apricot, planted 2.5 m on the row (beginning of third leaf)

The three axes need to be parallel, balanced regarding the vigour and the general growth and need to be garnished with fruiting branches disposed in spiral in order to form a fruiting high cone/cylinder (Figure 10).

Fig. 10. Balanced Trident canopy at peach (beginning of third leaf)

One of the most common problem that appears is the unbalanced growth of the three axes (Figure 11).
In species/varieties with a dominant growth of the central leader (some pear varieties, sweet cherry etc.), this has to be replaced trough transfer on some low vigour lateral shoot (Figure 12).

Fig. 11. Trident canopy at pear with a too vigorous central axe (acrotony), Ferrara, Italy

Fig. 12. Replacement of the vigorous central axe at sweet cherry with a weak shoot.

The unbalanced growth of the three axes can be caused by the polarity, the upper located axe on the trunk being more vigorous than the other two (Figure 13).
Also in this case, some special measures has to be taken in order to increase the vigour of the less vigorous axe, and to decrease the vigour of the most vigorous one (incisions, increassing of the growth angle, etc).

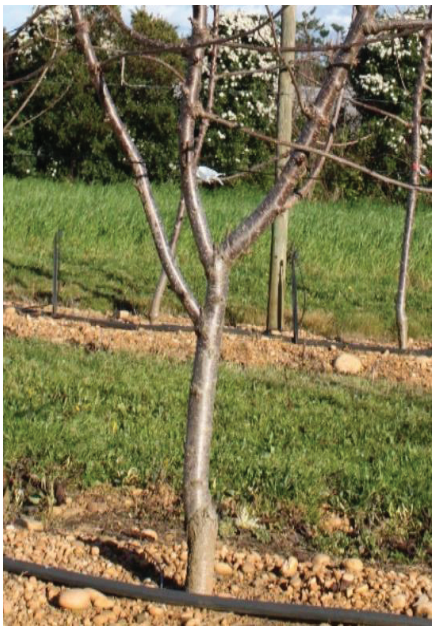


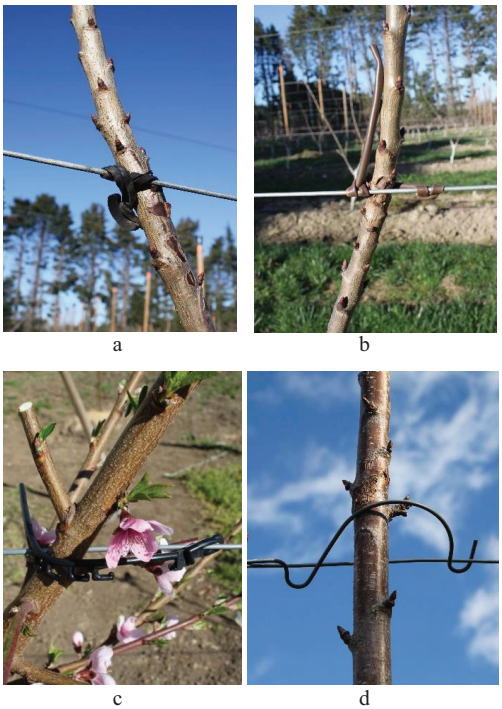
Fig. 13. Unbalanced axes vigour at sweet cherry Trident canopy, related to the polarity

Recently, the philosophy of the vertical axes canopies was transferred with great results to other fruit crops and especially to the fruit berries for fresh consumption (Asănică, 2017; Asănică et al., 2019).

During the formation for all the canopies with one, two or three vertical axes, some important principles has to be respected:

- by all the means, the vertical axe has to be stimulated to grow vertically;
- there are several technical possibilities to tied the axe on the trellising wire (Figure 14);
- in order to stimulate the circulation of the sap flow to the axe top, its annual growth (spear) has to be pruned each spring;
- the axe has to garnished with lateral fruiting shoots. Early spring incisions above vegetative buds or short branches can be executed, especially in sweet cherry (Figure 15);
- a ratio of 3: 1 has to be established between the diameter of the axe and of the lateral branches.

In all cases, after the pruning or the incisions of the axes, fungicides treatments against *Monilinia* has to be applied in order to prevent any wood infections, especially in stone fruits.



a b c d

Fig. 14. Vertical axe fixing on trellis wire with Tree-fix (a) and PVC tube (b), REMA (c) and Steel wire (d)

Fig. 15. Incision on the central axe at sweet cherry and the lateral shoots formation afterword

Pruning

The tree pruning was considerable simplified after the adoption of the vertical axe canopies, the same principles being applied in Vertical axe, Parallel U and Trident. Certainly, some differences are existing between species and sometimes between different fruiting types within the same species (spur or standard).

For **apple and pear** the main pruning principles refers to:
- all the shoots kept in the canopy need to have terminal flower (mixed) buds (Figure 16);
- the vegetative shoots will be eliminated;
- when the number of flowering spurs is too high, spur extinction has to be made, by keeping a distance of 10-12 cm between spurs (Figure 17);
- each lateral fruiting branch needs to have one direction of growth;
- old week branches have to be reduced in order to form new fruiting shoots;
- during the hand fruit thinning (end of May-June), the water shoots (suckers) need to be ripped off.

Fig. 16. Pruning of apple tree – Flowering rods and stubs

Fig. 17. Pruning of apple tree – spur extinction and stubs

In **stone fruits**, it is important to mention that all the branches that are removed from some reason have to be pruned in stubs. Their length is generally correlated to the branch vigour: higher the vigour, longer the stub (Figure 18). The stubs will stimulate the formation of good vigour mixed fruit shoots and will eliminate the risks of *Monilinia* infections.

a b c

Fig. 18. Effect of stub pruning on mixed shoot formation in apricot. Low vigour (a) medium vigour (b), high vigour (c)

An extremely important period for the canopy and fruiting management is summer pruning during May-June. With that occasion, after the fruit set, it is possible to evaluate the fruit load and to eliminate the empty branches. Besides the hand fruit thinning, a similar action can be made by pruning of the too loaded fruiting branches. A special attention has to be apply to the strong water shoots that started to form anticipates. They will be pruned at 4-5 leaves in order to block their initial growth and the stimulate the formation of 2-3 medium vigour mixed shoots (Stănică, 2019).

CONCLUSIONS

The vertical axe canopies, opened a new era in the fruit growing industry that can be defined trough few ideas:
- a moderate planting density between 1,000-3,000 trees/ha was generalized taking in consideration the species and the scion/rootstock vigour. Extremely high densities were banned both by farmers and specialists;
- the vertical axe canopies are in line with the fruit tree natural habit and growth tendency;
- besides the vertical axes trellising, no other expensive man labour activities are needed;
- the used poles for vertical axes trellising are generally utilised as hail net or rain protection supports;
- trees canopy is managed as vertical fruiting walls with all the advantages related to the excellent sun exposer and with positive influence on yield and fruit quality;
- soil mechanized management on the row and on intercrop is easily and efficient;
- for most of the species, the mechanical pruning is applicable;

- hand fruit thinning and picking and other manual activities as pruning can be made on moving platforms.

REFERENCES

Asănică, A. (2017). *Cultura pe verticală a arbuștilor fructiferi*, Ed. Total Publishing

Asănică, A., Stănică, F., Iacob, A., Perojuc, L., Ungurenuș, M. (2019). *First results of vertical cordon training system for currants in Romania,* XII International Rubus and Ribes Symposium: Innovative Rubus and Ribes Production for High Quality Berries in Changing Environments, Acta Horticulturae (in press)

Asănică, A., Stănică, F., Iacob, A., Ungurenuș, M. (2019). *Transformation of bush training system into vertical cordons, a pathway to boost the mature currant orchards*, XII International Rubus and Ribes Symposium: Innovative Rubus and Ribes Production for High Quality Berries in Changing Environments, Acta Horticulturae (in press)

Asănică, A., Tudor, V., Teodorescu, R. (2013). Distinctive behaviour of some sweet cherry cultivars related to rootstock type, *AgroLife Scientific Journal*, Vol. II, Number 1, 79-82

Butcaru, A.C., Stănică, F. (2018). *Cultivation technology of organic roses for petal production* (in press).

Caruso, T., Giovannini, D., Marra, F.P., Sottile, F. (1997). Two new planting systems for early ripening peaches (*Prunus persica* L. Batsch): yield and fruit quality in four low-chilling cultivars. *J. Hort. Sci*. 72, 873-883

Cean, I, Stănică, F. (2013). The Growth Characteristics of Six Pear Cultivars under the "Trident" Training System in South-East of Romania. *Scientific Papers. Series B. Horticulture*, Vol. LVII, 261-266.

Dorigoni, A., Lezzer, P, Dallabetta, N., Serra, S. and Musacchi S. (2011). Bi-Axis: An Alternative to Slender Spindle for Apple Orchards. Proc. IXth ISHS on Orchard Systems. *Acta Hort.* 903, 581-588.

Elkins, R.B., DeJong, T.M. (2011). Performance of 'Golden Russet Bosc' pear on five training systems and nine rootstocks. Proc. IXth ISHS on Orchard Systems. *Acta Hort*. 903, 689-694.

Franken-Bembenek, S. (2005). Gisela® 5 rootstock in Germany. *Acta Hort. (ISHS)* 667, 167-172.

Ghena, N., Branişte, N., Stănică, F. **(**2004). *Pomicultură generală (General fruit growing),* Editura Matrix Rom, Bucureşti, ISBN 973-685-844-8.

Hoying, S.A., Robinson T.L., DeMarree, A.M. (2012). *Do High Density Apple Planting Systems Make Sense*? Grand Traverse Orchard & Vineyard Show, January 24 2012.

Lauri, P.É., Lespinasse, J.M. (2000). The Vertical axis and Solaxe systems in France. *Acta Hort*. 513, 287-296.

Lewandowski, M., Sobiczewski, P., Żurawicz, E., Mikiciński, A. (2012). Susceptibility of selected apple rootstocks to fire blight caused by *Erwinia amylovora. Acta Hort* 1058, 493-498.

Meland, M. (2001). Early performance of European plum high density production systems. Proc. VIIth ISHS on Orch. & Plant. Syst. *Acta Hort*. 557, 265-273.

Musacchi, S. (2008). Bibaum®: a new Training system for pear orchards. *Acta Hort*. 800, 763-768.

Neri, D., Morini, F., Massetani, F. and Pirazzini, P. (2010). Pruning: how to manage shoot growth. Proc. XIVth ISHS Apricot Breeding and Culture. *Acta Hort*. 862, 355-363.

Robinson, T.L., Hoying, S.A., Reginato, G.H. (2011). The tall spindle planting system: principles and performance. Proc. IXth ISHS on Orchard Systems. *Acta Hort*. 903, 571-579.

Robinson T., Hoying S., Miranda M., Dominguez L., Fachinello J., (2012). Yield, fruit quality and mechanization of the tall spindle apple production system, *Acta Hort.* 1058, 95-103

Robinson, T., Dominguez, L. (2015). Comparison of the modified Spanish bush and the tall spindle cherry production systems. *Acta Hort*., 1058, 45-53.

Robinson, T., Fazio, G., Aldwinckle, H. (2013). New Apple Rootstocks for Organic Production. Intervitis-Interfructa, Stuttgart, 26th of April.

Stănică, F., Dumitraşcu, M., Peticilă, A. (2002). Behaviour of three pear varieties propagated *in vitro* and self-rooted, on Tatura Trellis canopy, Proceedings of the Eighth ISHS International Symposium on Pear Volume II, *Acta Hort*., 596, 647-649.

Stănică, F., Platon, I. (2011). Effects of three planting systems on apple tree growth and productivity. Proc. IXth ISHS on Orchard Systems. *Acta Hort*., 903, 651-656.

Stănică, F., Eremia, A. (2012). Behaviour of Some New Apricot Varieties under the Parallel Trident Planting System. Proc. Xth ISHS on Orchard Systems. Stellenbosch, *Acta Hort. (ISHS)* 1058, 129-136.

Stănică, F., Asănică, A.C., Grigore, S.C., Cârstea, O.M. (2014). Behaviour of Some Cherry Varieties under Parallel Trident Planting System. ISHS Int. Hort. Congress, Brisbane, Aug.

Stănică, F., Cean, I., Peticilă, A.G. (2014). Parallel Trident an Efficient Planting System for Pear Orchards. ISHS Int. Hort. Congress, Brisbane, Aug. (in press).

Stănică, F. (2019). Training and Pruning Peach and Apricot Trees. 7th Conference of "Innovations in Fruit Growing", Faculty of Agriculture, University of Belgrade, Serbia.

Stehr, R. (2011). Apple crop and fruit quality influenced by low and high planting densities on M.9 and M.27 rootstocks in Northern Germany.

Vercammen, J. (2011). Different planting systems for 'Conference' pear. Proc. IXth ISHS on Orchard Systems. *Acta Hort*. 903, 701-706.

Voigt, F., Stassen, P.J.C. (2012). The South African Deciduous Fruit Industry's Pome Fruit Rootstock Scenario and Future Initiatives

Wertheim, S.J., Wagenmakers, P.S., Bootsma, J.H., Groot, M.J. (2001). Orchard systems for apple and

pear: conditions for success. Proc. VIIth ISHS on Orch. & Plant. Syst. *Acta Hort*. 557, 209-229.
Wertheim, S.J. (2002). Rootstocks for European pear: a review. *Acta Hort.* (ISHS) 596, 299-309
Widmer, A., Krebs, C. (1997). Mikado and drilling (triplet) – two novel training systems for sustainable high quality apple and pear production. *Acta Hort.* 451, 519-528.
Widmer, A., Krebs, C. (2001). Influence of planting density and tree form on yield and fruit quality of 'Golden Delicious' and 'Royal Gala' apples. *Acta Hort.* 557, 235-241.