Australian Journal of Crop Science AJCS

AJCS 13(04):574-577 (2019) ISSN:1835-2707
doi: 10.21475/ajcs.19.13.04.p1542

Effect of different training systems to catch greater light interception in apple cultivar Maxi Gala in temperate climate

Guilherme Fontanella Sander, Tiago Afonso Macedo, Pricila Santos da Silva, Juliana Fátima Welter, Augusto José Posser, Leo Rufato, Aike Anneliese Kretzschmar

Department of Biotechnology, Santa Catarina State University, Brazil

***Corresponding author: pricilassilva@hotmail.com**

Abstract

Apple is one of the most consumed fruits in the world. In Brazil, apple is the deciduous fruit of major importance. Its production is focused in the southern region of the country. To increase apple tree yield and to optimize fruit quality, it is important to choose a suitable training system to obtain greater light interception and photosynthetic radiation. Therefore, the objective of this study was to evaluate vegetative and productive aspects of the cultivar Maxi Gala grafted on seven-year-old dwarf rootstock M.9, under three different training systems: Tall Spindle, Solaxe and Vertical Axis. The experimental orchard was implemented in August, 2010 in Vacaria city, Rio Grande do Sul province, Brazil. The experiment was conducted and evaluated in (2014-2017) seasons. The results showed that Tall Spindle, Solaxe and Vertical Axis driving systems had no effect on internode length, plant height, fruit diameter and quality parameters such as pulp firmness and soluble solids. Therefore, the Tall Spindle driving system was more efficient for accumulative production, being this the indicated combination for regions with the edaphoclimatic characteristics like those of the orchard under study.

Keywords: High density; Fruit production; Solaxe; Tall Spindle; Vertical Axis.
Abbreviations: ha^{-1}_hectare, m^3_cubic metre, m_meter, mm_millimetre, Mg_megagram, cm_centimetre, N_Newton °Brix_ Brix concentration/level.

Introduction

Apple (*Malus domestica* Borkh.) is one of the most consumed fruits in the world. China is the main producing country, accounting for 43 percent of total world production (Faostat, 2016). In Brazil, apple production in 2017 reached 1.2 million tons (Ibge, 2017). In Rio Grande do Sul state there are about 560 fruit growers, totally 14,808 hectares of cultivated area, with an average of 26 hectares of orchard per producer (Agapomi, 2014). Vacaria city is the main apple producer in Rio Grande do Sul state, 277,835 tons in the 2016 season (Agapomi, 2016). These values are also due to favourable climate, high altitude and low relief for fruit production (Lopes et al., 2010).

To increase apple production and to optimize fruit quality, it is very important to choose the correct training system to obtain light interception and photosynthetic radiation (Hampson et al., 2002). This combination tends to increase profitability by improving yield and/or reducing the cost of labour (Robinson, 2008). In Brazil, first apple tree orchards were conducted in the cup training system, in a low plant density (550 to 800 plants ha^{-1}). However, in modern orchards, high plant densities is recommend (1,500 to 3,500 plants ha^{-1}), which is possible with the use of a dwarfing rootstocks, inter-grafting and central leader training system (Petri et al., 2011). The M.9 dwarf rootstock produces compact plants with high productive capacity, with precocity of production and good fruit size (Huffman, 2012).

Orchards in high plant densities are created and trained to improve efficiency in interception and absorption of the solar rays. High density orchards make better use of available light when compared to conventional low density orchards (Hampson et al., 2002). There are a multitude of training systems and pruning techniques for apple plants in different parts of the world. Each system has its peculiarities, which may be related to the characteristics of the region, such as the relief, climatic conditions, technological level and cultural habits of fruit growers.

Tall Spindle and V-trellis training systems were developed to increase yield, fruit quality and precocity of production at high planting densities (Bergerman et al., 2012). There are also other management systems derived from a central leader used in apple orchards with high plant densities, such as Solaxe, Tall Spindle (D'Abrosca et al., 2017) and Vertical Axis.

The main characteristic of Tall Spindle is the high number of branches along the central stem, reaching large yields in the second and third seasons (Robinson et al., 2006). For this training system, Hoying and Robinson (2000) recommend renewing of branches throughout the orchard cycle, when they become vigorous.

Solaxe training was designed to locate fruiting points in buds on the periphery of the plants, making it also known as a centrifugal system. In this training system, shoots, spurs and

floral buds of the branches close to the stem (about 30 cm) are eliminated (Mafcot, 2000). In this way shade is reduced and light distribution within the canopy of the trees is improved (Lauri et al., 2004a).

Vertical Axis is an intensive training system with at least 1,235 plants per hectare, being used to obtain significant harvests in the first seasons after orchard implantation (Warmund, 2014). Fruiting branches are located along the stem, spaced one meter upwards. Renovation pruning is done normally after three years, with the main purpose of removing badly positioned branches and maintaining fruiting in young structures (two-year spurs and shoots) (Lauri, 2008).

Some studies on different vigour rootstocks, s have been evaluated in different apple cultivars and training system at several apple producing areas of the world. Buler et al. (2001) studied the effect of the Hytec and the Tall Spindle training system on cultivar Elstar grafted on dwarf rootstock and cultivar Šampion grafted on a semi-dwarf rootstock and they verified higher yield in Tall Spindle plants.

In Brazil, there are still few studies aimed at determining the best training system to be used in apple trees orchards. Doubts about the recommendation of the most efficient training system still exist. Correct recommendation is necessary for optimizing plant growth, maximizing light penetration, productivity, fruit quality and profitability.

This work aimed to evaluate vegetative and productive aspects of cultivar Maxi Gala grafted on the dwarf rootstock M.9, under three different training systems such as Tall Spindle, Solaxe and Vertical Axis in soil and climate conditions of Vacaria city, Rio Grande do Sul state.

Results and discussion

Production characteristics

Internode length and plant height were not influenced by the different training systems in 'Maxi Gala' apple trees in the studied season (Table 1). Corroborating to this study, Hampson et al. (2002) also found that Y-trellis (2976 plants ha^{-1}) and V-trellis (7143 plants ha^{-1}) did not interfere with plants height of cultivar Royal Gala grafted on rootstock M.9.

The mean value of canopy volume was higher when apple trees were managed in the Vertical Axis training system (4.02 m^3) in comparison to Tall Spindle (2.99 m^3) and Solaxe (3.11 m^3) in 2014, 2015 and 2016 seasons (Table 1). However, in 2017 season, canopy volume was higher in the Vertical Axis (6.04 m^3) than in Tall Spindle (5.10 m^3), with no difference for the Solaxe training system (5.66 m^3) (Table 1). In a study carried out in cultivar Jonagol grafted on the M.9, with the training systems Slender Spindle (4,761 plants ha^{-1}), Vertical Axis (2,857 plants ha^{-1}), Hytec (1,904 plants ha^{-1}), L-Super Spindle (5,000 plants ha^{-1}) and S-Super Spindle (10,000 plants ha^{-1}) higher volume of canopy was observed (Kiprijanovski et al., 2009).

Productivity was not influenced by training systems in 2014 season (Table 2). In 2015 season, productivity was higher for Solaxe training system (40.65 Mg ha^{-1}) compared to Tall Spindle (37.08 Mg ha^{-1}) (Table 2). In 2016 season, Vertical Axis and Tal Spindle had higher productivity (36.83 and 36.46 Mg ha^{-1}, respectively) than Solaxe (30.28 Mg ha^{-1}) (Table 2). However in 2017 season, Tall Spindle (31.51 Mg ha^{-1}) and Solaxe (35.77 Mg ha^{-1}) obtained higher productivity than Vertical Axis (22.77 Mg ha^{-1}) (Table 2). Considering accumulated productivity of all seasons, it is possible to observe Tall Spindle training system, presenting higher values in relation to other training systems (Table 2).

Fruit quality

Fruit diameter was not influenced by training systems on 'Maxi Gala' apple during the study (Table 2). However, fruit diameter was higher in Anna cultivars grafted on MM.106 on the Tiller training system than on Open Central Leader in density of 2,000 plants ha^{-1} (Hassan et al., 2010).

Pulp firmness and soluble solids were not influenced by training systems on 'Maxi Gala' apple trees (Table 3). However, 'Cripps Pink' grafted on MM.109 rootstock, conducted in the cup training system showed higher pulp firmness and soluble solids (Shafiq et al., 2014).

Materials and methods

Location description

The experimental area was implanted in August 2010 in virgin soil area, where fruit trees had not been previously cultivated. The orchard is located at Rasip Agropastoril S / A farm, in Vacaria countryside, Rio Grande do Sul state, Brazil, at 28 ° 26 "24.75" S and 50 ° 51 "51.60" W, 940 meters altitude. Seedlings used for implantation were produced in single stem system, without lateral branching, by Rasip company itself. The experiment was conducted and variables evaluated in 2014, 2015, 2016 and 2017 seasons.

Plant material

The Maxi Gala cultivar trees were cultivated in within spacing of 0.6 m and 4.0 m between rows, in a density of 4167 plants per hectare, for all training systems. Treatments were composed by central leader training systems: Tall Spindle, Solaxe and Vertical Axis. Trees were submitted to lateral branches arching in different angulations to stem, in accordance with each training system. Branches were arched at 120 ° in Tall Spindle, near 90 ° in the Vertical Axis system. In Solaxe system branches were arched above 120° leaving branches perpendicular to the ground. The same bowing procedure was performed every year on new branches, following characteristics already mentioned for each training system.

In all years of study, minimal pruning was performed on Vertical Axis and Solaxe training systems, removing bullshoots and secondary branches of 2/3 diameter or more in relation to central leader. In Solaxe, according to the principles of the system, structures (reproductive and / or vegetative) arranged along the first 30 cm and the secondary branches were removed. In Tall Spindle system, pruning was done to eliminate two or three secondary branches of larger diameter per plant.

Trial design

Trial design was a randomized block experiment of three treatments (Tall Spindle, Solaxe and Vertical Axis) with six replicates and ten plants per plot.

Table 1. Internode length, plant height and canopy volume of 'Maxi Gala' apple trees grafted on M.9 rootstocks in different training systems. Vacaria city, RS, Brazil, 2018.

Training System	Internode length (cm)				Plant height (m)				Canopy volume (m^3)			
	2014	2015	2016	2017	2014	2015	2016	2017	2014	2015	2016	2017
Vertical Axis	2.11 ns	2.23 ns	1.92 ns	1.86 ns	1.96 ns	2.43 ns	3.09 ns	3.37 ns	2.97 a	4.53 a	4.57 a	6.04 a
Tall Spindle	2.22	2.23	1.97	1.86	1.89	2.37	3.17	3.55	1.95 c	3.21 b	3.83 b	5.10 b
Solaxe	2.17	1.89	2.01	1.87	2.01	2.56	3.24	3.55	2.16 b	3.22 b	3.95 b	5.66 ab
Average	2.17	2.12	1.96	1.86	1.95	2.45	3.16	3.49	2.36	3.65	4.11	5.6
C.V * (%)	13.28	14.64	9.59	9.78	9.71	8.21	9.51	9.25	4.48	5.14	9.38	6.35

Averages followed by the same letter in the column, do not differ by Tukey's test at 5% of error probability (p≤0.5). ns = not significant. *coefficient of variation.

Table 2. Productivity and fruit diameter of 'Maxi Gala' apple trees grafted on M.9 graft holder in different conduction systems. Vacaria city, RS, Brazil, 2018.

Training system	Productivity (Mg ha^{-1})				Cumulated productivity (Mg ha^{-1})	Fruit diameter (mm)			
	2014	2015	2016	2017		2014	2015	2016	2017
Vertical Axis	33.8 ns	37.65 ab	36.83 a	22.77 b	131.05 b	67.04 ns	68.16 ns	64.75ns	67.33 ns
Tall Spindle	35.1	37.08 b	36.46 a	31.51 a	140.05 a	66.14	65.33	63.25	68.33
Solaxe	20.6	40.65 a	30.28 b	35.77 a	127.30 c	69.35	68.08	64.33	69.33
Average	29.8	38.5	34.52	30.01	8.04	67.5	67.19	64.11	68.33
C.V* (%)	8.96	5.4	5.9	11.93	132.83	4.53	4.04	1.69	5.59

Averages followed by the same letter in the column do not differ from each other by the Tukey test at 5% of error probability. ns: not significant. *coefficient of variation.

Table 3. Pulp firmness and soluble solids of 'Maxi Gala' apple fruit grafted on M.9 rootstock in different training systems. Vacaria city, RS, Brazil, 2018.

Training system	Firmness (N)				Soluble solids (°Brix)			
	2014	2015	2016	2017	2014	2015	2016	2017
Vertical Axis	86.07ns	71.48 ns	70.41 ns	77.67 ns	11.56 ns	10.00 ns	9.80 ns	11.55 ns
Tall Spindle	85.63	76.11	70.19	77.44	10.73	9.90	9.46	11.26
Solaxe	84.96	71.53	70.19	75.40	11.20	10.18	9.83	11.51
Média	85.55	73.04	70.26	76.84	11.16	10.03	9.69	11.44
C.V (%)	4.26	6.77	6.58	3.51	8.19	7.87	5.88	3.26

ns: did not differ among themselves by the Tukey test at 5% probability of error.

Variables analysed

Training length, plant height, crown volume, productivity, fruit diameter, pulp firmness and soluble solids were the main analysed variables. Internode length was obtained through measurements of the branch of the year length and its number of buds. Data was collected in vegetable dormancy period. Four branches per plant of the four central plants were evaluated. Measurements were performed with a metric unit scale. Branch size was divided by the number of buds, obtaining the average size of internode, and data was expressed in centimetres (cm).

The plant height was measured by a graduated topographic ruler. The readings were performed in July, measuring plant height from the point of grafting to the end of the central leader. Results were expressed in meters (m).

To calculate crown volume, measurements were made by graduated topographic ruler, in vegetable dormancy period (July). Width, length and height of the plant were measured. Plant height was measured from the lower branches inserted in the stem. Taking all three measurements, all values were multiplied, resulting in a cup volume value, expressed in cubic meter (m^3).

Productivity per hectare was estimated from planting density. The average yield per plant of each training system was multiplied by the number of plants per hectare. Results were expressed in Mega gram per hectare (Mg ha^{-1}).

To measure the average diameter of the twenty fruits, they were placed side by side in an "L" shaped wooden chute, graduated in centimetres to measure the calibre of the twenty apples. It was possible to obtain the average unit diameter by dividing this value by the total number, expressed in millimetres (mm).

Pulp firmness of pulp was obtained by a pneumatic penetrometer, with 11mm tip, attached to a support. The superficial layer of the fruit epidermis was exposed by means of a peeler, exposing the pulp to measure the firmness with the penetrometer, in the equatorial zone on two sides of the fruits. Results were expressed in newtons (N).

Soluble solids were determined from two equal size slices taken from each fruit. Juice of ten fruits was extracted with the aid of a digital refractometer and the results were expressed in Brix (° Brix).

Statistical analysis

Trial data were analysed by variance analysis (ANOVA) and subsequent multiple comparison of means using the Tukey test at 5% of error probability.

Conclusion

Maxi Gala apple cultivar on Tall Spindle training systems was more efficient for accumulative productivity. Tall Spindle, Solaxe and Vertical Axis training systems had no effect on internode length, plant height, fruit diameter and quality parameters such as pulp firmness and soluble solids.

Acknowledgement

The authors thank Rasip Company, for the availability of apple tress orchard to carry out the research. We also acknowledge the institutions CAV-UDESC, EMBRAPA, CAPES, FAPESC and CNPq for promoting the research.

References

Agapomi (2014) Gauc. Ass. of App. Prod. http://agapomi.com.br/wp-content/uploads/Safra-2014.pdf.

Agapomi (2016) Gauc. Ass. of App. Prod. http://agapomi.com.br/wp-content/uploads/Safra-2016.pdf.

Bergerman M, Sanjiv S, and Hamner B (2012) Results with autonomous vehicles operating in specialty crops. Rob. and Aut. Int. Conf. on IEEE.

Buler Z, Mika A, Treder W, Chlebowska D (2001) Influence of new training systems of dwarf and semidwarf apple trees on yield its quality and canopy illumination. Acta Hort. 557: 253–259.

D'Abrosca B, Scognamiglio M, Corrado L, Chiocchio I, Zampella L, Mastrobuoni F and Petriccione M (2017) Evaluation of different training systems on Annurca apple fruits revealed by agronomical, qualitative and NMR-based metabolomic approaches. Food chem. 222:18-27.

Faostat (2016) Agriculture Data. Available from: http://faostat3.fao.org/faostatgateway/go/to/home/E.

Hampson CR, Quamme HA, Brownlee RT (2002) Canopy growth, yield and fruit quality of 'Royal Gala' apple trees grown for eight years in five tree training systems. HortSci. 37: 627–631.

Hassan HSA, Sarrwy SMA, Mostafa EAM, Dorria MA (2010) Influence of training systems on leaf mineral contents, growth, yield and fruit quality of "Anna" apple trees. Res J Agric Biol Sci. 6: 443-448.

Huffman L (2012) Choosing Rootstocks http://www.omafra.gov.on.ca/neworchard/english/apples/21rootstock.h tml

Hoying SA and Robinson T (2000) The apple orchard planting system puzzle. Acta Hort. 513: 257–260.

Ibge (2017) Brazilian Institute of Geography and Statistics. Systematic Survey of Agricultural Production. Rio de Janeiro. Disponível em: https://sidra.ibge.gov.br/home/lspa/brasil.

Kiprijanovski M, Ristevski B, Arsov T and Gjamovski V (2009) Influence of planting distance to the vegetative growth and bearing of apple cultivar 'Jonagold' on rootstock 'MM 106'. Acta Hort. 825: 453–458.

Lauri PE, Willaume M, Larrive G and Lespinasse JM (2004) The concept of centrifugal training in apple aimed at optimizing the relationship between growth and fruiting. Acta Hort. 636: 35-42.

Lauri PE (2008) Trends in apple training in France – An architectural and ecophysiological perspective. Acta Hort. 772: 483-490.

Lopes F, MielniczukI J, Oliveira ES, Tornquist CG (2010) Evolution of land use in a pilot area of the region of Vacaria, RS. Braz J Agri Eng Campina Grande. 14:1038-1044.

Mafcot (2000) Pommier: Extinction et conduite centrifuge. Réussir Fruits et Légumes. 182- 4p

Petri J, Leite GB, Couto M, Francescatto P (2011) Advances of the apple culture in Brazil. Braz J Fruit. 33: 48-56.

Robinson TL, Hoying SA and Reginato GH (2006) The tall spindle apple production system. New York Fruit Quart. 14 (2): 21-28.

Robinson TL (2008) The evolution towards more competitive apple orchard systems in the USA. Acta Hort. 772: 491–500.

Shafiq M, Singh Z and Khann AS (2014) Pre-harvest ethephon application and training systems affect colour development, accumulation of flavonoids and fruit quality of 'Cripps Pink' apple. Aust J Crop Sci. 8 (12): 1579-1589.

Warmund RM (2014) The vertical axis System: A training method for growing apple trees. Univ. Of Miss. Ext., MU Guide, G6024, p.1-4, Last review.