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Present Status and Future of Walnut Production in Turkey

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ABSTRACT

Turkey is one of the most important producers of walnut in the world. In 2005, Turkey ranked fourth in world production with 133,000 t of production. According to the average 2000-2005 statistics, Turkish walnut production accounts for 8.89% of the World's total walnut production. This important role is due to Anatolia being a germplasm center, and to its suitable ecological conditions. Walnut has an exceptionally wide natural distribution in Turkey and it is a plant which does not need much labour and annual high operating costs. In general, walnut has been grown at the edge of farmlands in recent years in Turkey. Cultivated mainly for its nutritious nuts, it is used as a food, in the chocolate industry, for baked foods, and in the pharmaceutical and cosmetic industries. The leaves and green shells are used as a pigment in Turkey. Continuous seed propagation for thousands of years in Turkey has given rise to a great number of seedling walnut trees, which represent valuable walnut gene resources. The number of native trees is estimated to be over 6 million and they possess large genetic variability in yield, nut and kernel characteristics, late bud breaking, late flowering, winter hardiness, tolerance to disease. After recognition of the importance of propagation by grafting and budding by growers in recent years, the orchards are being established by standard cultivars. These standard walnut orchards are generally planted with cultivars selected in Turkey.

Keywords: breeding, cultivation, selection

CONTENTS

INTRODUCTION

Turkey is one of the important gene resources of world because of its position on important immigration ways (Silk Road), having many civilizations on its lands through ages, having four seasons. In Turkey, many fruit species (walnut, almond, apricot, chestnut, and rosehip) have been propagated from seed over the ages. In this species, because of seed propagation rich genetic resources occur throughout the country.

Juglans regia L. or walnut is native to a wide region extending from The Carpathian mountains across Turkey, Iraq, Iran, Afghanistan, and southern Russia to northern Indiana (Forde 1975). Vavilov had added Middle East and Near East to genetic resources of walnut, while Okmanich had added Moldavia as secondary center of walnut genetic resources (Akça 2005a).

Pliny (D.C.23-79) explained in his history book 'Nature' that walnut had been carried from Persia to Greece in the years B.C. 750-500. Walnut carried from Greece to Rome had been named Jovis Glans, meaning 'Fruit of Jupiter'. It is recorded that walnut had been grown in England since 1526 and in California since 1871 (Şen 1986; Akça 2001, 2005a).

The history of walnut in Turkey is very old. In the tomb of King Midas (I) in Gordion, near Polatlı in Turkey, it is determined by wood analyses that furnitures embedded with King Midas had been made from *J. regia* L., *Taxus baccata* L., *Cedrus libani* Loud., *Juniperus foetidissima* Willd., *Buxus sempervierns* L. and *Pinus sylvestris* L. (Aytuğ 1987). Members of the *Juglandaceae* family have been founded in Konya-Süber from Neolitic ages (Aytuğ 1967). In the Akçaabat county of Trabzon province, a fossil walnut fruit was founded in the Plio-Quaternary sediment (**Fig. 1**). The fossil had been completely and well protected.

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Invited Review

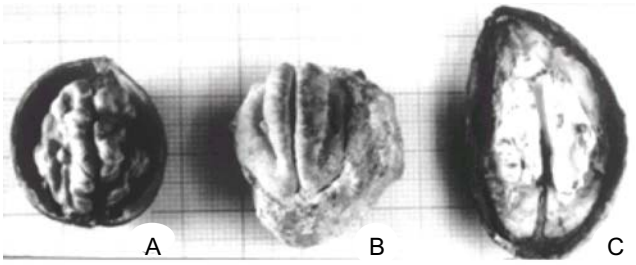

Fig. 1 Fresh (A, C) and fossil (B) walnut fruits (original). Reprinted from Kutluk and Aytuğ (2001), with permission.

POSITION IN WORLD PRODUCTION

Walnuts are generally grown in USA, Europe and Asia. Over 1.5 milion tons are produced annually in the world (FAO 2005). According to the FAO (2005) statistics, China leads production with 420,000 t, followed by the USA (322,000 t), Iran (150,000 t) and Turkey (133,000 t). Turkey is an important world producer of walnut. According to the 2000-2005 statistics, Turkey ranks fourth in world walnut production yielding approximately 123,500 t (**Table 1**).

The most commonly grown walnut species in Turkey for fruit production is *J. regia* (Akça 2005a; Şen *et al*. 2006). Recently, *J. nigra* and *J. hindsii* are also being grown only for personal afforestation and personal arboretum. According to 2006 statistics, there are approximately 6 million walnut trees in Turkey. In recent ten years, orchards have been established by standart walnut cultivars all over the country and grafted trees have replaced native trees (Akça 2005b; Kaşka 2005; Şen 2005). There are populations of walnut (*J. regia*) with great genetic variation for resistance to pests and diseases, lateral bud fruitfulness, leafing times and nut quality.

The mean value of fruit yield for walnut production is 2500 kg/ha for Turkey, 3600 kg/h for USA and 2700 kg/ha for Iran (Akça 2005a).

GEOGRAPHICAL DISTRUBITON OF WALNUT PRODUCTION IN TURKEY

In Turkey there are 4 districts, 12 towns and 40 quarter named with 'ceviz' means walnut in English (Şen 2005). Walnut trees are spread almost in all regions of Turkey. However, due to more suitable ecological conditions such as average temperatures, precipitation and soil characteristics and especially the interest of local peoples to walnut, the provinces that have widespread and dense walnut tree are Zonguldak, Hakkari, Çorum, Van, Kastamonu, Bursa, Kahramanmaraş and Tokat. *Juglans hindisii* and *Junglans nigra* are spread through Marmara region (especially in Yalova province).

USAGE OF WALNUT

Walnuts are a rich source of dietary minerals and a good source of vitamins. *J. regia* contains multiple beneficial components such as unique fatty acid profile and high levels of thiamin, riboflavin, niacin, vitamin B-6, flocin and vitamin A. Also potassium, phosphorus, magnesium and iron are found in significant quantities in walnut kernel. The is 0.30 mg, niacin is 0.82 mg, vitamin B-6 is 0.44 mg, flocin is 56.00 µg, vitamin A is 146 IU (Akça 2005a).

Walnuts reduce the risk of coronary heart diseases, prevent blood from coagulation, lower cholesterol and triglyceride levels, and its vitamin, mineral and trace element contents have an important role for human metabolism and also carbohydrate content of walnut is low (Fraser *et al*. 1992; Fraser 1999; Almario *et al*. 2001; Akça 2005a). One hundred g of kernel walnut (*J. regia*) contains about 3-3.5 g of carbohydrates. The higher content of silver and selenium of *J. regia* compared to other species has positive impact on children's brain improvement (Akca 2005a).

Walnut is named 'Ceviz' or 'Koz' in Turkish. Walnut has an important place in Turkish culture. The walnut tree is known as the protein tree in Turkey, with its fruit known to be an aphrodisiac and source of energy. Turkish people use the fruit, leaves, green husks and roots of walnut trees. As a result of their fatty acid content, walnuts are an important nutrient for human nutrition and health. *J. regia* kernel walnut contains 7.6% saturated, 11.0% monounsaturated and 42.6% polyunsaturated fatty acid. Turkish people in undeveloped regions and rural areas get a large portion of their protein needs from walnut fruits. Bread with walnut is an indispensable nutrient for people in rural areas (Şen 1986; Akça 2005a).

Turkish people use medicines from walnut foliages to prevent hair loss, in the treatment of pimples, in skin care, as a bath lotion and to fight parasites (Akça 2005a; Şen *et al*. 2006). Teas made from leaves are used for reducing triglyceride and cholesterol levels (Akça 2005a). Also, Turkish people believe that walnuts can strengthen the liver, stomach, and gall and are good as an apoplectic and in the prevention of trots (Şen *et al*. 2006). It is believed that eating a preparation of walnut with fig, garlic and flower of rue (*Ruta graveolens* L.) prevents food poisoning (Şen *et al*. 2006). It is known that a little walnut foliage used in beach oils and perfumes ensure a good sun tan (Şen *et al*. 2006). However, there is no study, to our knowledge, reporting such an effect. In Turkish culture, it is believed that walnut fruit brings abundance and luck. Traditionally, meals have been made with walnut on holidays and special days. Nutritious and energizer meals especially for proteins and fats have been made by using walnuts in sweets. In Turkish cuisine, 'keşkek', 'batırak', 'aşure', 'çerkez tavuğu', 'kek', 'cevizli helva', 'cevizli ekmek', 'baklava', and 'kadayıf' are important meals made with walnut. In short, walnuts are multipurpose fruits in Turkish cuisine (Şen *et al*. 2006).

Table 1 Production of walnut in the World between 2000 and 2005.

Country	Production (tons)						Average
	2000	2001	2002	2003	2004	2005	
China	310.000	252.000	343.000	394.000	415.000	420.000	355.667
USA	217.000	277.000	256.000	296.000	295.000	322.000	277.167
Iran	131.000	168.000	178.000	150.000	150.000	150.000	154.500
Turkey	116.000	116.000	120.000	130.000	126.000	133.000	123.500
Ukraine	50.000	55.000	57.000	79.000	91.000	93.000	70.833
India	31.000	29.000	30.000	31.000	34.000	31.500	31.080
Romania	31.503	33.942	37.523	50.819	15.608	15.500	30.815
France	28.615	27.815	33.211	23.352	26.422	33.241	28.776
Egypt	20.440	26.680	27.000	27.000	27.000	27.000	25.853
Greece	23.518	22.341	19.692	20.120	20.181	21.643	21.249
Austria	17.082	15.751	13.914	20.338	17.735	17.000	16.970
Germany	18.200	15.700	16.900	16.900	16.900	16.900	16.917
Mexico	18.500	18.500	19.000	19.000	19.000	19.000	15.667
World	1,240.357	1,264.497	1,351.610	1,473.063	1,471.628	1,526.816	1,387.995

Source: www.fao.org

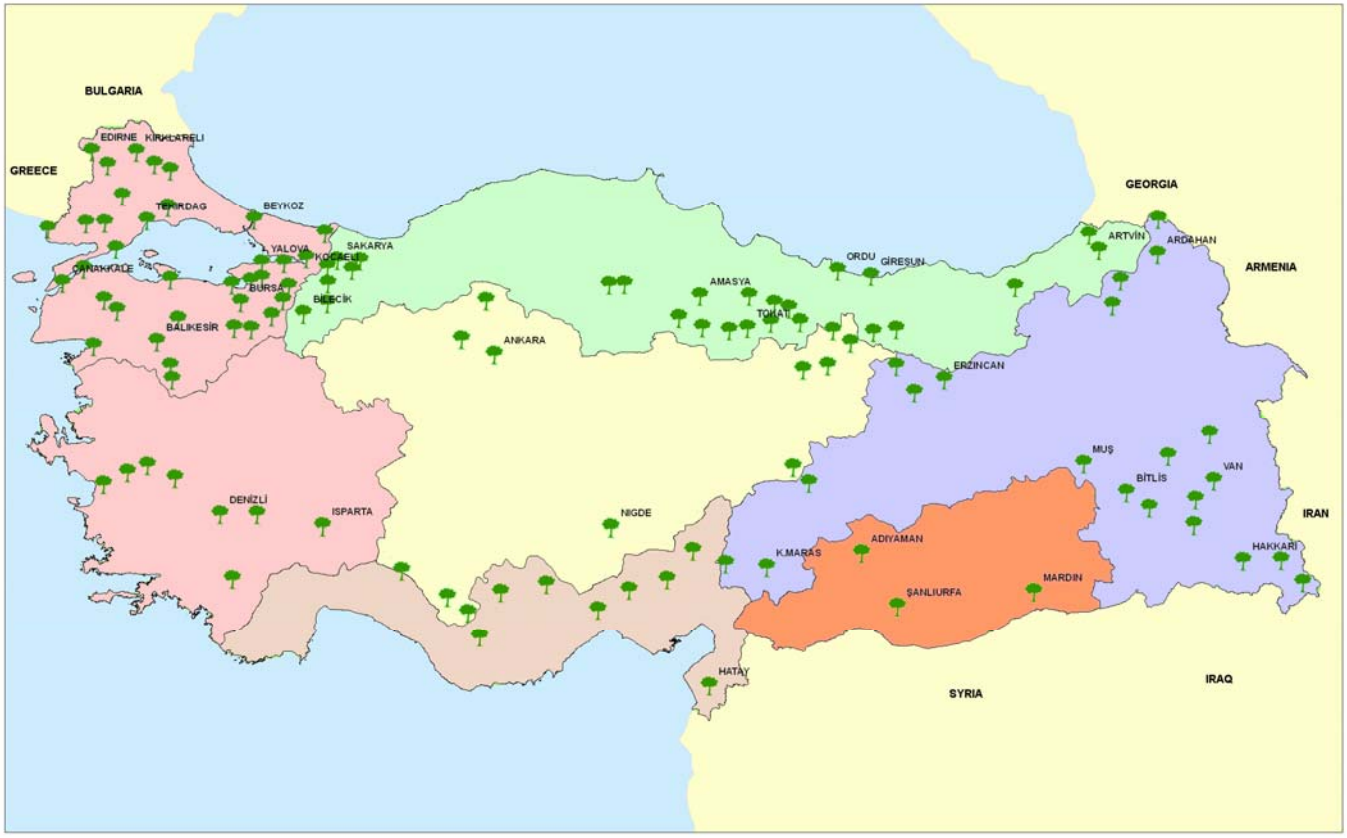

Fig. 2 Areas in which selection studies have been implemented in Turkey.

PROPAGATION OF WALNUT IN TURKEY

In Turkey, walnut had been propagated only by seeds until 1970. The numbers of grafted saplings have increased to 1.5 million units/year in 2005 while this number was only 2400 units/year in 1976 (Akça 2005b). Most commonly, the patch budding method is used for propagation of walnut in Turkey. *J. regia* generative rootstocks are used for budding. Saplings are marketed potted or nonpotted. However, in some regions, for example the Kaman district of Kırşehir province, propagation by seed continues. The most important walnut types propagated by seed in Turkey are 'Kaman 1' and 'Kaman 5' types. Growers do not believe in the variation caused by using seed of 'Kaman 1' and 'Kaman 5'. However, the genotypic differences among these two genotypes were reported in a study using molecular markers (Inter Simple Sequence Repeats (ISSR) and Sequence-Related Amplified Polymorphism (SRAP) (Kafkas Salih, pers. comm.).

BREEDING STUDIES

Turkey is one of the important genetic resources of walnut and has been offering important opportunities to plant breeders with its genetical potential. Even so, there are many walnut types that are late leafing, resistant to diseases and insects and highly lateraly fruitfull, and have good fruit quality. Especially, types that are resistant to bacterial burn (*Xanthomonas campestris* pv. *juglandis*), codling moth (*Cydia pomonella)*, and anthracnose (*Gnomonia leptostyla*) are interesting (Akça 2001).

Walnut breeding studies are abound with cultivar breeding. There are no adequate studies on rootstock breeding. In cultivar breeding studies conducted in Turkey, almost all regions that have rich walnut genetic resources have been investigated and a selection of superior walnut aspects of fruit quality have been completed.

The first breeding study in Turkey was started in 1974. Superior walnut varieties that have high fruit quality were selected from among a native walnut population of the Marmarian region of Turkey and then selections have been propagated by grafting since 1974. Subsequently, selection studies have been implemented in native walnut populations of Kemah, Erzincan, Koyulhisar, Suşehri, Ahlat, Adilcevaz, Çatak, Bahçesaray, Hakkari, Gevaş, Erciş, Darende, Gürün, Ermenek, Çameli, Bozkurt, İkizdere, Borçka, Kızılcahamam, Ayaş, Niksar, Başçiftlik, Bor, Oğuzlar, İskilip, Sivas, Malatya, Küçükmenderes, Muş, Amasya, Göynücek, Hatay, Bursa, Adıyaman, Ardahan, Posof, Ödemiş, Isparta, Denizli, Tokat, Bursa, Kahramanmaraş, Adıyaman, Mardin, Urfa and Van regions of Turkey (**Fig. 2**; Ölez 1971; Şen 1980; Çelebioğlu *et al*. 1988; Akça 1993; Beyhan 1993; Ferhatoğlu 1993; Akça and Ayhan 1996; Akça and Osmanoglu 1996; Kaşka *et al*. 1996; Küden *et al*. 1997; Seçilmiş 1997; Oğuz 1998; Osmanoğlu 1998; Balcı 1999; Yaviç 2000; Akça *et al*. 2001; Güven and Güleryüz 2001; Şahinbaş 2001; Serdar *et al*. 2001; Sütyemez and Eti 2001; Oğuz *et al*. 2003; Akça and Özongun 2004; Taşkın 2004).

All Turkish walnut cultivars have been selected from a native walnut population. In initial breeding studies, breeders had mostly focused on fruit quality characters and chose large fruited trees. Other characteristics such as late leafing, lateral fruitfulness and resistance to disease and insects had been omitted.

The important distinctive characteristics of Turkish walnut cultivars are their early leafing out dates and low lateral fruitfulness. The most important risk that threatens walnut production in Turkey are spring frosts. The National Walnut Cultivar Breeding Program was initiated in 1998 to derive late leafing and laterally fruitful walnut types. In this breeding study, introduction of new walnut cultivars that are late leafing and laterally fruitful were targeted by selection and hybridization methods. In the hybridization phase of study late leafing domestic and foreign cultivars were crossed with early leafing and laterally fruitful domestic and foreign cultivars. Also within this study, different cultivars were crossing to improve nut and kernel quality (Akça 2001).

The aim of the Turkish National Walnut Breeding Program is to search for walnut types and new promising rootstock candidates that have resistance to salt, lime and

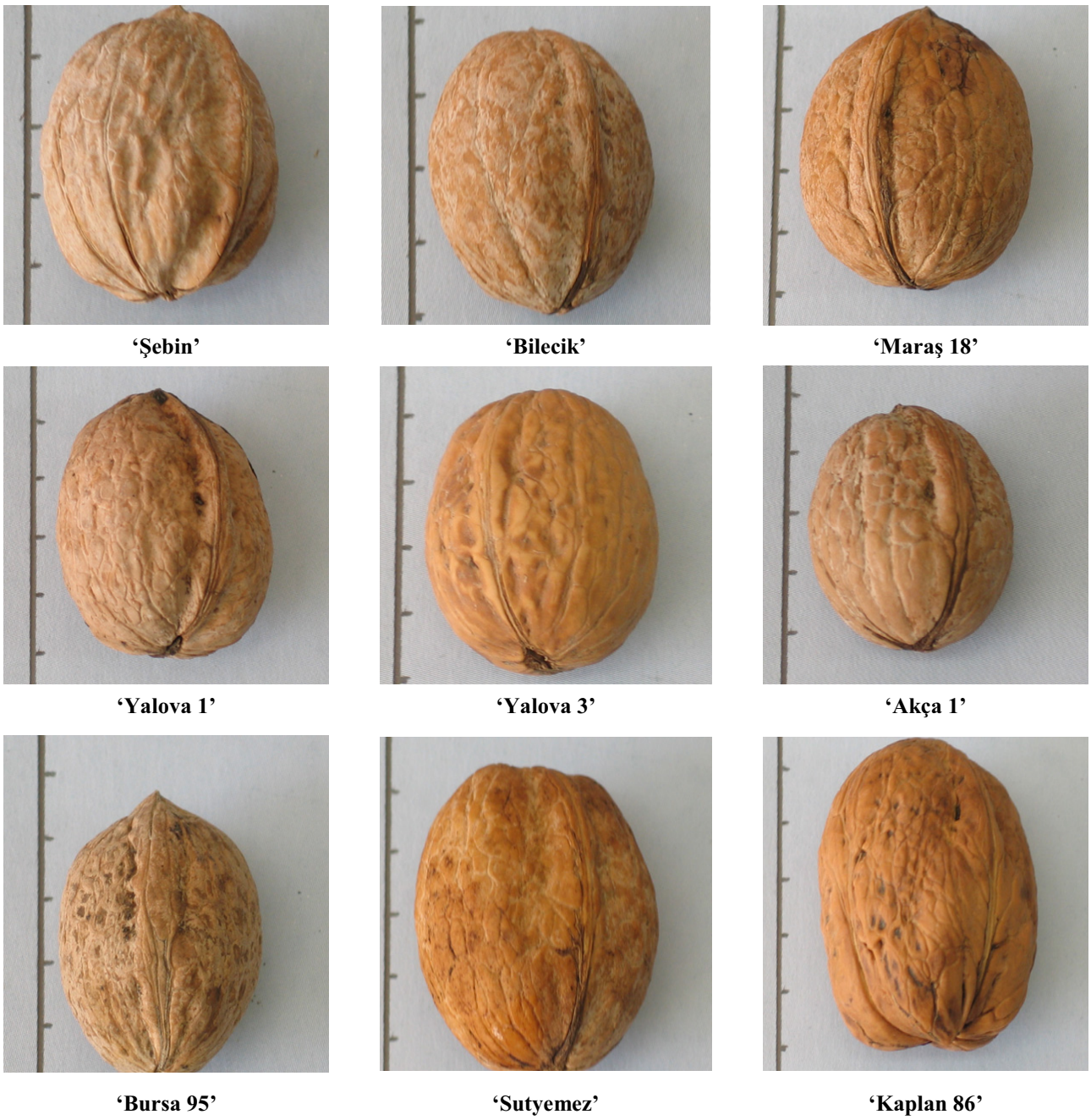

Fig. 3 Walnut cultivars grown in Turkey.

drought, are tolerant to *Agrobacterium tumefaciens* and *Armillaria mellea* among *J. regia* seedlings and from seed sources homogeneous development, high germination rate, and appropriate development in one year for grafting or budding (Akça 2005a). Tolerance to *A. tumefaciens* and *A. mellea* are the main objectives of these studies since among all the walnut rootstocks, *J. regia* is the most sensitive species to these two microorganisms.

CHARACTERS OF TURKISH WALNUT CULTIVARS

Until the last decade, it was very difficult to find established orchards using standard cultivars since walnuts had been grown from seed up to the present, despite the large quantity produced. However the importance of propagation by grafting and budding is being realized in recent years and as a result orchards established by standard cultivars are becoming increasingly widespread. These standard walnut orchards are generally planted with cultivars selected in Turkey.

All Turkish walnut cultivars (**Fig. 3**) have been selected from a native walnut population. Important characteristics of some domestic cultivars have been presented in **Tables 2** and **3**.

GENETIC EROSION

In Turkish tradition, chests made of walnut wood have been gifted to girls to get married. Also an important portion of home furnitures have been veneered with walnut wood. Villagers in rural areas that earn little money from walnut fruits have been cutting trees to sell as timber (**Fig. 4**). Thousands of walnut trees had been cut down in the eastern part of Turkey and sold abroad after the 1980's. Old and healthy trees were logged because of high timber prices that caused important genetic erosion and a decreased nut production. Recently, the number of logged trees has decreased under pressure by the Civil Society Associations and legalities.

Due to regulations in acts, the preliminary condition to get a cutting license is the property of the land where the trees are needs to be belonging to someone other than state and non-forest area. Cutting of walnut trees in these properties needs a positive report that is given by a commission established by a forest engineers and an agronomists. A cutting license is issued after approval of the positive report of the commission by authorized offices. Unavoidable con-

Table 2 The pomological characteristics of walnut cultivars grown in Turkey (based on data from Akkuzu and Çelik 2001; Kaşka and Sütyemez 2001; Akça 2005b).

Cultivar	Type of maintenance	CLRV status	Time of bud break	Type of fruiting	Dichogamy	Nut weight (g)	Kernel percentage	Kernel quality	*Cydia pomonella* susceptibilty	*Gnomonia leptostyla* susceptibilty
Şebin	In the field	Unknown	Early	Intermediate	Protandry	12.68	61.24	Good	high	high
Bilecik	In the field	Unknown	Early	Terminal bearing	Protogeny	12.87	50.11	Medium	moderate	moderate
Akca 1	In the field	Unknown	Medium	Lateral bearing	Protandry	11.89	55.24	Good	low	low
Maraş 10	In the field	Unknown	Early	Lateral bearing	Protandry	11.05	56.47	Medium	moderate	moderate
Maraş 18	In the field	Unknown	Early	Lateral bearing	Protandry	8.25	55.22	Medium	moderate	moderate
Bursa 95	In the field	Unknown	Early	Terminal bearing	Protandry	5.94	50.17	Medium	moderate	high
Yalova 1	In the field	Unknown	Early	Terminal bearing	Protandry	17.16	47.76	Medium	moderate	high
Yalova 3	In the field	Unknown	Early	Terminal bearing	Protandry	13.42	6.84	Medium	moderate	high

Table 3 Distribution of fatty acids, dietary fibre and mineral content of walnut cultivars grown in Turkey (based on data from Ağar *et al*. 1995; Akça *et al*. 2005, 2006).

Cultivar	Palmitic acid*	Stearic acid*	Oleic acid*	Linolenic acid*	Linoleic acid*	PUFA	Dietary fiber*	K**	Mg**	Ca**	Fe**	Zn**	Cu**	Na**	Mn**
Şebin	5.58	2.75	22.55	55.81	12.93	68.74	12.26	347	146	319	1.9	1.9	0.9	1.2	2.3
Bilecik	5.76	2.83	20.99	56.85	13.14	69.99	10.73	371	114	345	2.4	1.9	1.2	0.6	2.2
Akça 1	7.08	2.36	18.40	56.94	14.84	71.78	10.10	-							
Maraş 10	7.57	2.81	28.32	50.27	10.56	60.83	11.05	314	140	214	6.9	1.9	1.6	0.5	6.0
Maraş 18	5.79	3.41	28.26	53.23	8.99	62.22	9.90	322	115	307	2.3	2.5	1.4	0.7	5.4
Bursa 95	7.61	3.28	21.49	52.52	14.65	66.17	12.35	419	142	251	2.9	1.2	0.5	0.6	2.4
Yalova 1	5.77	3.21	30.14	53.08	7.77	-	-	-	-	-	-	-	-	-	-
Yalova 3	7.05	2.72	19.41	59.61	10.85	-	-	-	-	-	-	-	-	-	-
Hartley	5.69	3.27	15.82	63.54	11.25	74.79	11.01	398	110	414	3.7	3.8	2.2	2.5	3.8
Pedro	6.65	2.73	14.14	60.22	15.90	76.12	11.30	396	123	262	1.4	2.5	0.9	2.2	1.3

*:g/100 g kernel weight
**: mg 100 g^{-1}

Fig. 4 Cut down walnut trees for timber.

ditions of destruct are looked for giving a cutting license to walnut trees; these trees should not yield due to disease and age, trees should be damaged from natural disasters (flood, wind, strike, etc.), dried, left in compulsory construction and establishments like road, dam, etc, damage neighbor's property. Otherwise cutting of these trees are not permitted (Akça 2005a).

However, genetic erosion has continued as a result of imported late leafing and laterally fruitfull cultivars such as 'Chandler', 'Pedro' and 'Fernor', and senseless and unrestrained logging of native trees.

Serr (1965) investigated Turkish walnut population. In his research report, he declared that people had believed that walnut and almond are sown by God and that trees do not need irrigation, fertilization and cultural applications. For that reason seedling-grown trees are usually not irrigated, fertilized and pruned properly. However in the walnut orchards that have been established in recent years, irrigation, fertilization, spraying and pruning are done properly.

IMPORTANT DISEASES AND INSECT PESTS

In Turkey, there is no spraying against diseases and pests on the seedling-grown old walnut trees. However in walnut newly-established orchards, there are methodical spraying programs against especially codling moth (*Cydia pomonella*), walnut aphids (*Chromaphis jugladicola*) and anthracnose (*Gnomonia leptostyla*). Certified chemicals are used against diseases and pests. Biological agents are not commonly applied. There is no virus-clean seedling production. But there are improvements in cell culture production of walnuts. Cell culture produced saplings are imported from USA, France and Spain.

Most common diseases and insect pests observed in Turkey are anthracnose, bacterial blight (*Xanthomonas campestris* pv. *Juglandis*), root rot (*Phytophthora* spp.), codling moth (*Cydia pomonella*), and walnut aphids (*Chromaphis juglandicola*). Among domestic cultivars, 'Şebin' is the most susceptible to *C. pomonella*, since 'Akça 1' and 'Bilecik' are resistant to this insect (**Table 2**).

Anthracnose (*Gnomonia leptostyla*) have been controlled by using IPM rules in Turkey. Herbicides are not used to control weeds. Chlorotic Leaf Roll Viruse status of the Turkish walnut population has not been scientifically investigated. There is not any area of transgenic walnut produced in Turkey. There are laws that prevent the production of transgenic plants in Turkey.

RESTRICTING CLIMATE FACTORS

The most important climate restriction for walnut production are spring frosts in Turkey. In fact, due to frost in spring of 2006, about 40% damage has been observed in Turkey's walnut production. In regions with a humid Black Sea climate, anthracnose and bacterial burn have been restricting walnut growth.

HARVEST AND POST HARVEST

One of the important factors that affects shell quality is harvest time. Especially in continental climates, ripening of the kernel and husk occur at different times. Although the kernel ripens, the husk does not so that harvest is made later than it should. For that reason puckerings and darkening occurs in the kernel (Akça 2005a). Harvesting can not be made mechanically because native trees are big but rather with long sticks by hitting the branches. This operation affects and limits the following year's yield, and because of the long harvest time the kernel quality can decrease. In re-

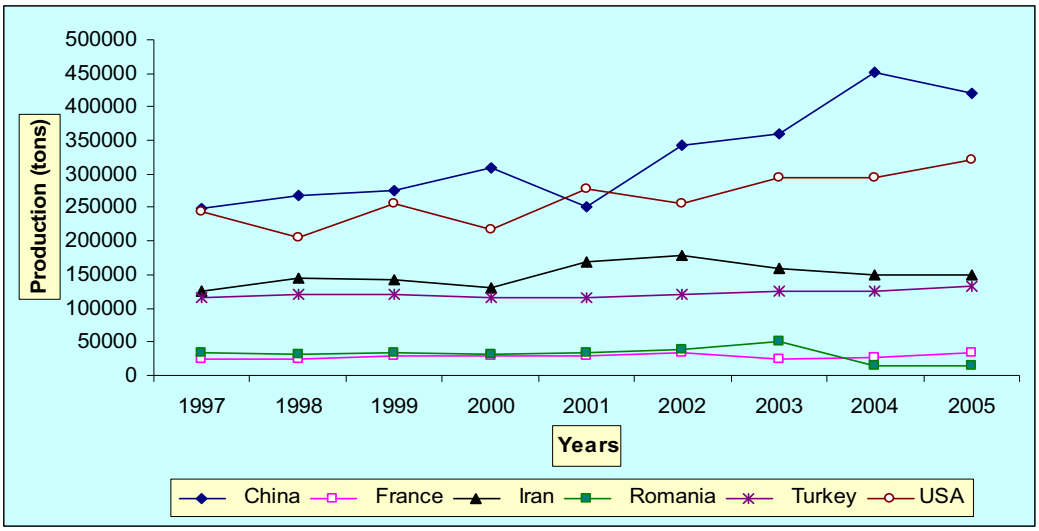

Fig. 5 The production of important walnut producing countries.

cent years, studies have been attempted to adapt shaker machines used in olive trees to walnut harvest (Yalçın Muammer, pers. comm.).

Harvested fruits with a green husk are usually clumped together and kept for a long time for separation of the husk itself (Akça 2005a; Şen *et al*. 2006). This process causes darkening of the shell and kernel. Green husks of fruits are usually skinned manually. Harvested walnuts must be dried as soon as possible and moisture content must be decreased to 4-5%. Problems with the drying process of fruits in Turkish walnut production cause a loss of quality. Skinning of the green husk has not yet been mechanized. The shell surface becomes darkened because walnuts are draped under thick cloth until the green husk is skinned by itself. Manually skinned walnuts are dried in direct sunlight for 5-7 days (Akça 2005a; Şen *et al*. 2006).

ORGANIC WALNUT PRODUCTION

It can be said that almost all walnut trees in Turkey have been grown without the use of pesticides and chemical fertilizers so that production shows organic qualifications (Özkan 2005). Furthermore, in recent years, in appropriate areas and policies have started to organic walnut production.

PROCESSING OF WALNUT AND WALNUT INDUSTRY

Mechanization is not used in the cracking process of shelled walnuts but is rather done manually, in general, by women workers. Shelled walnuts are stored in cool storage and presented for consumption throughout the year. Bitterness in unshelled walnuts is observed in four months at 21°C, but for two years at 1°C. Shelled walnuts can be stored without rot for 18 months at 4.4°C due to low moisture content. If the temperature can be dropped down to 3°C, quality losses drop down to a minimum. Nuts can be stored between -15°C to -20°C without quality losses (Akça 2005; Sen *et al*. 2006). Kernels are marketed in vacuum packages. There are no references on postharvest packaging techniques and advances in Turkey. Walnuts are commonly used in the dessert production industry. Also, by using mulberries and grapes special products such as 'pestil' and 'köme' are made. Walnuts also are used in ice cream and halva production, and in the dried fruit industry.

MARKETING

Marketing channels of walnut have not developed in Turkey. Shelled nuts are marketed in local bazaars, markets and other consumption centers. There are grower unions that gather growers to market their production. Nowadays, grower unions have been established in important production areas. However, those grower unions are not yet strong enough.

Turkey's walnut production has been around 120,000 tons for a significant amount of time (**Fig. 5**). Turkey's shelled walnut export value is 500 tons/year. Turkey imports almost 30,000 t of shelled and kernelled walnut each year from Bulgaria, Turkmenistan, Kyrgyzstan, Moldovia, and Uzbekistan to compensate domestic consumption. But in the next 10 years, Turkey would have exported walnuts and become an important producer (Akça 2005a).

RESEARCH ACTIVITIES

The latest research on walnut breeding has intensified on cultivar breeding. In recent years, studies have been made on nitrogen, phosphorous and water requirements of trees, methods of contesting with diseases and insects, effects of harvest time to fruit quality, using possibilities of ethrel on harvest, allelopatic effect of walnuts on other plants, determination of chemical contents of domestic and foreign cultivars, propagation by tissue culture, determination the resistance of 'Şebin' cultivar to salt, drought, and boron, storage of shelled walnut and kernel, conservation of genetic sources and rootstock breeding. Characterization of Turkish walnut germplasm and determination of apomixis by using molecular marker techniques have also been on-going studies.

There are two crossing breeding program in Turkey. The first was started in 1997, in order to obtain new more productive cultivars with late leafing and higher nut quality. Late leafing walnut types were pollinated by walnut types with lateral bud fruitfulness. The female inflorescences were isolated with a bag before stigma emergence. The catkins were collected before shedding. Hybrid nuts were kept during the winter in a cold room and soaked in a 75 ppm GA_3 solution during 24 hours before sowing in spring. The nuts were sown in spring. In this program, 757 seedlings from controlled crosses were planted in 1998 and 624 seedlings were planted in 2000. The leafing out of each hybrid was ranked in one of four classes as very early, early, late and very late. The study is still in progress (Akça 2001).

The second program was started in 2000. The aim of this program was to obtain new types with high nut quality

Table 4 Important nut characteristics of types used in crossing breeding.

Type	Nut weight (g)	Kernel weight (g)	Shell thickness (mm)
186	25.80	12.29	1.35
432	16.36	7.82	1.05
310	14.84	7.94	1.14
Serr	13.68	7.80	1.21

(Sütyemez 2001). In this ongoing study, the important nut characteristics of using types were determined as explained in **Table 4**.

Walnut types grown from seed are common in Turkey and some of these have very valuable genetic characters. In selection studies among walnut populations started from the 1970s, most types had been selected according to their nut weight and other nut characteristics. 'Şebin', 'Bilecik', 'Yalova 1', 'Yalova 3','Yalova 4' Turkish walnut cultivars were obtained by selection breeding in populations. Late leafing, lateral bud fruitfulness and resistance to bacterial blight was not considered in most of researches.

There is a lot of adaptation research in Turkey. These researches were started in ecological conditions of Kahramanmaraş, Gaziantep, Şanlıurfa, Erzincan, Tokat, Ankara, Bursa and Yalova Provinces. The objectives of these studies were to obtain favorable walnut cultivars according to yield and fruit quality. 'Chadler', 'Pedro', 'Serr', 'Midland', 'Amigo', 'Tulare', 'Hartley', 'Payne', 'Franquette', 'Şebin' 'Bilecik', 'Yalova 1', 'Yalova 3', 'Yalova 4', 'Kaman 1', 'Kaman 5', 'KR-2' walnut cultivars and types are used in these studies (Akkuzu and Çelik 2001; Akça and Aydın 2005; Tosun and Akçay 2005).

A new breeding project has started for selection seed source from *J. regia* for high germination, production of homogenous and strong saplings, tolerance/resistance to salt stress, tolerance/resistance to root tumor and root grass nematode, root cancer plus *Phytophthora* and *Armillaria*.

First research was carried out to determine the apomictic seed in '197/7', 'Şebin', 'Yalova 2' and 'Yalova 3' walnut cultivars in Bursa ecological contitions. The ratio of apomictic seed development was determined as 27% in '197/7' (Soylu and Ertürk 2001). Second research was carried out to determined the formation of apomictic seed in 'Kaman 1' and 'Kaman 5'. A couple of hundred flowers of 'Kaman 1' and 'Kaman 5' walnut genotypes were bagged to get apomictic seed in the spring of 2005 and 2007. Unfortunately, there was no fruit set. Seedlings of these genotypes were bought from two different nurserymen to apply DNA tests using ISSR and SRAP molecular markers. Both ISSR and SRAP markers proved that 'Kaman 1' and 'Kaman 5' seedlings are genetically different from each other and from the original material tree (Kafkas Salih, pers. com.).

DKW (Driver-Kuniyuku Walnut Medium) medium is used for cell culture production of 'Yalova 1' walnut cultivar. In this study, effects of different doses of BAP and IBA hormones are experienced on explants' growth. Best growth in var. 'Yalova 1' was observed with the application of 0.1 and 1 ppm BAP and 1 ppm IBA. In 50-80% of media and explants darkness was observed (Yarılgac and Yılmaz 2001). In the second research 'Şebin' and 'KR-2' walnut cultivars were tried to propagated *in vitro*. The important problems were contamination and browning in this research (Fidancı 2005).

Kantay and Kantay (2001) observed the properties and use of *J. regia* wood, the oven-dry density was 0.46-0.64, g/cm^3, compression strength parallel to grain was 38.8-72.5 N/mm^2, bending strength was 94.4-147 N/mm^2, tensile strength was 95.0-100 N/mm^2, impact bending strength was 054-1.95 kN/cm, and MOE was 10800-13000 N/mm^2.

In an ongoing study the determination of salt stress resistance of 'Şebin' walnut cultivar is being assessed. In this experiment, sodium bicarbonate ($NaHCO_3$), magnesium chloride ($MgCl_2$) and calcium chloride ($CaCl_2$) salts are used to increase saltiness of the irrigation water to determine tolerance of saplings (Şimşek Hüseyin, pers. comm.).

70 different walnut varieties were gathered from 24 different regions in Turkey. Physical and chemical analyses were made in these varieties. Protein content ranged from 13.59 to 22.30%, oil content was 56.38-70.59%. Mineral content of these varieties were: K, 223-712 mg/100 g; P, 88.8-1000 mg/100 g; Mg^{2+}, 56.2-188.2 mg/100 g; Ca^{2+}, 37.2-120.9 mg/100 g. Linoleic acid content ranged from 50.18 to 63.65%, and linolenic acid content ranged from 8.05 to 13.74% (Şahin and Akbaş 2001).

In the another study, the chemical content of native walnut types ('Akça 1', 'Hidayet', 'Kaman 1', 'Şebin', 'Bilecik', 'Mert', 'Şeker 2', 'Şeker 3', 'Sütyemez 1', 'Sütyemez 2', 'Bursa 95' 'Maraş 10', 'Maraş 18' and 'Maraş 19') and foreign walnut cultivars ('Hartley', 'Pedro', 'Chandler' and 'Serr') were investigated. Turkish walnut types 'Maraş 10' and 'Maraş 18' had the highest oleic acid content among all the varieties analyzed. In all analyzed cultivars and types linoleic acid accounted for more than 50.0% of total fatty acid content. It ranged from 50.27% in 'Maraş 10' to 64.42% in 'Şeker 2'. Some Turkish walnut varieties had more than 70% poly-unsaturated fatty acids. Total dietary fibre content walnut ranged from 9.83-12.59 g/100 kernel weight basis. 'Şeker 3' showed the highest dietary fiber content among all the varieties (Akça *et al*. 2006).

FUTURE OF WALNUT PRODUCTION IN TURKEY

Each year 1.5 billion saplings have being produced by which thousands of hectares of walnut orchards have been established in Turkey (Kaşka 2001; Akça 2005). As a result of newly established orchards, Turkey has started to produce standard walnuts. In orchards, 7×7, 8×8 and generally 10×10 m planting distances are used. Dripping and mini spring irrigation systems have been used in this orchard. Contestation with diseases and insects is being made well. Product of these orchards is being sold at 3 times higher prices than products of native trees.

Turkey's walnut production is expected to increase about 20,000 t in the next 5 years with the initiation production of newly established orchards and in the next 10 years, Turkey would have exported walnuts and become an important producer (Akca 2005a).

Health benefits of walnuts are being accentuated to raise inshell walnut consumption all over the country. In recent five years, consumption of inshell walnut has increased.

As a result, Turkish walnut germplasm is open for international researchers. Collaborative researches could be implemented for collection and protection of walnut germplasm, determining the effects of walnut consumption on human nutrition and on human health.

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