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An Early Warning System of Apple Scab in Turkey

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ABSTRACT

Apple scab caused by *Venturia inaequalis* (Cooke) G. Wint. is the most important disease affecting apples. If uncontrolled, the disease reduces quality and quantity of fruits during the vegetative period and can continue to develop in storage as pinpoint scab or storage scab resulting from late-season infections. Apple scab is controlled mainly by spraying fungicides and sanitation depending on the orchard size. Various varieties of apple are grown in Turkey and the susceptibility level to apple scab varies among the apple cultivars. Therefore, forecasting the disease with weather monitoring equipment is very important for determining a control strategy. This review is focused on a disease warning system of apple scab and its implementation in Turkey.

Keywords: chemical control, cultivar resistance, epidemiology, PCR-based methods

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INTRODUCTION

Apple (*Malus domestica* (Borkh.) Mansf.) is cultivated throughout Turkey because of the suitable ecological conditions and it's a center of origin and genetic diversity as a source of gene. The most convenient apple growing area is in North of Anatolia. This area covers coast of Black Sea and climatic transition zone between Central Anatolia and East Anatolia plus Lake District including Isparta (Yikar 2003). In addition, apple can be grown in Aegean Region and hot and dry areas of South-East Anatolia with altitude of 500 m and over 800 m, respectively.

There are many usage of apple mainly sold as fresh fruit. Apples can be canned, juiced, and optionally fermented to produce apple juice, cider, vinegar, and pectin. Apple wine can also be made.

Apple production has topped 59 million tonnes in approximately 5700 ha areas worldwide. Totally 72% of apple production has shared by ten country in the the world. Leading apple producing countries are China, the USA, Poland, Russia, France, Iran, Turkey followed by Italy, Germany and India. Turkey is the 6th leading producer with approximately 2.5 million tonnes productivity in world production (Anonymous 2005). Turkey also has placed among ten countries with 21.000 tonnes amount of exportation with low proportion among exporters.

Apple has a proportion of 7% in fruit plantation areas and 19% in fruit production in Turkey. Apple has been produced 2.5 million tonnes in 109.000 ha. There are approximately 39 million apple tree including producing fruit and non-producing fruit in apple growing areas and has 75.2 kg yield average per tree in Turkey. Although China has the highest production ratio which is in the first place in world production, the yield has been 8.2 tonnes per hectar. Turkey has 23 tonnes per ha taking 4th in place world production compared to highest yield ratio of 36.3 ton per ha in U.S.A. However, it has been suggested that total production amount and yield per ha may be increased because of the establishment of dwarf apple nurseries intensively in some apple pruduction areas including Central Anatolia within the several years. Yield can be approximately 75 tonnes per ha from newly designed nurseries. However, the statistical data about the number of tree and production amount have not been reflected completely to these data yet (Anonymous 2004).

Apple gowing can be done in the most of provinces have suitable climatic conditions of Turkey and production has become a reality accounting for 76.4% in ten leading provinces. Among these provinces, Isparta is the first leading apple producers and has accounted 22% of total country exportation. Apple has accounted 65% (3.200.000 tree) of total fruit tree number (4.900.000 tree) and 82% of total

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production in this province (Anonymous 2004).

There are more than 7500 known cultivars of apples and difeerent cultivars are available for temperate and subtropical climates. Turkey has a big collection with approximately 500 cultivars. The most productive varieties are 'Starking Delicious', 'Golden Delicious', 'Starkrimson Delicious', 'Granny Smith', 'Starkspur Golden Delicious', 'Beacon', 'Jonathon', 'Black Staymen Improved' and the local variety 'Amasya'. The most commonly grown apple varieties in Turkey are 'Starking Delicious', 'Golden Delicious', 'Starkrimson Delicious', 'Amasya' (Yikar 2003) and 'Granny Smith' recently.

One of the most important factors in marketing are selection of cultivar and standardization. Commercially popular apple cultivars supported for production are winter varieties such as 'Granny Smith', 'Starking Delicious', 'Golden Delicious', 'Skyline Supreme', 'Starkrimson Delicious', 'Starkspur Golden Delicious', 'Black Staymen Improved 201', 'Mutsu', 'Gloster 69', 'Lutz Golden', 'Cooper 7SB-2' and 'Prima' and summer varieties such as 'Starkearliest', 'Beacon', 'Vista Bella', 'JerseyMac' and 'Summered'. Some varieties including 'Gala', 'Mondial Gala', 'Fuji', 'Breaburn', 'Pink Lady' and 'Scarlette spur' have been required by some countries increasingly and production of them are becoming widespread recently. Modern and intensive commercial apple breeding methods are starting to be used instead of traditional techniques in developing countries. The cloned rootstocks are being used in production completely such as M9, M26, Mac9, B9, Geneva 11, 16, 30, 65, MM106, MM111 rootstock in U.S.A, the 2nd leading country, and M7, M9, M,26, MM106, MM111 in France and Italy (Askin *et al*. 2002). Recently, the plantation of Spur varieties using dwarf and semi-dwarf rootstocks such as M9, M26, MM106 and MM111 become widespread and increasing of yield is supported by cultivar standardization (Akgul *et al*. 2005). It provides some advantages such as ease of harvest, fungicide application and ventilation for reduction of disease incidence.

APPLE SCAB

Apple scab, caused by *Venturia inaequalis* (Cke.) Wint (anamorph *Spilocaea pomi*) is the most important disease of apple and occurs wherever apples are grown in the world and also in Turkey. Scab-like leaf lesions and fruit spots lead to defoliation and reduction in fruit quality and quantity. The disease can cause big economic losses in comercial apple growing areas. Apple scab causes reduction in yield, quality and prize of marketable fruit by 20-45% and 30-60%, respectively (Turkoglu 1978).

Apple scab causes intensive infections in Lake District and Black Sea Region where has humid and temperate climate in Turkey. In addition, the disease can be epidemic in Central Anatolia where has relatively low relative humidity dependig of the rainy periods.

Fig. 1 Apple scab leaf lesions covered with a velvety growth (H. Ozgonen 2006).

Fig. 2 Typical cork like apple scab lesion (H. Ozgonen 2006).

Fig. 3 Pinpoint scab (H. Ozgonen 2006).

Symptoms

Venturia inaequalis, an Ascomycet fungus, affects leaves and fruit most noticeably and twigs, petioles and pedicels. Infection of leaves first appears as olive-green spots and then these spots became darken greenish to black with a velvety appearance causing defoliation (**Fig. 1**) Infections of fruit appears as dark spots resulting in deformation and cracking with age (**Fig. 2**). On severe infections, the fruit may drop off before ripening. The scab lesions may develop deep cracks in the fruit. Small black spots resulting from infections occurring late in fruit development are named pinpoint scab (**Fig. 3**). Although infection occurs only in the orchard, pinpoint scab symptoms do not develop until the apples are in storage.

Disease cycle

The fungus overwinters on fallen leaves. Ascospores in ascostroma matured in early spring are splashed by rain or blown by wind to initiate infections of developing plant tissue with condition of at least 5 mm precipitation. To initiate the first infection of ascospores, wetness of leaves is a necessary condition that depends on the temperature. The infection period extends to 12 h of wetness of surface when the temperature is low but it is reduced to 1-2 h as the temperature icreases. Symptoms appear within 9-17 d after infection. Germination of conidia in secondary infections needs shorter periods of surface wetness, 3-15 h at 17.2-23.8°C, than those of ascospores. Also, scab lesions are important in the epidemiology of disease as a source of spores for additional infections. During the season, 6-8 asexual cycles happen, depending on the weather conditions (Mills and la Plante 1951).

ANALYSIS OF FUNGICIDES USE IN APPLE AND EARLY WARNING SYSTEM

Chemical control is the most commonly used for apple scab. Penrose and Dodds (1994) noted that effective control against apple scab could be performed with 0-7 applications depending on the environmental conditions under natural infection. This number averaged 7.3 in Turkey (Karamürsel *et al*. 2003). Boyraz *et al*. (2005) reported that producers even apply 5-20 pulverizations for protection against apple scab infections during the rainy periods of spring, especially in the Egirdir district of Isparta in the growing season.

In Turkey, 286 commercial preparations belonging to 39 active ingredients have been licenced to apple scab. Of 386 commercial preparations, 169 are imported and 117 are manufactured with imported active ingredients in Turkey from 47 local and foreign agricultural chemical companies. These licenced preparations are copper compounds, dithiocarmates, dicarboximides and phytalimides, nitro compounds belonging to protective fungidices and benzimidazoles, triazoles, morpholines belonging to systemic fungicides and others. According to 2005 data, in total the apple market consumed in Turkey from agricultural chemical companies a total of 3955 tonnes in 1.293.000 ha with a value of 21 million $US (pers. comm., Syngenta). Control of apple scab and powdery mildew have been performed in 309.000 ha with 1534 tonnes of use of commercial fungicides, amounting to 7.108 million $US only for apple scab and powdery mildew in total. This is equivalent to 1/3 of the total apple market, proportionally. Copper compounds occupy a big portion (quantitively) of fungicides used against apple scab. Of the total proportion, Cu compounds and other protective fungicides account for 85% of total fungicides, while systemic fungicides used account for over 40% of total marketable fungicides (monetarily-speaking). These data represent big local and foreign agricultural companies, although it is believed that some commodities and fungicides come from China and Korea but have not been included. These fungicides are intensively used in the Lake district including Isparta, the North part of Taurus mountain (Karaman province) and the South part of the West Black Sea Region (Amasya Province), which have relatively higher precipitation. The use of fungicides against apple scab and powdery mildew was 524 tonnes in 2001, but increased to 1534 tonnes in 2005; this increase was relatively high compared to the increase of apple production.

Naturally, untimely and excessive use of these fungicides that have different active ingredients against pathogens lead to a lack of effectiveness. It is more and more evident that resistance of numerous diseases and pests to pesticides is a big problem in agriculture. Therefore, some studies have been conducted to determined the resistance of pesticides used intensively. Likewise, it has been reported that there is a reduced effect of pesticides which are commonly used against apple scab because of the development of resistance (Jones 1981; de Waard *et al*. 1993). Dodine was known to be one of the most effective fugicides to control apple scab in the 1960's but resistance to dodine by apple scab was reported in the 1970's (Ross and Newberry 1977).

Gilpatrick (1982) reported that economical losses occurred as a result of resistance to fungicides by apple scab such as dodine, benzimidazole, fenarimol, myclobutanil and triflumizole. Similarly, resistance to Penconazole was also reported (Polani and Lalithakurnari 1999) Demethylation inhibition fungicides (DMI) also used for for apple scab have an effectiveness problem (Köller *et al*. 1997; Köller and Wilcox 2001).

Sensitivities of certain active ingredients used for apple scab were also reported in Turkey. Among these active ingredients, benomyl and dodine (Benlioglu and Kilic 1994); flusilazole and hexaconazole (Benloglu and Kilic 1995) were the most noticeable. Demircan and Yılmaz (2005) pointed out that fungicides had 74.2% of usage in Isparta province, used especially in apple-growing areas while the remaining areas used other pesticides for different aims. In addition, these pesticides have been used in over-doses rather than the recommended application doses by 5.51-186%. Turkey is faced with many problems including pesticide residues, higher costs and resistance to diseases as a result of the excessive application of fungicides. Especially, the intensive use of copper compounds and sulphurs between January and March and fungicides that are used against apple scab between April and June.

Many studies that demonstrated disease prediction and early warning systems for diseases have an epidemiological character; most of the results from these studies were used practically in these systems. These models have helped to determine initial infection and the potential of disease occurence to determine the first application time of fungicides during critical periods. Thus, the unnecessary use of fungicide is prevented via these warning systems. Many studies were conducted about the epidemiology of apple scab in the world and also in Turkey. Mills and la Plante (1951) showed the relation between leaf wetness period, temperature and apple scab infection. According to the Mills table, minimum number of hours of continuous wetness required for leaf infection by ascospores at temperatures between 6 and 25°C and more than two days of wetting was required for infection by ascospores for all temperatures below 6°C. In addition, infection by conidia required only two-thirds the duration of wetting required by ascospores at a given temperature. Schwabe (1980) reported that depending on the temperature, ascospore infection needs longer or shorter leaf wetness periods for germination and penetration. In addition ascospore discharge is much higher during the day and less after sunset then during the night. Conidial infection also needs a similar climate to the ascospores. Ascospores and conidia can survive in the absence of free water for only a certain length of time. The literature shows a wide variation, from 3-32 hours, depending on the temperature. Dwelled upon control of apple scab is an early warning for possibility of most effective and minimum application numbers. In this context, the effects of climatic factors on primer and seconder infection source of agent (O'Leary and Sutton 1986; Aylor and Sutton 1992; Aylor and Kiyomoto 1993; Stendsvan *et al*. 1997; Gadoury and MacHardy 1986; Gadoury *et al*. 1998; Rossi *et al*. 2001, 2003) and additional studies related to effective control of apple scab (MacHardy and Gadoury 1989; Aylor 1993, 1995, 1996, 1998) were investigated. In the light of these findings, prediction methods were developped with the Revised Mills table based on temperature and leaf wetness, an can be used to predict when infection is likely to occur. This aids in determining whether the trees are protected by sprays that have been applied. Methods of leaf sampling have been developed in order to determine the level of scab present in the orchard and the level of inoculum which will be present in the orchard in the spring. In Turkey, biological control methods of apple scab and economical losses (Turkoglu 1956) and in central Anatolia the conditions in which cultivars reacted to apple scab, epidemiological aspects and cultural and chemical methods (Turkoglu 1962; Turkoglu and Erkal 1967) were investigated. Studies related with disease prediction and early warning systems in different climatic conditions in different regions were conducted since the 1980's under the scope of several projects and results of these studies are used practically nowadays (Demir and Hepdurgun 1988; Yurut *et al*. 1988; Turan *et al.* 1992; Demir 1989; Cakir and Ceylan 1990).

A recent study conducted in Isparta, aiming to explain the producers' motives for using fungicides produced astonishing results. According to the study: 35% of all producers are applying fungicides when they discover a problem, 22% according to the advisories by the warning system, 15% according to the advise of the agricultural organizations, 15% according to how much the disease or the prob-

lem spread, 7% observing other producers (Boyraz *et al*. 2005).

When the control of apple scab conducted chemically using classical control methods, fungicides are used excessively and unconsciosly because of the mistake of timing. Control of apple scab is difficult in certain years especially when serious infections depend on the climatic conditions in the season and could not possible to overcome despite intensive fungicide applications.

As a result of this, economic cost increases for the producer; apples for market have considerable residues after application and have a negative effect on human beings and are environmentally undesirable. It is possible also to development resistance as a result of excessively and unconsciously using fungicides.

An early warning system, which is an integration of work proposed on measurement and analysis of meteorological and ecological conditions while observing the biology of diseases and pests is performed with the minimum or no application of pesticides without damaging the environment and biological balance in agricultural systems. Meteorological data (maximum, minimum and average temperatures, relative humidity, precipitation and leaf wetness duration) in the region can be obtained via these systems throughout the year (**Fig. 4**).

Studies on early warning systems in apple became widespread by the 1980's. In the past, these studies were performed with mechanical equipment, but had been accelerated by the 2000's with an increasing number of established computerized early warning systems in different provinces. The aims of early warning systems are to increase the crop quality and quantity, to apply fungicides at the correct time and number if needed, to reduce the application number of fungicide-reducing residues and to use equipment, labor and labour force productively.

According to the informatin obtained from some big firms marketing early warning system equipments to collect meteorological data for different aims, formal and private foundations, approximately 150 data loggers have become present in Turkey recently (the last six years) 80 of which were used for apple plantations and others for grapevine areas, vegetables and field crops. One part of these systems is used by universities for research and large parts are used by the Ministry of Agriculture while the rest is by private organisations (pers. comm., Birkan Agricultural Technologies). When the number of these dataloggers is combined with those already existent in preeceding years, it is stated that more than 150 dataloggers work actively with collector and computer systems. Totally 23 data loggers connected to a computerized center are present in Isparta, which has 22% of apple production for the purpose of being all districts with app. 20.000 ha and after collection of data, producers are informed about the first infection time and other critical periods in the whole. Under this system, data are collected by Ministry of Agriculture and warnings are announced free. The other 57 data loggers for apple plantations in other production areas except Isparta are being used in changing numbers according to largeness of regions. The announcement is done in a similar way in other regions.

Stations established for disease prediction and early warning have data collector (datalogger), data transferring equipment, sensores for climatic data (precipitation, relative humidity, temperature and leaf wetness, soil temperature if needed). These data are tranferred in certain time periods to datalogger. Datalogger takes power from an energy source with solar collector. Transferring data from sensors is performed by radio wave or modem channel and data can be stored in sensores for a period of 10-30 days. Data are evaluated in main computer system by Agricultural Ministry of Province and Districts and then early warning times are announced to producers against apple scab plus powdery mildew using this systems. In Isparta Province producers are informed especially against apple scab from April to June.

Fig. 4 Datalogger in apple plantation (Birkan Agricultural Technologies 2006).

CULTURAL PRACTICES

As a cultural method, picking up and destruction of leaves sheded on the ground in fall especially in small areas for prevention of the main primary source of infection has reduced the disease incidence by 51.2% (Turkoglu 1962). Thus, unnecessary pulverization numbers ranging between 3-7 in spring and summer times could be omitted in view of the condition of region and year. In addition, applications of 5% urea to leaf litter may be applied in fall in order to hasten leaf decomposition and thus reducing primary inoculum. In central Anatolia conditions, application of chemicals has reduced disease incidence by 11.7% in accordance with phenological parameters including bud formation, pink bud and petal fall plus picking up leaves succesfully. The epidemy was not expected and under threshold if the average temperatures and total temperature in January were over 3°C and 95°C, respectively (Turkoglu 1978). Pruning trees are also of importance to open the canopy to light, air, and spray penetration. Cultivars which are resistant to the disease are important when establishing a new orchard. This provides protection to disease, but productivitiy of cultivars is an important factor, too.

CULTIVAR RESISTANCE

Apple scab is the most widely distributed disease and breeders concentrate on developing scab resistance before targeting any of the other diseases. Apple varieties display different disease severity ratios and levels of resistance against apple scab. Among the apple varieties known as resistant to apple scab are 'Enterprise', 'Goldrush', 'Liberty', 'Jonafree', 'Macfree', 'Prima', 'Pristine', 'Redfree', 'Sir Prize', 'Freedom', 'Nova Easy', 'Priscilla', 'Williams' Pride'; variety being moderately resistant is 'Jonathon'; moderately susceptible varieties are 'Idared', 'Empire', 'Paulared', 'Spartan', 'Golden Delicious' and highly susceptible varieties are 'Red Delicious', 'McIntosh', 'Cortland Rose', 'Beauty', 'Jersey Mac', 'Jonagold' and 'Mutsu'.

In addition, many studies have been conducted on sensitivity of different apple varieties against apple scab under natural infection conditions. Rosenberger (2003) reports that 'McIntosh', 'Cortland', 'Orin', 'Cameo', 'Sunrise', 'Shizuka', 'Gala' and 'Golden Supreme' were susceptible with 30% of disease severity, while 'Pristin', 'Enterprise', 'Goldrush' were resistant with <1% infection. In Sweeden, a study was conducted in two different localities, and the resistant varieties were 'Priscilla', 'Nova Easygro', 'Prima', 'Warner's King', 'Akane', 'Remo', 'Co-op 25', 'Liberty', 'McShay' and 'Katinka' in the first, and 'Co-op 22', 'Enterprise', 'McShay', 'Prima', 'Priscilla', 'William's Pride', 'Luke', 'Apelsinoe' and 'Judeline' in the latter (Sandskar

and Gustafsson 2004). In another study, genetically resistant varieties were 'Imrus Chistotel', 'Orbvim', 'Orlavskij Pioneer', 'Pomjat', 'Pomjat Isajiva', 'Pervinka', 'Slavyanin', 'Liberty Freedom' in Estonia. The varieties show that rapidly infected kinds were 'Borovinka Ananasnaya', 'Pirja', 'Maikki', 'Mantet' and 'Red Atlas' (Tiirma *et al*. 2006). Sestras (2003) determined that susceptible cultivars are 'Fuji', 'Aki-fu', 'Nebuta', 'Sekai ichi' and found strong infection at the leaves of 'Kaltherer Böhmer', 'Starkrimson', 'Red Delicious', 'Mutzu', 'Wellspur', 'Jersey Mac'. Resistant cultivars are 'Prima', 'Priscilla', 'Sir Prize', 'Liberty', 'Florina', 'Generos', 'Priam', 'Pionier', 'Voinea', 'Ancuta', 'Black John', 'Gloria', 'Granny Smith', 'Idared', 'Nured', 'Jonathan', 'NJR 2/11-20', 'NJR 64', 'Ribston Pepping', 'Sovari', 'Prima', 'Voinea florina', 'Azusa', 'Akane', 'Ardelean', 'Cardinal', 'Romus 3', 'Discovery', 'NJR 64C', 'Claralb', 'NJR 60', 'Romus 2', 'Italia Cj', 'Rozde Virginia', in Transylvania. Except 'Generos' that shows horizontal resistance, others have vertical resistance determined by *Vf* gene. Sierotzki *et al*. (1994) reported that specific pathogen genotypes are specific to host genotype because isolated isolates show intensive lesions from their isolated cultivars, but not in others.

In Turkey, there is a lack of studies about cultivars' reactions up to now. Turkoglu and Erkal (1967) conducted a selection study to choose resistant cultivars from local varieties against apple scab in Central Anatolia climatic conditions and, 37 resistant, 19 moderate and susceptible cultivars were determined in 9 different provinces. Recently, some studies have been conducted by our group in many cultivars that are related to resistance under natural infection conditions during three years (unpublished data).

MOLECULAR STUDIES OF APPLE SCAB RESISTANCE

The genes conferring resistance to apple scab have been known to exist in some cultured and crabapple varieties. In apple breeding programs, studies have been conducted in connection with monogenic resistance from wild type apples and studies have been going on for 20 years to obtain resistant cultivars (Crosby *et al*. 1992). One of the important sources of resistance is *Malus floribunda* Sieb., clone 821 among the crabapple Malus in apple breeding strategies because *M. domestica*, domestic type, does not contain these genes. The resistance of genes has been known for 60-80 years (Crosby *et al*. 1992). The *Vf* gene originated from *M. floribunda*, the most known, confers resistance to apple scab for races 1-5 (Williams and Kuc 1969). Thus, these apple cultivars have durable resistance. Also, *M. floribunda* 821 and its derivatives maintain resistance to race 6 (Parisi *et al*. 1993), but they are vulnerable to race 7 (Roberts and Crute 1994) However, an isolate of apple scab could infect a cultivar that has *Vf* resistant gene (Parisi *et al*. 1993; Roberts and Crute 1994) and in order to develop a cultivar against disease resistance, genes have been introgressed into domestic types especially from wild type, using traditional breeding techniques for a long time (MacHardy 1996). Besides the traditional techniques, molecular markers linked to resistance gene *Vf* to apple scab have been identified using molecular-based methods recently. By the year 2000, 18 resistant cultivar to apple scab maintained *Vf* gene from *M. floribunda* had been developed (Janick 2002).

Resistant genes have been identified in different crabapple cultivars such as 'Adams', 'Adirondack', 'American Spirit'(Amerspirzam), *baccata* 'Jackii', 'Cardinal', 'Centurion' (Centszam), 'Dolgo', 'Donald Wyman', 'Doubloons', *floribunda*, 'Hery Kohankie', 'Indian Summer', 'Liset', 'Ormiston Roy', 'Prairiefire', 'Professor Sperenger', 'Purple Prince', 'Red Jewel' (Jewelcole), 'Robinson', 'Royal Raindrops' (JFS-KW5), 'Sentinel', 'Strawberry Parfait', 'Sugartyme' (Sutyzam) and *x zumi* 'Calocarpa'. These genes are isolated and used in plant breeding. Amog these, the most known types are *Vm* gene from *Malus micromalus*, Vr gene from *M. pumila*, *Vbj* gene from *M. baccata jackii*, *Vb* gene from Hansen's baccata 2, *Va* gene from Antonovka PI172623 (Williams and Kuc 1969), *Vj* gene from Jonsib and *Vc* gene from Cathay Crab. As stated before, *Vf* gene originated from *M. floribunda*, an ornamental crabapple variety, is the most used one in studies (Keen 1990). *Vf* gene has been identified in 70 resistant varieties up to now (Janick *et al*. 1996) and thus there are many resistant varieties all around the world.

Since many resistance genes have been identified to apple scab, its necessary to transfer more than one gene to cultivar using traditional breeding methods. Therefore, it is possible to determine which varieties carry these genes. Molecular markers which are tightly linked to genes, *Vf* (Tenzer and Gessler 1997; Tartarini *et al*. 1999; Xu *et al*. 2001; Huaracha *et al*. 2004), *Vr* (Hemmat *et al*. 2002), *Vr2* (Patocchi *et al*. 2004), *Vx* (Hemmat *et al*. 2002), *Va* and *Vb* (Hemmat *et al*. 2003), *Vm* (Patocchi *et al*. 2005), *Vh2* and *Vh4* (Bus *et al*. 2005a), *Vh8* (Bus *et al*. 2005b) and *Vbj* (Gygax *et al*. 2004) have been identified and converted into sequence specific PCR-based markers including linked random amplified polymorphic DNA (RAPD), simple sequence repeat (SSR), sequence characterized amplified region (SCAR). The resistant genes in cultivars can be determined using these markers linked to the resistance genes that can be identified.

Vf gene conferring resistance to apple scab was first identified in McShay (Sandskar and Gustafsson 2004). Prima was the first resistant variety that was bred with *Vf* gene (Dayton *et al*. 1978).

For breeding, sexual hybridization studies were conducted between the cultivars known to be resistant such as 'Florina', 'Liberty', 'Mc Free', 'Priam', 'Prima', 'Primula', 'Priscilla', 'Resista' and 'Selena' and susceptible cultivars and *Vf* gene could be maintained to varieties with no infection (Blazekb *et al*. 1999). Using *Vf* gene from *M. floribunda* 821, characterization studies were conducted in Czech apple cultivars (Vejl *et al*. 2003; Melaunova *et al*. 2004).

Plants have biochemical defence mechanisms against pathogens. The rapid synthesis of phenolic compounds (Schwalb and Feucht 1999) and phytoalexin have antifungal properties (Stract 1999) that play an important role in disease resistance. The resistance genes are known to be involved in regulating the phenol synthesis in resistant genotypes (Michalek *et al*. 1999). Thus, phenolic acid metabolism is generally related to disease resistance. In relation to this, many studies have been conducted about the role of plant methabolites in *Vf* resistance mechanism. Among these, chlorgenic acid, a derivative of cynnamic acid is the most important one which has antioxidant property in leaves and fruits (Torel and Cillard 1986). According to a report, the elicitor, yeast, application to the cell suspansions of cultures of apple scab-sensitive 'McIntosh' and –resistant 'Liberty' cultivars has induced new six compounds including malusfran, 2′-hydroxyaucuparin in response to cell and cultured medium of resistant varieties, but not in susceptible ones. These compounds were reported in most of the Rosaceous plants (Hradzina 1998). Chlorgenic acid was studied in resistant ('Topas', 'Goldrush', 'Goldstar') and susceptible ('Golden Delicious Weinsberg' and 'Golden Delicious' clone B) apple cultivars (Petrovsek *et al*. 2003). In leaves of apple scab resistant 'Goldrush', chlorogenic acid had the highest rate.

CONCLUDING REMARKS

Being one of Turkey's major staples, apple is cultivated largely on several locations throughout the country. Lately, Turkey has been targeting European markets more seriously applying new techniques such as cultivar standardization and modern production systems. Although Turkey is the 6th largest apple producer in the world market, total amount of supply is far less below the potential. A drastic increase in capacity requires the building of new cultivation establish-

ments immediately. Making use of these establishments, Turkey will be able to meet the expectations of the European market in both diversity and quality.

Recently, largely cultivated and universally renowned winter species such as 'Red Delicious', 'Golden Delicious', 'Granny Smith', Gala group, 'Fuji', 'Jonagold', 'Idared', 'Jonathon', 'Black Staymen Improved 201' and summer species such as 'Starkearliest', 'Beacon', 'Vista Bella', 'Jersey Mac', 'Summered' have begun to be produced in large scales in Turkey.

Turkish Ministry of Agriculture is the major force, which is steering and supporting the agricultural production. Privately owned businesses with international ties and some European based nurseries are promoting rootstock and species diversity to local producers and contributing to steering activities of the ministry.

There are currently several enterprises performing both rootstock and seedling importation and production in Turkey. Nevertheless importing seedlings bears another problem about epizootic mainly caused by previously unknown viruses in Turkey and galls which are caused by *Agrobacterium tumefaciens*.

Although there are numerous studies on the yield and quality adaptation of largely cultivated newly introduced new breeds, studies particularly on apple scab and reaction to other pathogens are largely missing and there is still need for new research to be conducted in this field.

There are no substantial studies on reactions of species against phytopathological problems, yield and their impact on both yield and quality as of writing of this document. Studies in this area must be supported and coordinated by universities and related directorates in Ministry of Agriculture, detailed projects should be carried out and the results of these studies must be realized.

Turkey where there is an intensive application of pesticides against apple scab is considered as an important market for both local and foreign agricultural chemical companies. Moreover, application of fungicide without considering disease epidemiology limits the probability of success, leaving unwanted residual chemicals to remain over the product. The excessive use of chemicals causes contamination risks such as soil contamination, underground water contamination and air pollution. Furthermore, excessive chemical use causes an increase in production costs.

Although early warning against apple scab studies started as early as 1960's, substantial results from these studies has been concluded and integrated into computer based prediction systems in recent times. In spite of the development of these systems, evaluation of meteorological data and warning of producers in timely manner, frequency of application of pesticides and consumed amount are still far more over acceptable range. The compliance of the producers to the early warning system advisories will increase the performance of the struggle against apple scab drastically.

In the Early Warning equipped areas, together with the meteorological data, the deployment of spore traps and documentation of ascospore flight and the amount and training of the producers are important factors in increasing the performance of the struggle against apple scab. These studies are important tools in the hands of related agencies, which are seeking for ways of stopping the excessive application of chemicals.

These methods have proven to be effective in important apple production areas where producers used to apply excessive chemicals against black scab. The frequency of application has recently reduced from 7-8 applications to merely 2-3 applications. The system accounts for a cost reduction of some 5 Million YTL (3.5 M USD) in Isparta and about 3 Million YTL (2M USD) in Sakarya. However, advertisement based propaganda from the chemical producers is very influential on producers. This effect could only be prevented with the proper training of the entities and individuals working in agriculture sector.

Besides the traditional breeding techniques, biotechnological and PCR-base methods have been employed for resistance to disease recently. However, there is a lack of studies on this subject and researches must be proposed to focus on these subjects in Turkey because genetic diversity covers wild and domestic types as material source.

Turkey aims at the upper segment in the supply market employing new species and modern establishments. Infrastructure and R&D investments are currently increasing to support the growth of the amount, quality and exports potential.

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