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REVIEW PAPER

Rapid advanced in agricultural production and development of modern orchards establishment: a bright prospect for horticulture development in Kermanshah province, Iran

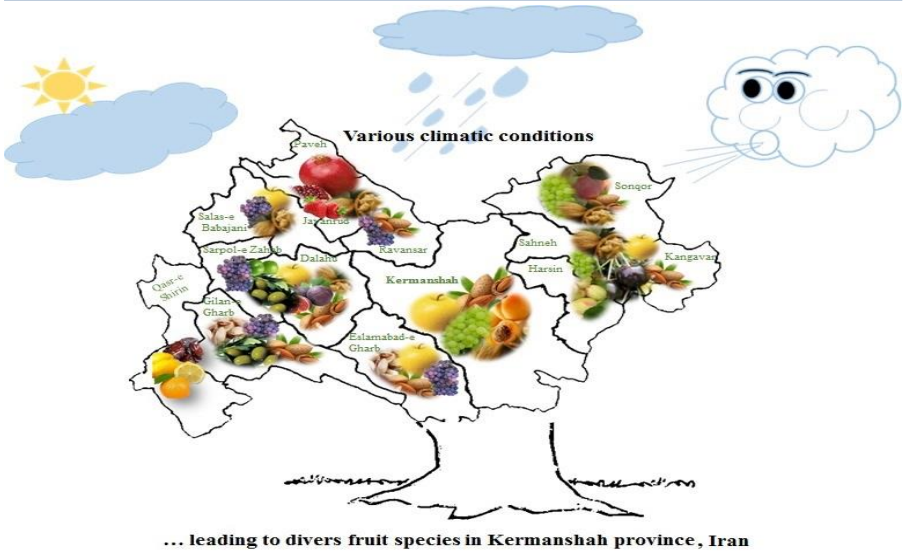
Shadab Faramarzi *, Pardis Boroomandan, Isa Arji

Department of Production Engineering and Plant Genetics, Campus of Agriculture and Natural Resources, Faculty of Science and Agricultural Engineering, Razi University, Kermanshah, Iran

Highlights

- Modern fruit orchards can guarantee the economic stability and food security of a country.
- Kermanshah province due to diverse climatic conditions has the capacity to produce many of fruit trees.
- Tall Spindle system is one of the most profitable planting systems for apple trees.
- Training and pruning system are considered as inseparable managing tools in high-density apple orchards.

Graphical Abstract



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Abstract

Pomology is one of the most important aspects of agricultural economy in many countries. The development of sustainable agriculture through the implementation of long-term plans such as the establishment of modern orchards can ensure the economic stability and food security of a country. Modern orchards are those that are often "high density," meaning a density of 1000 to 5000 trees per hectare. Therefore, modern orchards are generally considered commercial orchards, as the cultivated trees are no longer considered trees in the true sense of the word. Kermanshah province, which has a long history of horticulture, has an area of about 25000 km^2, of which about 40000 ha are set aside for orchards. Due to diverse climatic conditions and almost sufficient rainfall, Kermanshah province is capable of producing many fruit trees such as temperate, tropical and subtropical fruits, nuts and small fruits. In this regard, establishing modern orchards with high planting density (about 1000 to 2000 trees/ha) can be an effective step to expand horticulture in this province. The latter requires the incorporation of various scientific and artistic fields, such as tissue culture technology, to produce dwarf rootstocks as the main element of a modern orchard. In addition, the education and pruning system is considered an inseparable management tool for high production in this system. This review addresses the important aspects of modern orcharding to help all students, growers, and stakeholders.

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*Corresponding author: shfaramarzi1602@gmail.com (S. Faramarzi)

1. Introduction

1.1. Kermanshah province: the land of four seasons in the west of Iran

Kermanshah province with an ancient history in terms of habitation and agriculture as well as an area of about 25,000 km² has an area of 40,000 hectares of fruit orchards. The average annual production of these orchards is about 250,000 tons (Carfagna and Gallego, 2005), which this average production is very low. In terms of geographical location, Kermanshah province is located in the middle of the western part of Iran (34°18′N 47°4′E), having diverse climates has caused this province to become the land of the four seasons and almost important cultivars of fruit trees such as temperate fruits, nut fruits, small fruits and tropical and subtropical fruits are cultivated and produced across the province. Fig. 1 clearly shows the diversity of fruit species produced in Kermanshah province.

Fig. 1. Fruits map of Kermanshah province highlights diverse species of fruit production.

Owing to diverse climatic conditions, the dominant species of fruit trees in Kermanshah province can be presented as follows:

Group 1: Temperate zone fruits, which include apples, pears, cherries, sour cherries, peaches, apricots, figs, etc.

Group 2: Nut fruits, which include walnut, pistachio and almond.

Group 3: Small fruits, which include grapes, berries and strawberries.

Group 4: Tropical and subtropical fruits, which include date fruits, citrus fruits and olives.

Unfortunately, despite the high genetic diversity (Arji and Arzani, 2003; Faramarzi et al., 2014a; Bashiri et al., 2017) and climatic conditions and favorable rainfall conditions in the province (Zeinanloo et al., 2015), the level of its orchards is much lower than average. Due to the above grouping and the variety of fruits available, familiarity with modern methods in orchard establishment, rejuvenation of old orchards, the use of plant tissue culture technology to mass production of rootstocks, application of integrated pest management (IPM) system of fruit trees etc., can develop horticulture industry in the province and make the economy of these areas more dynamic. The purpose of this article is to study the recent dense cultivation systems for pome fruits particularly apple orchards worldwide.

1.2. Modern orchard establishment: the basis of sustainable production in the fruit industry

First, it is necessary to provide a basic and standard definition of a modern orchard that can be compared with traditional orchards. Modern orchards are those that are often "high density", a density of more than 370

trees per hectare; in some cases, 20,000 trees per hectare may even be planted. Thus, modern orchards are generally considered commercial orchards, because cultivated trees are no longer considered trees in the true sense of the word, like many shrubs, require care and support for establishment (Parker and Young, 1996). Having a large number of trees per hectare, a modern orchard should reach the fruiting stage within 2-3 years after planting, for which purpose, it is necessary to use a dwarf and early-bearing rootstock (Reig et al., 2019). Numerous studies have shown that the yield of these orchards may be twice as high as other cultivation methods (Robinson et al., 2008; Parker and Young, 1996).

Certainly, high planting densities will make tree canopy management difficult and costly, so continuous fruit production is essential to offset the increased establishment and construction costs. Because the trees in these orchards bear fruit early, it is necessary to establish a permanent guardianship system to support the trees. Primary production is directly related to the number of trees planted per hectare. The more trees there are, the more light received by trees in the early growth stage. In Europe and the Pacific Northwest, orchards with a density of 5,000 to 9,000 trees per hectare have been planted (Parker and Young, 1996). However, there is hesitation whether they are controllable. So the next question to consider is "What is the most profitable tree density for a high-density orchard?" A study conducted at Cornell University's Geneva Research Station in New York found that for the first seven years of an orchard, the yield per hectare increased unaffected by the size of the rootstock used in the orchard. Dwarf rootstocks have shown significantly higher yields in the third year. Economic profitability was increased by tree density to about 1,000 trees per hectare. Preliminary studies in North Carolina showed that a density of 1,000-1,300 trees per hectare could be most profitable depending on the climate, soil, and consumer markets (Parker and Young, 1996). Research in Australia has shown that small trees are just as productive as large trees when yields are expressed per unit area of the canopy.

Over the past 50 years, the planting density of fruit trees has risen from about 85 trees per hectare to more than 5,000 trees per hectare in some cases. In experimental orchards, even the planting density exceeds this figure. Dense planting systems for apple orchards include the Slender Spindle, which was the most common system in Northern Europe, the Vertical Axis, which was more common in southern Europe, North America, and New Zealand, and the Super Spindle with a density of about 5,000 trees per hectare. In the late 1990s, a new planting system called the Tall Spindle was introduced, which can be said to be a combination of the above systems. Today, the Tall Spindle system is one of the most profitable planting systems for apple trees in New York, USA (Robinson et al., 2006). The advantages of this system include high efficiency, excellent fruit quality and lower initial investment cost compared to the Super Spindle system (Robinson et al., 2008). Fig. 2 shows a view of a row of apple orchards with a Tall Spindle system.

(a) (b) (c)

Fig. 2. Tall Spindle system in the apple orchard in mechanized pruning stage (a), flowering stage (b) and fruiting stage (c) (Sazo and Robinson, 2013).

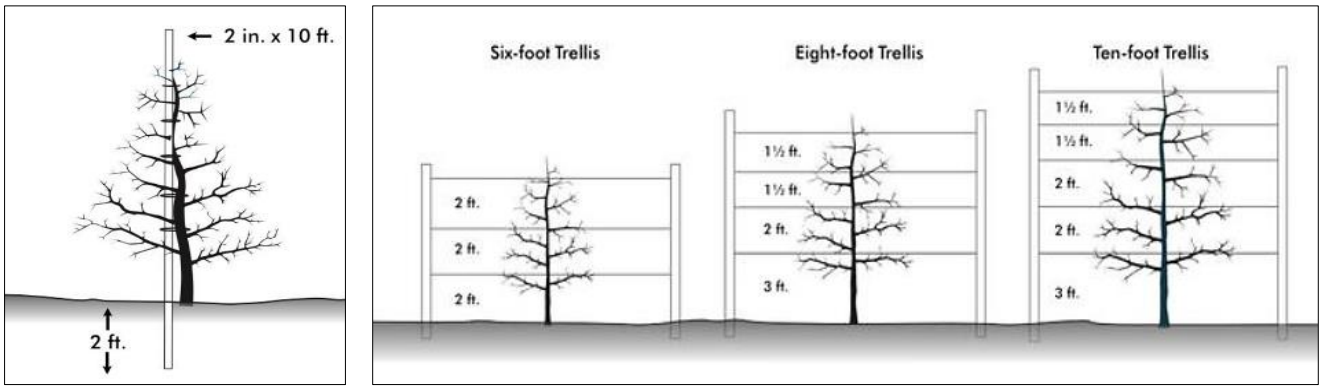
a) The width of the tree canopy in the Tall Spindle system after hedging where is 4 ft at the bottom and 2 ft at the top.
b) Tall spindle system in apples during blossom.
c) Tall Spindle system in apple orchard during fruiting, known as fruiting wall.

This system looks like a wall of fruits. Pruning should be done in modern orchards to minimize wind damage and increase fruiting levels, which can be mechanized in a Tall Spindle system (Sazo and Robinson, 2013; Karkee et al., 2014). Mechanical pruning was generally unsuccessful in the 1960s and 1970s because it led to overgrowth of the tree and reduced fruit quality due to the use of vigorous rootstock, but still, in orchards with a long spindle system due to using dwarf rootstocks (Reig et al., 2019) , mechanized pruning, which is one of the most important components of a modern orchard (Bhusal et al., 2017), Tall Spindle is applicable (Sazo and Robinson, 2013).

1.3. Important parameters involved in the modern orchard establishment

All the important and necessary factors and steps for the construction of an orchard must be considered. Choosing an orchard site is the most important parameter for construction an orchard because choosing not suitable site can reduce the yield and consequently reduce profitability, and in some cases, even reduce the life of the orchard. In choosing the site of the orchard, access to the market and the condition of the roads leading to the market should also be considered. Other factors such as altitude, land slope and the direction of the slope in their turn have a significant impact on the condition of the orchard.

One of the most important elements of a modern orchard is tree rootstock. The rootstock should be dwarf and suitable for the climatic conditions and soil of the region. In apple orchards with a Tall Spindle system, the commonly used rootstock is M.9. In fact, M.9, Bud.9 and M.26 are the best types of dwarf apple rootstocks that can be used in dense apple orchards. These rootstocks show good resistance to spring frosts and bear fruit from the first year. However, they are very susceptible to fire blight (Zhao et al., 2019) and woolly apple aphid (Brown et al., 1995) pests. Usually, the above dwarf rootstocks need a support system that is about two ft below the ground (Fig. 3a). In espalier training systems, depending on the height of the tree between 6 and 10 ft, 3 to 5 wires can be used (Parker and Young, 1996) (Fig. 3b).



(a) (b)

Fig. 3. a) Depth of support which impedes rootstock (Parker and Young, 1996); b) The distance between the wires in espaliered apple trees (Parker and Young, 1996).

In addition to the rootstock, grafted cultivars also have different reactions to the fruiting wall system and it is necessary to conduct a pilot and preliminary study for the desired species and cultivars because different species and cultivars have their own physiological and phenology characteristics. In France, for instance, it has been reported that there are limitations to the fruiting wall system, including 1) the height of the tree is limited, 2) the amount of production on apples of the cultivar 'Gala' is limited to 80-70 tons per hectare, and 3) fruit size becomes about 5 mm smaller (Parker and Young, 1996)

Pruning is one of the main management practices of orchard management with high-density planting system (Schupp et al., 2017). Tree density, or more precisely the amount of light interception, is a factor that affects early production (Bhusal et al., 2017). If the trees are not severely pruned, it will significantly affect the productivity of the first three years. In mature trees, light interception is reduced due to the shading of the upper branches on the lower branches. Light interception also depends on the height of the tree and the

distance between the rows. In general, the height of the tree should not be more than twice the width between rows of orchard trees to maximize light interception. The distance between two rows in the orchard is about 3.5 meters (Parker and Young, 1996)

The amount of pruning trees depends on the cultivar planted because it has a significant effect on yield. For example, apple cultivar 'Golden Delicious' is reported to be 60 cm width for the best fruit, apple cultivar 'Honey Crunch' is 70-80 cm width, apple cultivar 'Gala' is 80 cm width and apple cultivar 'Granny Smith' is one meter width. It is also difficult to find an effective workforce for pruning fruit trees because few people are willing to climb tall trees for pruning. Therefore, it can be concluded that modern orchard hedging is better mechanized and its amount and intensity in the Tall Spindle system should be adjusted according to the cultivar and its fruiting habit. Fig. 2a shows the tree canopy in the Tall Spindle system, which is 120 cm width at the bottom and 60 cm width at the top of the tree.

Physiological disorders usually reduce yield, fruit quality and/or both. An effective product management program from the site preparation stage (before planting) and monitoring the nutritional status of the orchard throughout its life is essential to detect nutrient deficiencies, toxicity and imbalances before they reduce fruit yield or quality. Of course, this management operation (irrigation, fertigation, spraying, etc.) can be done mechanized (Schupp et al., 2017). These management actions may even be designed and performed automatically, which are called smart orchards. It has been reported that the pesticide use efficiency is much higher rather than high-density orchards (Parker and Young, 1996).

2. Conclusion

As mentioned above, in traditional horticulture, the planting density was between 85-100 trees per hectare, and other plants, such as vegetables, were planted between rows until the orchard bear fruit. Today, in modern orchards, high-density trees are planted from 1000-5000 trees per hectare. The use of dwarf rootstock and controlling their growth in high-density cultivation systems is a basic need. The yields of these orchards may be twice as high as other planting methods. Therefore, the goal of modern orchards is to increase early production. Many "new" cultivars that are customer-friendly and in high demand selling than current cultivars. Hence, having orchards that can produce a significant crop yield in the first 2-3 years is a sufficient reason to build an orchard with high density. Due to early production and higher yields, many higher-density orchards die back earlier than traditional orchards. In modern systems, orchard management is easier and all parts of the tree are exposed to the right amount of light. In addition to all the advantages mentioned, the high cost of establishing an orchard can be a disadvantage for this system. In general, establishing a high-density orchard by the second year requires approximately $ 25,000 per hectare. These orchards also need high management, during the first 6 years, compared to traditional orchards, especially in summer, they need more training and minimal pruning. Lack of attention in the early years of establishment of these orchards creates a very high probability that the orchard will never be profitable due to the high costs of establishment. Therefore, there is a need for continuous training of orchard managers and workers in order to apply the various pruning techniques required for this category of the orchard.

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