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Training and pruning the apple tree according to the SALSA System¹

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Introduction

According to Robinson (2003) training systems for apple can be categorized in four tree canopy shapes, i.e., spherical, conic, flat planar and V-shaped. More recently, Musacchi and Greene (2017) considered planar, angled and vertical canopy, this latter category grouping the first two “shapes” of Robinson. More than 30 training systems have been described so far (Robinson, 2003), but considering that each grower adapts training and pruning procedures to his/her specific plant material and environment, it is likely that much more training systems co-exist all over the world. This highlights that the procedures that are given to maintain the apple tree architecture within a given “shape” do not suffice in themselves to fulfill the two main objectives of apple tree cultivation that are regular bearing and fruit quality. The intrinsic architectural and functioning characteristics of the cultivar-(interstock)-rootstock entity are determinant on the success of the orchard. In the following, I will take the example of applied research works developed in France to illustrate that the progress in apple orchard performance over the last 40 years was essentially based on the improvement of our knowledge in apple tree architecture and functioning.

Whole-tree *versus* branch and fruiting spur: what is the relevant scale?

The first initial step was the classification of apple “fruiting types” by Bernhard (1961; French: “types de fructification”) from Type I (“spur type” with upright branches and fruiting in lateral position) to Type IV (with down-swept branches and fruiting in terminal position). Working at the tree scale Lespinasse and colleagues proposed to sort apple trees according to two variables, position of branches along the trunk (more at the bottom or more towards the top) and branch orientation (upright *versus* horizontal)(Lespinasse, 1977, 1980; Lespinasse and Delort, 1986). These classifications and others such as the ones of Forshey et al. (1992) grouping apple cultivars according to their “growth” and “fruiting habits” are useful for their descriptive interest (Laurens et al., 2000; Watkins and Smith, 1997) but they hide the variability of apple tree growth and fruiting within each apple “type” depending on the cultivar. This is the case for some ‘Fuji’ clones that belong to type IV according to Lespinasse typology but may be characterized by a strong irregular bearing pattern (Lauri et al., 1997). Furthermore, the apple tree is a composite entity combining the cultivar, grown for fruit, and the rootstock used for adaptation to the environmental conditions, possibly with an interstock. A consequence of this is that a same rootstock may significantly change the bearing pattern specific to a cultivar. For example, as shown by Barritt et al. (1997), a vigorous rootstock may decrease

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irregular bearing on a spur-type cultivar while increasing irregular bearing on a standard- or tip-bearing cultivar.

Researches developed in the apple from the beginning of the 1990's in France (Lauri, 2002; Lauri and Laurens, 2005; Lauri and Corelli-Grappadelli, 2014; Lauri, 2018) and further extended in New-Zealand (Breen et al., 2015, 2016) show that precision management of fruiting in the orchard needs more knowledge on how the tree balances vegetative growth and fruiting.

Two main aspects have been developed, the relationship between branching density and return-bloom, and the concept of autonomy of the fruiting shoot.

- 1) Working on a range of apple cultivars, we have shown that, generally speaking, cultivars with high branching density have a low bourse-over-bourse whereas cultivars with a low branching density have a high bourse-over-bourse (Figure 1a). Interestingly in these latter cultivars, low branching density is often related to longer side shoots and to the natural death of young spurs, termed "natural extinction" (Figure 1b). Our physiological hypothesis is that the tree balances the number of growing meristems and their organogenesis: the lower this number the higher the growing potential of the remaining shoots and the higher the organogenesis, and consequently the frequency of flower cluster, of the apical meristems (Lauri et al., 1995).
- 2) There is a relationship between the length of a shoot and the frequency of fruiting in apical position on that shoot. This relationship is curvilinear and may vary depending on the cultivar indicating that fruiting frequency is the highest within an optimal cultivar-dependent 'length window' (Figure 2). Interestingly this relationship has also been found on Mango (Normand et al., 2009).

All together, these studies strongly support the concept of the physiological autonomy of the spur, at least for flower induction and fruit-set, provided it develops a minimal leaf area. However, regular bearing may also be observed on cultivars with high-alternating and desynchronized individual spurs (Lauri et al., 1995; Lauri and Laurens, 2005).

From knowledge to applied aspects – the path to the SALSA system

In the beginning of the 1990s the Solaxe system was proposed pointing to the interest of branch bending to improve flowering and avoiding the risk of inaccurate tree reaction to heavy pruning (Lauri and Lespinasse, 2000). However, it quickly appears that such intensive bending leading to a high flowering in the 3rd or 4th year after planting could also increase the risk of a fast entrance into alternate bearing. It was then proposed to implement "artificial extinction" on the Solaxe trained trees as a spur thinning method to decrease spur, and therefore flowering, density (Lauri et al., 2004). This improved system was named "Centrifugal Training" because it included a "light well" or "light chimney" along the trunk where all shoots and spurs were removed in order to improve light penetration until the bottom of the tree. This chimney could enlarge as the tree gets older in a "centrifugal" way. Centrifugal training is still well adapted to cultivars with a clear hierarchy between the trunk and the side branches (e.g., spur-type, 'Braeburn'). Main rules for Centrifugal Training have been already published (Lauri, 2009) and won't be presented here again. However Centrifugal training is less adapted to cultivars with more polyarchic architectural framework where strong and competitive branches may develop along the trunk, typically at the bottom (e.g., 'Granny Smith')(Figure 3). For these cultivars, there is an interest to use as much as possible the vegetative growth potential of the

tree during the very first years in the orchard and to adapt the support system to the tree intrinsic development.

Basically, tree management follows two main objectives:

- 1) The canopy has to be porous to light and air to improve leaf functioning and fruit quality (fruit growth and internal quality, coloring) in all sites in the canopy.
- 2) Each fruiting spur, i.e., the morphological complex including the bourse bearing the fruit(s) and bourse-shoot(s) which develops at the axil of bourse leaves (Figure 4), has to be sufficiently autonomous to ensure both current fruit growth and floral initiation for the following year. A main condition for this is that, as shown before, the spur has to reach a certain size. The empirical knowledge that shoots of 15-20 leaves, ca. 10-20 cm ("brindles"; Lauri and Lespinasse, 1993), are those having the higher frequency of apical flowering, fruit-set and fruit size, is still valid whatever the cultivar (Breen et al., 2015).

Practical procedures to manage the SALSA system

These rules have been recently defined in a paper (Lauri et al., 2016). They will be only summarized here. The architectural framework of a SALSA tree is made up with 2 to 5 "reiterative trunks", depending on the plant material (rootstock, cultivar) and on the environment, whose vigor is intermediate between the one of the initial trunk and the one of a side branch of the centrifugal trained tree. These reiterative trunks are typically branched at the bottom of the trunk. As a rule of thumb, the tree has a parallelepiped shape of about 3 m high and 0.8-1 m width. Planting distances are around of 3.5-4x1.2-1.5 m corresponding to ca. 2000-2400 trees ha⁻¹ or ca. 6000 reiterative trunks ha⁻¹. A vertical support system, with horizontal wires at 0.7, 1.4, 2.1 and 2.8 m is commonly used.

SALSA trained trees may be obtained in two ways. The first trees that inspired the SALSA concept were grown in an experimental site at INRA Montpellier in the beginning of the 1990s. They were obtained using M7 rootstock whose vigor entailed the concomitant growth of the initial trunk and of sylleptic (i.e., growing in the same year) "reiterative trunks". This growth pattern resulted at the end of the first or second year, in a 2-5 multiple-trunk tree.

In the past decade, SALSA trees were obtained in the same way keeping the well-developed reiterative trunks developing at the bottom of the tree instead of removing them as usually done on centrifugal trained trees. SALSA trained trees may also be obtained using bi-axis trees directly bought in nurseries with the "Bibaum®" technique (Musacchi and Greene, 2017). Importantly, we are not looking at a fixed number of reiterative-trunks in a tree. Rather, this variable number of reiterative trunks depends on the vigor of each individual tree in the orchard and is a way to better balance vegetative growth and fruiting potential over the years.

The concept of fruiting branch is abandoned, and consequently branch bending, which is a main operation on centrifugal trained trees, is consistently reduced and even cancelled especially when there is more than two reiterative trunks. As a result, the fruiting spurs are directly attached along the reiterative trunks and are distributed homogeneously within the tree canopy volume. Canopy porosity and autonomy of the fruiting spurs are improved through winter thinning cuts carried out on 2-year old and older branches in overcrowded and shaded sites in the canopy. Artificial extinction is usually made around pink stage to remove excess flowering spurs and to allow a convenient space around each fruiting spur over the years. Once the fruiting spur is positioned within the SALSA canopy, the objective is to maintain a good light

interception at all sites within the canopy and to avoid competition with other fruiting spurs.

Discussion and conclusion

As shown here, the SALSA concept results from a history of constant knowledge improvement along past decades. It is based on the idea that a sustainable and economically sound training system has to take into account the biological specificities of the plant material in interaction with the pedoclimatic environment. All cultural operations, such as strong heading cuts, have to avoid unnecessary vegetative growth that would impair good fruiting. The training system also has to adapt to the socioeconomic context. Although Centrifugal training is still relevant for high fruit quality and regular fruiting, which is well adapted to the premium market, it also needs, more or less depending on the cultivar, high work load. Facing the socioeconomic issue, the SALSA system appears more adapted to mechanization. For example, some minimal mechanical pruning is now implemented at certain stages of tree framework management, keeping precision pruning for human-made operations.

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Figures

Figure 1 – a) succession of bourses over consecutive years, b) natural extinction phenomenon (yellow circles) on 1-year-old branch indicating the death of these side shoots.

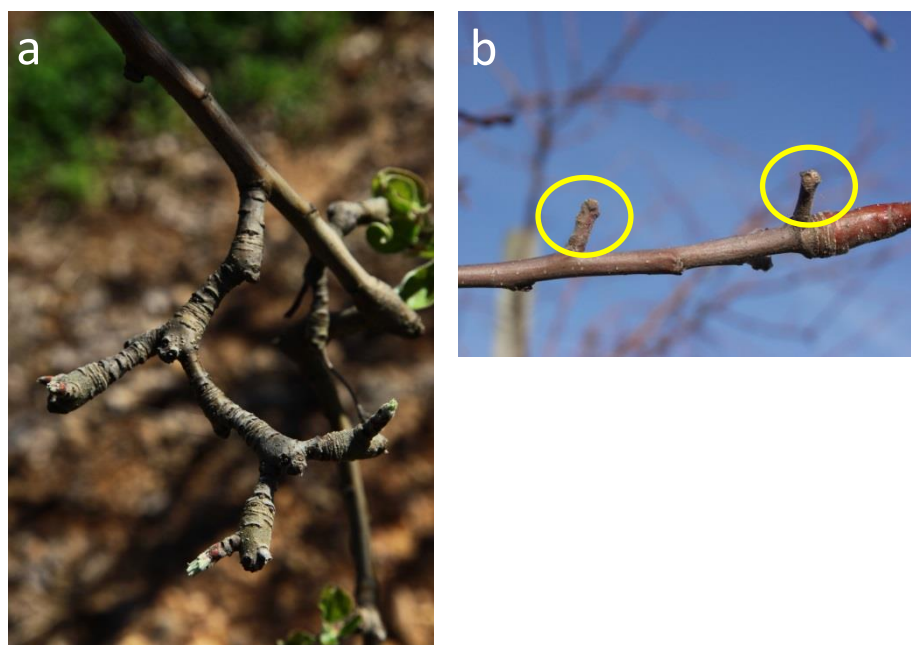


Figure 2 – Relationship between the number of leaves of a shoot in year Y and the frequency of fruiting in apical position in year Y+1 for two cultivars, 'Pitchounette' and 'Chantecler' (from Lauri and Corelli-Grappadelli, 2014).

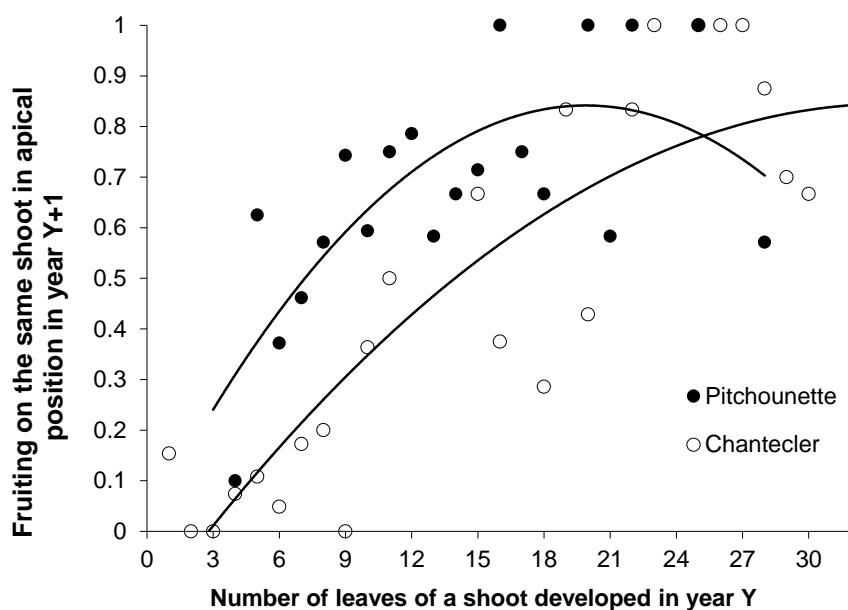


Figure 3 – Polyarchic tree architecture characterized by “reiterative trunks” competing with the initial trunk. Such tree architecture is well adapted to the SALSA system (own-rooted hybrid apple, INRA, Montpellier).

NB: here, reiterative trunks below 50cm have been removed to make easier weeding on the row.



Figure 4 – The fruiting shoot composed of the flower cluster with three young fruits and a bourse-shoot (arrow)

