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Introductory Chapter: Apple Cultivation – Recent Advances

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1. Introduction

Apple (*Malus x domestica* Borkh.) originated in Northern Anatolia, the Southern Caucasus, the regions in the southwest of Russia, and around Central Asia. This very nutritious fruit has spread all over the world from Central Asia. Apple has a wide adaptability to be grown in many climatic zones of the world. Besides Central Asia, East Asia, West Asia-Europe, and North America Gene Centers, countries such as Australia and New Zealand, which do not have gene centers, have played a major role in the emergence of new varieties.

The changes in apple production in European countries between 2014 and 2019 and the production estimates for 2020 are given in **Table 1**. While apple production decreased in Western European countries because of unfavorable weather conditions, Poland became the country with the highest increase in production (**Table 1**). When apple production in European countries between 2014 and 2019 was examined based on variety, there was a significant decrease in the production of Boskoop, Cox Orange, and Idared varieties grown with Golden Delicious and Red Delicious (Starking, Starkrimson, etc.) groups. Production increases that started with Jonagold and

Countries	2014	2015	2016	2017	2018	2019	(1)2020	(2)%
Italy	2.456	2.280	2.272	1.704	2.264	2.096	2.080	3
France	1.444	1.674	1.515	1.424	1.477	1.651	1.431	-6
Germany	1.116	973	1.033	597	1.093	991	951	6
Spain	505	482	495	480	476	555	467	-7
England	206	243	239	207	219	205	207	-2
Netherlands	353	336	317	228	267	272	234	-8
Poland	3.750	3.979	4.035	2.870	4.810	2.910	3.400	-4
Hungary	920	522	498	530	782	452	350	-40
Romania	382	336	327	230	425	327	343	5
Total	12.541	12.326	11.834	9.251	13.275	10.783	10.711	-4

(1) Product estimates. (2) Increases and decreases in production in 2019 and 2020.

Table 1.

Changes in apple production in Europe countries between 2014 and 2018 and 2020 production estimates.

Varieties	2014	2015	2016	2017	2018	2019	2020 (1)	(2)
Cripps Pink	249	244	261	260	275	289	277	1
Elstar	431	399	387	265	357	363	312	-5
Fuji	321	338	288	290	332	316	294	-6
Gala	1.318	1.382	1.312	1.271	1.467	1.439	1.490	7
Granny S.	383	405	384	363	393	372	369	-2
Jonagold	644	633	567	298	577	391	310	-27
Jonagored	491	519	539	335	563	246	231	-39
New Varieties	165	207	213	209	344	359	405	33
Pinova	79	119	104	85	155	140	154	22
Red Delici.	675	643	632	558	737	678	660	0
Red Prince	98	104	156	114	371	407	437	47

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Table 2.
Changes in the production of apple varieties in Europe countries between 2014 and 2019 and the year 2020.

Braeburn continued with Elstar, Gala, Fuji, and Pink Lady varieties. In recent years, the production of new varieties and club apples has started to increase, especially the Red Jona Prince (**Table 2**). Türkiye, Golden apple production in the previous years mostly depends on Golden Delicious, Starking Delicious, Granny Smith, and Amasya varieties and did not include many types and varieties in some statistics. With the popular use of new apple varieties and the establishment of a fully enclosed garden facility with them, statistics can be determined more easily. In Türkiye, the production of the apple varieties of Gala, Braeburn, Jonagold, Fuji, and Modi is estimated to be about 300,000 tons in 2020. This production amount constitutes a significant part of the total apple production. Apple production in the world apart from China, the varieties that are expected to increase in production are Cripps Pink, Honeycrisp, Gala, Scifresh / Jazz®, and Sciros / Pacific Rose®. Other varieties are significantly reduced [1, 2].

2. Pollination of apple

In addition to the varieties and rootstocks in the apple orchard establishment, other important factors are pollination and fertilization of the varieties. In the pollination process, biological and physical factors, sexual incompatibility, simultaneous flowering, pollinator vectors, and weather conditions at the time of pollination are important. When one or some of these factors are blocked or do not occur, pollination and consequently fruit set and quality are negatively affected. All apple varieties require foreign pollination in commercial cultivation. Self-productivity level varies according to varieties. For example, the Delicious variety is completely unfertile to itself, while Golden Delicious is partially fertile to itself. In terms of foreign pollination requests, all red and red spur types are similar to their parental plants and show incompatibility. These varieties can easily fertilize each other in the gardens that will include Gala apples, Fuji, Scarlet Spur, Redchief, and Granny Smith, which are also included in the experiments and are other commercial varieties. In general, the flowering period in

apples lasts 10–15 days. Early and medium, and medium and late flowering varieties can pollinate each other. On the other hand, in addition to sufficient pollen production for pollination, flowering times must also coincide with each other.

For sufficient pollination;

1. Pollinator variety and main variety should bloom at the same time,
2. Pollinator varieties are diploid, and the vitality of flower pollens should be high,
3. The pollinator variety should not be too far from the main variety, it should be kept in the garden at appropriate rates,
4. Honeybee or other insect activities should be organized in the garden at the time of flowering,
5. Weeds, which attract more attention of bees and bloom at the same time with apples, should not be kept in the garden,
6. In the selection of pollinator varieties, information such as the vitality of the pollen on the flowers of apple varieties and the flowering period of the main and pollinator variety are required.

Bee flight also becomes very weak in windy, rainy, and overcast weather. Therefore, wasps could be used for pollination in cold and rainy climates.

3. Apple rootstocks

3.1 Generative rootstocks

In many countries, seeds of Winesap, Rome Beauty, G. Delicious, McIntosh, and Yellow Newton varieties are preferred to obtain rootstocks. In Türkiye, generative rootstocks of apples such as seeds of Golden Delicious and Ferik apple varieties can be advised to obtain rootstocks.

Although the high-density planting of apple orchards using dwarf and semidwarf rootstocks has gained importance in the world, apple orchards in Türkiye are still mostly established with apples grafted on seedlings.

Besides, deep-rooted and strong rootstocks are needed for the apple orchard plant in dry and insufficient irrigation areas.

3.2 Clonal apple rootstocks

Alnarp2 (A2): It was obtained in Sweden. It is a strong rootstock and suitable for cold regions.

AR Series: It was obtained at East Malling Horticultural Research Institute in England. The growing strength is between M9 and M27. It is better than M27 in terms of fruit size. The growing strength of the AR series range from M27 to MM106.

Budagovski Series: They are rootstocks obtained by crossing in Russia by Budagovski. The most important is B9. Other important Budagovski rootstocks are B146, B469, and B491.

CG Series: Selected from free pollinated seedlings of M8 by H. Guengerich in Stark Bros young plants in the USA. It is slightly stronger than the M9.

Cornell Geneva Series: It was obtained at New York Geneva Test Station. Geneva® breeding program is the first program to reveal several dwarf apple rootstocks (G41, G969, G214, G210, G202) that are more efficient and have a different resistance than MM106, and MM111 types have been.

J9 Series (Jork9): It was obtained from free-pollinated M9 seedlings in Germany. Some of its characteristics are similar to the M9.

JM Series: It was obtained by crossing medium-strong rootstocks Marubakaido (*M. prunifolia*) and Mitsubakaido (*M. sieboldii*) with M9 in Japan. The rootstocks that gain importance are JM1, JM5, JM7, and JM8. All of them are stunted from M26, while JM1, JM5, and JM8 are stunted from EMLA9.

KSC Series: Robusta No.5 main variety obtained in Kentvil in Canada and Antonovka rootstock were used as pollinators. The KSC is numbered from 1 to 30.

MAC Series: It was obtained by R.F Carlson at Michigan State University in the USA. MAC 1, 4, 9, 16, 24, 39, and 46 gained importance.

MH Series: British M and MM series rootstocks in Israel did not yield good results due to high soil temperatures and insufficient rest. MH 14–5 and MH 15–6 were obtained from Hashabi, a local apple variety.

Ottawa Series: It was obtained in Canada. It is named from 0.1 to 0.17. They are cold-resistant rootstocks.

P Series: These rootstocks are more resistant to cold than English rootstocks obtained by crossing Antonovka and M.4 and M9 in Poland. P1, P2, P16, P14, and P22 have gained importance.

V Series: It was obtained at Ontario Horticultural Research Station in Canada. Range from V.605–1 to V.605–7.

3.3 Series of East Malling very dwarf rootstocks

M27 was obtained by crossing M13 and M9 rootstocks in 1929. It is a very dwarf rootstock. It is not used to a great extent in practice. It is used as a transitional rootstock in strong rootstock weak-cutting relationships.

3.4 Dwarf rootstocks

M26 was obtained by crossing M16 and M9 rootstocks in 1959, and it has found a very fast usage area due to its earliness and 40–50% shortening compared to seedlings and productivity. It does not like very moist soils. It needs to be attached to a stake toward the ground to keep it in the ground.

M8, M9: The common characteristics of these two rootstocks are that the root systems are outcrop and fringe rooted; their holding in the soil is very weak. Also, trees grafted on both rootstocks begin to yield 2–3 years after planting, they become small-crowned and dwarfed. The dwarfing characteristics of M8 and M9 rootstocks are also used as transitional rootstocks. Besides, M9 rootstock dwarfs the apple trees by 65–75%.

3.5 Semidwarf rootstocks

Root depth on the soil of both M2 and M7 rootstocks is better than the previous rootstocks. They have medium-sized canopy and fructify early. These rootstocks are

Varieties	Rootstocks	Planting distance (m)	Numbers of trees (pcs/ha)
Golden D.	M9	3,0 × 1,0	3333
Granny Smith	M9	3,0 × 0,80	4166
Jonagold	M9	3,0 × 1,0	3333
For Red Delicious			
Standard types	M9	3,5 × 1,5	1904
Standard types	MM 106	5,0 × 4,0	500
Spur types	M 26	3,0 × 1,0	3333
Spur types	MM 106	4,0 × 1,5	1666

Table 3.

Rootstocks suitable for some apple varieties, planting spacing, and number of trees in one hectare.

resistant to soil moisture. M2 and M7 rootstock are dwarfed by 25% and 35–45%, respectively, in apple varieties grafting on these rootstocks.

Strong rootstocks M1 and M13, M25, very strong rootstocks M12, M16. There are also Malling Merton rootstock series except for East Malling rootstocks. These are MM104, MM106, MM109, and MM111.

Among these rootstocks, MM106 is commonly used. The rootstock is semidwarfing and very fertile. It likes loamy soil, has a root system that can hold well in the soil, and tends to start very late in the spring development period, leaf fall, and winter rest period. MM 106 rootstocks induce 25–40% dwarfing in apple varieties grafting on the rootstock. The rootstock is not fertile in cropland with drainage problems or watery land.

The commonly used planting distances and the required seedlings for 10 decares considering the varieties and rootstocks are given in **Table 3**.

4. Club apples and varieties

Apple club varieties emerged in the late twentieth century and have been on the rise since the 2010s. In 2009, around 30 varieties of the apple club were distributed to stores around the world. The apple club continues mainly in Europe. Mostly, apple varieties play a role besides cherry and pear. In this system, the world market is managed by centralized hiring, and apples are produced in limited quantities under license and brand protection in high standard quality. Prospective producers negotiate with the licensee about production and marketing before joining the club.

Producers are required to ensure the fruit quality criteria determined in the fields of breeding and marketing. With quality control, fruits are sold at a high price or at least a standard price is provided. Production is controlled and prevented by nonmembers.

Major important club apple varieties: Civni-Rubens®, FavDiwa® (Junami®), Pink Lady®, Rosy Glow, Modi®, Kanzi, Ambrosia, Jazz™, Lady Alice, Pacific Rose™, Piñata®, Sonya, Sweetango™, Red Prince, Caudle (Cameo®), Cripps Pink (Pink Lady®), Delblush, (Tenta- tion®), Honeycrisp (Honeycrunch®), Brak (Kiku® 8. Nicogreen-(Greenstar®), Sciros, Pacific Rose®.

5. Importance of apple for health

Apple is the most consumed fruit in the world and is important for health. Apple is a powerful source of antioxidants and it has been determined to increase resistance against some types of cancer, cardiovascular diseases, asthma, and diabetes. In studies, it has been determined that apples contain strong antioxidants, such as catechin, floridzin, and chlorogenic acid, various chemical compounds and quercetin, thus reducing lipid oxidation and reducing cholesterol and preventing the proliferation of cancer cells. It is stated that there are 1500 mg of vitamin C in 100gr fresh apples, and that polyphenols, quercetin, and glycosides are found in the apple peel. It has been determined that apples contain two times more antioxidants than citrus fruits, about five times more than bananas, and 10 times more than Goji berry juice [3].

6. Covering systems in apple orchards

Nets are mostly used for protection from rain, winter frosts, and sun. As in the rest of the world, increases in the value of sunlight receiving our country have been observed in the last 5 years. In some ecologies in the temperate climate zone where apple cultivation is carried out, it is known that apples are sensitive to high temperature and solar radiation (light intensity), which is seen especially in summer and causes sunburn in fruits; however, it varies according to apple types. In apple cultivation, sunburn damage occurs on fruits at temperatures above 35–40°C and this damage negatively affect the quality and storage time of the fruit. While sunburn damage occurs in fruits with high light intensity and lux, fruits are not colored well with low light intensity [4].

7. Pruning of apple trees

Pruning in apple orchards are made in three groups:

- a. Important points in shape pruning on young trees: Over-pruned seedlings bear fruit late, so the seedlings should be pruned according to the purpose. Branch angles should be considered while creating side branches. Therefore, the variety and characteristics of the rootstock should be well known. The shape of the apple trees could be created depending on the region [5].
- b. The purpose of pruning on productive trees is to keep the crown of the tree at a certain size and to ensure trees' yields every year.
- c. Rejuvenation pruning is applied to trees after 30–35 years of age to ensure fruit size and economical production. Since rejuvenation pruning is very severe, pruning should be completed in 2–3 years and technical works, such as fertilization, irrigation, and agricultural struggle, should be done carefully. Grafting paste should be used after the pruning processes. In the dwarf system, renewal pruning should be applied to keep the trees young.

In fruit trees, there are three separate life cycles: the period between planting and the beginning of the tree to yield is called “Juvenil,” the period from yield to losing productivity is called “maturity,” and the following period is called “old age.”

Farmers want the period of juvenility to last as short as possible. Therefore, they use some technical measures to get shorted this period, such as cutting roots, drowning the stem, fertilizing fruit seedlings with nitrogen fertilizers in a balanced way, and using weak rootstocks. In addition, creating a regular, strong, and balanced canopy in fruit trees, leaving branches long or not cutting at all, widening the angles of strongly growing branches or narrowing the angles of poorly growing branches, cutting off some of the excess branches, and bending or twisting branches are some used methods to balance between root and crown in trees in a shorter time.

7.1 Pruning times

Winter pruning: The period after fruit trees enter winter dormancy is the best time for pruning in places where the winter is warm. In regions with cold winters, pruning is done after severe frosts to prevent the fruit trees from getting cold on the cutting surfaces, and the resistance of the tree against frost is increased. The most suitable period for pruning fruit trees is the period between the days following the defoliation and the beginning of the spring development period.

Summer pruning: All of the processes, such as reducing the shoots from branches during the summer, taking the tip, bending, connecting the branches and widening, and narrowing the angles, are called summer pruning. When the branches of fruit trees begin to become woody, summer pruning should begin and continue this process in June, July, and August, and continue this process until the end of September in some cases. After that, winter pruning should not be done. Summer pruning is an important technical procedure that should be done especially during the shaping years of fruit trees. On the other hand, the branches that need to be removed by cutting can be used by bending, twisting and such branches, which are harmful to trees, can be used well. Therefore, early initiation of the flower bud of fruit trees can be achieved and their yields can be increased.

Yield pruning: Fruit trees enter physiological balance at the end of certain periods. The balance between shoot and fruit development should continue for a long time. This can only be achieved by yield pruning.

Branch break: In modern apple cultivation, when there is an imbalance of development on side branches in trees, usually backward pruning is performed in Spur and Standard apple varieties. Recently, the branch-breaking method is performed when there is an unbalance of development in the side branches in standard varieties.

7.2 Tree shape pruning in apples trees

Classic orchards (Free Shapes): Goble, central leader, modified leader.
using modern dwarf rootstocks and compulsory shapes: Palmets, Cordons (Vertical and Inclined Cordon), Spindel, Super Spindel, Tall Spindel, Normal Spindel, Vertical Axixs, HYTEC, Solen, Solax, Mikado, and Bibaum.

Shape criteria in pruning, and relationship between row planting spaces and trunk diameter.

Canopy projection diameter less than 50 cm² on Cords and row distances 40–50 cm.

Canopy projection diameter 50–100 cm on Super Spindel, Fruit Wall, Bibaum, High Tree Shape, row distances 50–100 cm.

Canopy projection diameter greater than 100 cm Normal Spindel, Solax, Tall Spindel, Bibaum, row distances 100–120 cm.

In classic dwarf orchards, tree heights were limited to 2.2–2.5 meters in spindle pruning. In these orchards, as the trees get older, the pruning labor cost increases with each passing year. The figure below shows trees that have not been pruned and pruned on classic dwarf apples. Too many cuts are applied here.

8. Thinning methods in apple

Thinning in apple trees is especially important in terms of fruit quality. The purpose of thinning is to increase the amount of marketable fruits.

Nowadays, fruit thinning is done by hand, hormones, and chemicals. Hand thinning in 15–20 cm per fruit or one fruit per 40 to 50 leaves, in the spindle system, pruning is done at 20–25 fruits per tree approximately 30 days after full bloom.

In the thinning studies carried out on apples, chemical substances, and hormones applications provide regular yields every year, while the hand thinning applications decrease the yield in the following year.

9. Soil properties and soil cultivation of apple trees

The best soil for apple growing is sufficient amount of loam, loamy-sandy, and sandy-loam permeable soils, including lime and humus. Apple trees are more sensitive in terms of soil characteristics in an arid area than in a moist area.

Although apple roots generally grow upward, the groundwater is not desired to be above 1 meter. If there is less salt in the soil, the tree is able to grow in this situation. The apple tree is more sensitive to unfavorable soil conditions than the pear tree.

Trees in very calcareous soils turn yellow due to problems with iron absorption. The most favorable soil reaction is between pH 6 and 8 levels. Soil tillage methods to be applied in apple orchards able to be formed into two main parts.

Open soil tillage: The purpose is to keep clean the bottom of the trees and the orchards by using all kinds of tillage tools in summer and winter. Thus, it is possible to eliminate the competition of weeds with plant roots. The open tillage method should never be applied in a field that is widely exposed to water and wind erosion.

Conservation soil tillage: As the name suggests, this method is to keep the soil surface covered with some cover plants. In this system, depending on whether the cover is permanent or not, it is divided into two temporary covered and permanent covered.

Autumn cover crops, such as wheat, rye, winter vetch, red truffle, sweet truffle, and clover, are planted in temporary coverings. In the spring, the cover plants are buried in the soil by using a disc harrow.

Mulching: It provides benefits in numerous fields, such as preserving moisture, weed control, temperature, reducing labor and cost, protects the soil structure, improving soil structure, reducing nutrient and water loss, high-quality fruit, pest and disease control, early harvesting, and high-quality yield.

10. Conclusion

Recently, modern apple-growing techniques are developed and spread all around the apple-growing areas. With the fast development in science and technology,

understanding the importance of apple on human health, increase and easiness of transportation and exportation, gained more importance to apple growing. Thus, in different countries in the world, apple's marketing and growing techniques developed by the results of many research studies and publications.

Malus domestica Borkh. is one of the most important fruit species widely spread to various climatic and soil conditions with the use of different rootstocks. This wide adaptability of *Malus* species gives the opportunity to be grown in many different climatic areas. Despite high genetic variability, thousands of cultivars are distributed throughout the world. There are also many studies on growing apples in the subtropics and tropics with low-chilling apple cultivars.

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