Review

Important pests, diseases and weather conditions affecting apple production: Current state and perspectives

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Abstract

Apple production represents 20 % of the cultivated area of rosaceous fruit trees in Morocco. It forms the backbone of the economy for growers in the Ifrane Province. However, apples are subject to several pests, diseases and adverse weather conditions which cause significant economic losses to commercial fruit growers. The purpose of this literature review was to highlight apple pests, which include insects, diseases, and weeds, and establish the integrated pest management strategies. Several important pests posing problems for apple growers in the Ifrane Province include apple scab, apple powdery mildew, fire blight, apple tree root rot, codling moth, aphids, spider mites, scale insects and weeds. Adverse weather conditions cause water shortage, low chilling requirements, hailstorms and frosts. As a result, fruit quality is compromised by physical injury and reduced leaf area since the means of protecting the orchards are limited. The management of pests is based on the choice of rootstocks and cultivars. The orchard sanitation practices can reduce both active and dormant insects and pathogens. Emphasis will also be placed on biological control methods, as pesticide-intensive management practices pose substantial risks due to rising input costs, growing pesticide resistance, human health hazards and environmental degradation. Thus, the government restricts pesticide use.

Keywords: Apple, pests, diseases, pesticides, Morocco.

Importants ravageurs, maladies et conditions météorologiques affectant la production de pommes: État actuel et perspectives

Résumé

La production de pommes représente 20 % de la superficie cultivée en arbres fruitiers rosacés au Maroc. Il constitue la colonne vertébrale de l'économie des producteurs de la province d'Ifrane. Cependant, les pommes sont soumises à plusieurs parasites, maladies et conditions météorologiques défavorables qui entraînent des pertes économiques considérables pour les producteurs de fruits commerciaux. Le but de cette revue de la littérature était de mettre en évidence les ravageurs des pommiers, qui incluent les insectes, les maladies et les mauvaises herbes, et d'établir les stratégies de gestion intégrée des ravageurs. Parmi les principaux ravageurs posant des problèmes aux pomiculteurs de la province d'Ifrane, figurent la tavelure, l'oïdium, le mildiou, la pourriture racinaire du pommier, le carpocapse, les pucerons, les tétranyques, les cochenilles et les mauvaises herbes. Des conditions météorologiques défavorables entraînent une pénurie d'eau, des exigences de refroidissement réduites, des tempêtes de grêle et des gelées. Par conséquent, la qualité des fruits est compromise par les blessures physiques et la réduction de la surface foliaire car les moyens de protection des vergers sont limités. La gestion des nuisibles est basée sur le choix des porte-greffes et des cultivars. Les pratiques d'assainissement des vergers peuvent réduire les insectes et agents pathogènes actifs et dormants. L'accent sera également mis sur les méthodes de lutte biologique, car les pratiques de gestion à forte intensité de pesticides posent des risques considérables en raison de la hausse des coûts des intrants, de la résistance croissante aux pesticides, des risques pour la santé humaine et de la dégradation de l'environnement. Ainsi, le gouvernement limite l'utilisation de pesticides.

Mots-clés: Pomme, ravageurs, maladies, pesticides, Maroc.

INTRODUCTION

In Morocco, apple orchards cover a surface area of about 48,671 ha. In 2016, apple production was approximately 686, 964 metric tons with an average yield of 20 t/ha (Anonymous, 2017 as cited in Khoudane, 2018). This sector generates 3 million working days, and about 10 billion dirhams of annual turnover for the country (Alami, 2017). The main production areas are located in the mountainous regions of the Middle and High Atlas. Nearly 50 % of the area is concentrated in the region of Meknès-Tafilalet. There are about 39,000 apple farmers nationwide and 79 % of them have very small orchards (less than 1 ha) (MADRPM, 2014).

Apples are subject to numerous plant diseases, of which the vast majority is caused by pathogenic fungi. The most common diseases are apple scab (*Venturia inaequalis*), powdery mildew (*Podosphaera leucotricha*), tree root rot diseases (*Phytophthora spp.*) and fire blight (*Erwinia*

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amylovora). In apple-producing regions, disease control is a major annual expense for farmers. Several diseases such as *V. inaequalis* have been extensively studied worldwide (Ferree and Warrington, 2003).

The insect pest damage caused to apple trees in Morocco is mainly due to codling moth *Cydia pomonella* L. (Lepidoptera, Tortricidae); aphids, especially *Aphis pomi* De Geer (Homoptera: Aphididae); spider mites represented by *Panonychus ulmi Koch* (Acari: Tetranychidae) and *Tetranychus urticae Koch* (Acari: Tetranychidae); and San Jose scale, *Quadraspidiotus perniciosus* Comstock (*Hemiptera: Diaspididae*) (Vicente *et al.*, 2003). Weeds and other flora compete with apple trees for nutrients and water, especially in newly established orchards (Walsh *et al*., 1996).

Meteorological conditions are important environmental factors affecting apple quality. Adverse weather conditions cause water shortage, low chilling requirements, hailstorms and frosts. As a result, fruit quality is compromised by physical injury and reduced leaf area. In addition, the risk of pathogen penetration via injury is greater. Alternating periods of high and low temperatures in winter disrupt bud dormancy and the process of flower differentiation (Maazouz, 2016). Moreover, extreme climate events such as freeze injury during the blooming period as well as high temperature and heat during the swelling period can directly affect apple quality (Qu and Zhou, 2016). Insufficient chilling greatly influences flower initiation and fruit coloration along with deterioration in fruit texture and taste. Further, lack of proper chilling also poses serious problems like scab disease, premature leaf fall and infestation of red spider mite in apple (Rai *et al*., 2015).

With regard to pest control, it is difficult to establish a calendar-based treatment for all situations (Oukabli, 2004). Pesticide-intensive management practices pose substantial risks due to rising input costs, growing pesticide resistance, human health hazards, environmental degradation, and increasing government restriction on pesticide use. Keeping in view the importance of pests and meteorological conditions in the literature, the present study was carried out to highlight the phytosanitary problems and the impacts of climate change on apple production in the Ifrane province of the Middle Atlas of Morocco.

THE APPLE

Taxonomy, origin and distribution

Apple tree (*Malus x domestica* L. Borkh) belongs the family Rosaceae, the subfamily of Spiraoideae and the subtribe of the Pyrinae (Potter *et al.*, 2007). Thus, the family Rosaceae comprises 3,000 species (Shulaev *et al.*, 2008), with the third rank among the tree crops grown in temperate regions (Dirlewanger *et al*., 2002).

Apple is known to be among the oldest domesticated tree crops in the world (Jackson, 2003, Harris *et al*., 2002). This crop originated from the mountains on the border between Persia and Asia (Jackson, 2003, Harris *et al.*, 2002). Its distribution started around 3000 BC owing to human migration to Egypt, Greece and Italy (Jackson, 2003, Harris *et al*., 2002). Today, apple is cultivated everywhere in the temperate regions with high altitudes in the tropics on all continents except Antarctica (Luby, 2003).

The first apple orchards in Morocco were established in the 1920s on the basis of Spanish cultivars with low chilling requirements. The major areas of apple production are located in the regions of the High and Middle Atlas (MADRPM, 2014).

Apple production in Morocco

Apple production represents 20 % of the cultivated area of rosaceous fruit trees, making it the second largest area of rosaceous trees planted after almond in Morocco. Apple orchards cover a surface area of about 48,671 ha, producing over 600,000 metric tons of fresh apples per annum, with an average yield of 20 t/ha (MADRPM, 2014). The apple sector generates 3 million working days, 10 billion dirhams of turnover (Alami, 2017).

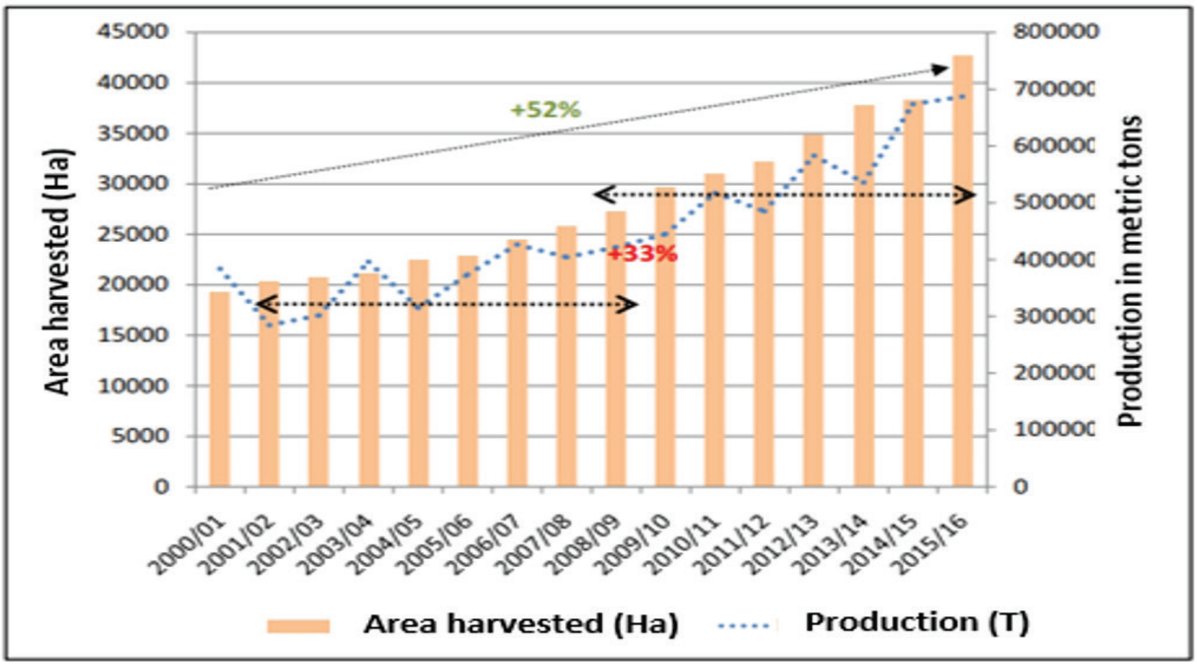

Figure 1: Evolution of the area and production of apple in Morocco (Anonymous, 2017 as cited in Khoudane, 2018)

In 2016, apple production was approximately 686, 964 metric tons. Over the past decade, the annual production of fresh apples has increased from 365, 295 metric tons (2001/2009) to 543, 490 metric tons (2009/2016), thus ensuring an increase by 33 % between the two periods as shown in Figure 1.

According to the survey conducted in the production year 2015/2016 (Anonymous, 2017 as cited in Khoudane, 2018), the geographical distribution of apple orchards showed that the production is dominated in the regions of Fes-Meknes and Draa-Tafilalet which account for 36 % and 31 %, respectively, of the surface area cultivated in the country (Figure 2). The production regions are located in the mountain range of the High and Middle Atlas of the country. The number of apple farmers in the country is about 39,000 of which 79 % of them have very small orchards with surface area less than 1 ha. Orchards with surface less than 3 ha represent 94 % of orchards and 46 % of the total area. An average area per orchard is 0.8 ha (MADRPM, 2014).

Botany and cultivation

Apple trees are deciduous, hermaphroditic trees (Westwood, 1988). Buds are ovoid, leaves are serrate or lobed and flowers grow in cymes and are white, pink or carmine in colour. The fruit is the pome or apple which ranges from 5 to 9 cm in diameter (Westwood, 1988). The haploid number of chromosomes is 17 and most commercial cultivars are diploid. Triploid cultivars (51 chromosomes) exist, but their pollen has a low viability (Dennis, 2003).

In autumn, growth of the trees ends with extensive leaf drop and the formation of the last buds prior to obtaining winter hardiness. Figure 3 shows the phenological stages of apple. In winter, little activity takes place in the plant except for winter chilling, a process where growth inhibitors are broken down in flower and vegetative buds. Cultivars differ in chilling requirements (Westwood, 1988).

Apple rootstocks and cultivars

Apple trees are propagated by budding or grafting on a range of rootstocks (Jackson & Palmer, 1999). The use of clonal rootstocks in stool beds is preferred over the use of seedlings, because uniformity and performance is less variable (Wertheim and Webster, 2003). A wide variety of combinations of rootstocks with scions has created cultivars that produce optimally in warmer, wetter or dryer regions (Jackson, 2003).

The choice of rootstocks varies in different regions depending on the environmental conditions, the economic constraints and the management strategies of the particular apple production enterprise (Wertheim and Webster, 2003) and is an important area of research in many parts of the world.

The most frequently used rootstock in Morocco is MM 106. Other commonly used Malling-Merton rootstocks are MM 109 and MM 111 and that of East Malling are M26, M9 and EMLA 9 (Oukabli, 2006; Walali and Skiredj, 2003). Other rootstocks recently introduced are Pajam1, Lancep, Pajam2, Cepiland and NAKB (Walali and Skiredj, 2003). These rootstocks affect the yield and quality of fruits.

The cultivars of apple in Morocco are Anna, Einschiemer, Vista Bella, Jerseymac, Summer Delbar, Earlygold, Sungold, Primgold, Ozark Gold, Newgold, Arkcharm, Sunrise, Akane and Dorset Golden. However, the main varieties used are Starking Delicious, Starkrimson, Gloden Delicious, Golden Smoothee, Dorcset Golden, Royal Gala, Ozargold, Anna and Fuji (Alaoui, 2005). Two factors to consider in choosing the cultivars are the inter-pollination and the cold weather conditions of the region. A variety planted without a pollinator cannot produce. This is why Anna has the pollinator Einschiemer. Vistabella is pollinated by Jerseymac, Idared, Prima, Malus Floribunda Everest and Akane pollinator Golden Delicious, Idared, Reine des Reinettes, etc. (Walali and Skiredj, 2003).

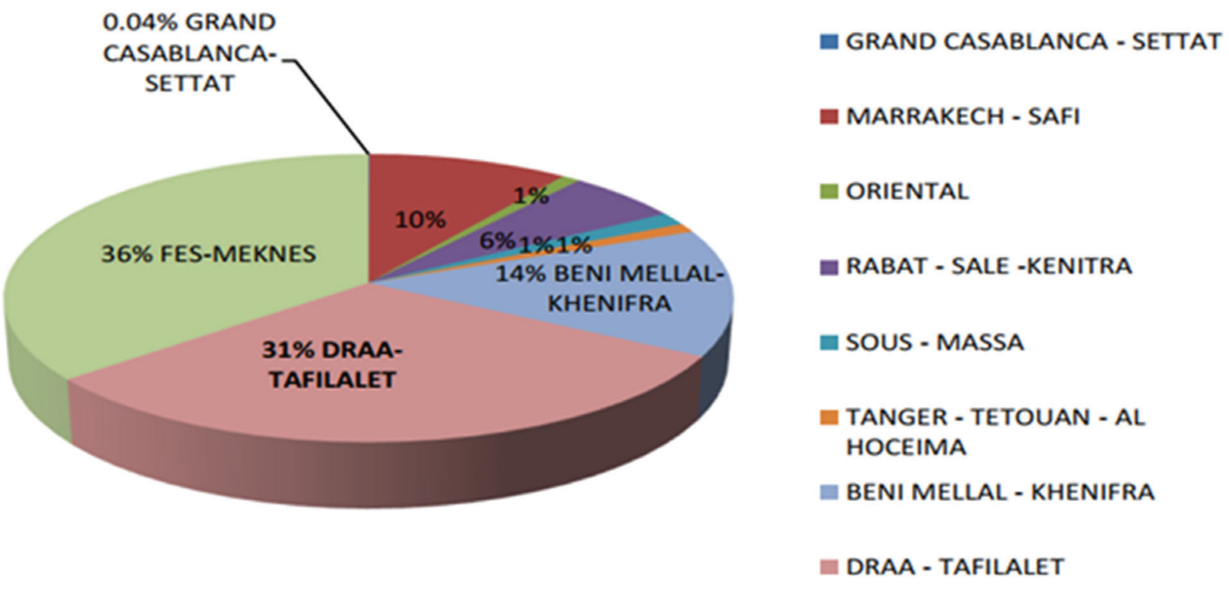

Figure 2: Distribution of the surface area of apple orchards surveyed by region in 2015/2016 (Anonymous, 2017 as cited in Khoudane, 2018)

It is necessary to take into account the density of planting and the shape of the trees. This has to do with the vigorousness of the cultivar-rootstock association, the fertility of the soil and the sunshine of the place. There are different planting systems: extensive orchards (80 to 150 trees/ha), intensive (1000 to 1500 trees/ha) and high density (2500 trees/ha) (Walali and Skiredj, 2003). Traditionally, but depending on cultivar, spacing between tree rows is 4.5 m to 5 m and 2.5 m to 4.5 m within the row. The height of the trees ranges from 1.5 m to 7 m and can be pruned to a round-head or pyramidal shape(Jackson & Palmer, 1999). This spacing corresponds to an optimal density in a system with intensive tendency and possibilities to mechanically work the inter-lines and to treat the trees easily (Oukabli, 2004).

CULTIVATION TECHNIQUES OF APPLE IN MOROCCO

Soil maintenance

Soil maintenance involves implementing a set of techniques to maintain the soil in good condition after planting and for proper root functioning. The soil can either be mechanically worked at the surface layer, or chemically weeded, or covered with mulch. All of these techniques are aimed at destroying weeds and reducing evapotranspiration. As the water resources are surplus, the cover of the soil with a temporary or permanent green manure allows enrichment of this soil with organic matter and an improvement of the quality of the fruits.

Fertilisation

It must be based on the soil analysis, which must be repeated every 3 years at the same place under the same conditions. As an indication and for trees in full production, it is necessary to add:

- 20 to 25 tons/ha of compost manure;
- 120 kg/ha of nitrogen split into 3 parts: 1/3 at bud break stage, 1/3 at flowering stage and 1/3 at fruiting stage;
- 50-100 kg / ha of P_2O_5 in the form of superphosphate during winter.

Potassium intake depends on the texture of the soil, particularly its clay content. It is applied in the form of sulphate or sulphate of magnesia. In sandy soil, the input is 50-75 U/ha of 75-100 U/ha in loamy soil and 150 U / ha in clay soil. Magnesia is supplied as sulphate of magnesia at a rate of 20-30 U / ha to compensate for losses. In case of deficiency, 30-50 U/ha is recommended. The other elements: Zn, Cu, Mn, Fe, B, can be brought in the form of foliar sprays.

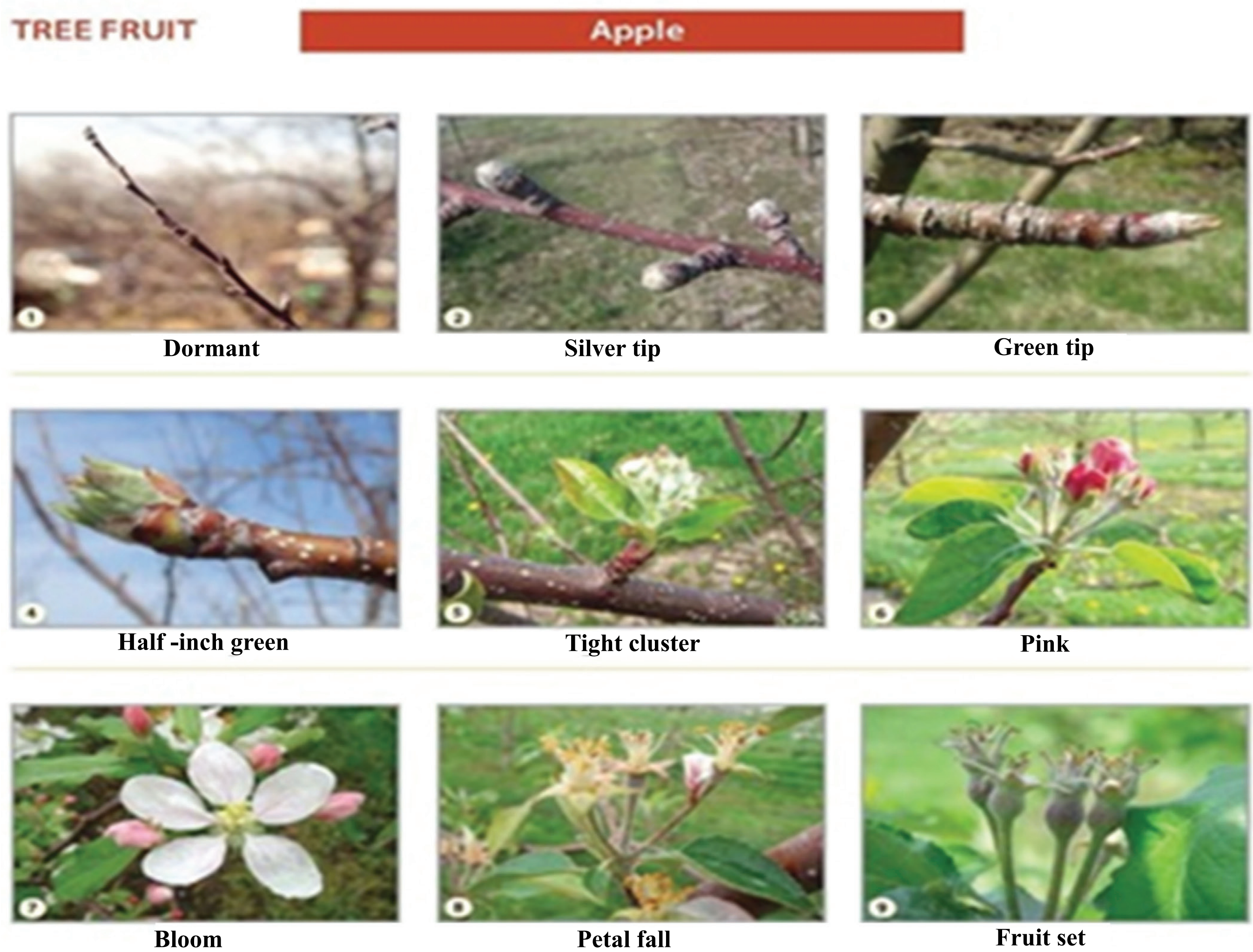

Figure 3: Common growth stages for apple trees (Norton, 2014)

Irrigation

The irrigation system must be defined before planting. It can be by runoff, submersion, sprinkling or drip. In sprinkling and micro sprinkling, the soil is a reservoir for the gradual water intake by plants. This technique consists in replenishing the soil reserve when it is exhausted. In the case of drip, it is considered that the volume of the wet soil is much too low and that it constitutes water transfer zone. The amount of water needed by the apple tree for growth and production varies from 700 to 900 mm /year. Water requirement of an apple tree during the growing season (March to September) decreases to 600 mm due to some amount of precipitations (Walali and Skiredj, 2003).

Pruning

The major types of pruning are corrective pruning, maintenance pruning and spur pruning. Corrective pruning makes it possible to give the tree a well-defined structure, and to obtain a certain balance between the different branches. The different types of sizes meet the objectives of intensification and duration of the orchard. The purpose of spur pruning is to lighten the branches, ensure sufficient light penetration and establish an annual balance between vegetation and fruiting (Walali and Skiredj, 2003).

Thinning

The improvement of fruit size and thus of the quality of the production can be obtained by the thinning of the fruits. This technique can be done manually for more security and precision, and involves removing a number of fruits to reduce competition. The operation organizes the load of the tree by allowing the maintenance of the fruits from the main flowers at the level of the bouquets (King flowers). It is practiced 1 to 1.5 months after the full bloom (Oukabli, 2004). 100g/100 L of carbaryl gives very good results, especially on the variety Ozark Gold (Alaoui, 2005).

ADVERSE WEATHER CONDITIONS

Climate change may cause an increase in the frequency and intensity of weather extremes, which could have adverse consequences for the agricultural productions and the economy at large.

Frost

It is a climatic phenomenon that is to be feared during the flowering stage, fruit set and at the beginning of the fruit's growth (April-May) of the apple tree (Maazouz, 2016). Frost can cause total destruction of flowers and fruits. When the duration of frost is short, rings of gel appear on the young apples. The damage may vary according to the intensity of the frosts and the phenological stage of the plant material.

Hailstorm

It is a climatic phenomenon that is becoming more and more frequent and alarming especially in the mountainous areas in Morocco. Hailstorm damage is important and can destroy the entire orchard. The fruit is the most vulnerable organ that is affected by hail (Maazouz, 2016). As a result, fruit quality is compromised by physical injury and reduced leaf area. In addition, the risk of pathogen penetration via injury is greater. According to some authors (Botzen *et al*., 2010), hailstorm damage will increase in the future if global warming leads to a further temperature increase. It was estimated that by 2050 climate change may have led to a 25-50% increase in crop damage due to hailstorms (Botzen *et al*., 2010).

Water shortage

Water shortage which is related to drought and over-pumping groundwater has, unfortunately, also hinders the extension of apple growing (Maazouz, 2016).The amount of water needed by the apple tree for growth and production varies from 700 to 900 mm/year. Water requirement of an apple tree during the growing season (March to September) decreases to 600 mm due to some amount of precipitations. The strongest demand occur in July-August (Walali and Skiredj, 2003).

Chilling requirements

The apple tree is a species of temperate zones, it requires a long period of dormancy to satisfy chilling requirements which vary between 800 and 1600 hours with the temperature lower than 7.2°C according to the climate in Morocco. The species can withstand temperature as low as -35 °C during dormancy, but the most favorable areas for cultivation are those with cold winters and moderately hot and relatively humid summers. The arrival of low temperatures in autumn (November) allows buds to enter dormancy early in the season (Oukabli, 2012).

Declining chilling has a negative to perennial temperate crops. This hinders the extension of the apple sector (Maazouz, 2016) in the mid-altitude areas to the benefit of crops that are less demanding. In addition, alternating periods of high and low temperatures in winter disrupt bud dormancy and the process of flower differentiation.

Mitigation measures against frost and hailstorms

The ways of mitigating effect against frosts and hailstorms is by using silver iodide burners and/or anti-hail nets. Effects of anti-hail nets on orchard light microclimate, apple tree growth, fruiting and fruit quality (Treder *et al*., 2016). Even so, in some years and under certain conditions, this remedy does not produce completely satisfactory results (Iglesias and Alegre, 2006). Adaptation measures that entail mitigation of damage may increase the resilience of farmers to the impacts of natural disasters and limit future costs of climate change (Botzen *et al*., 2010). Installation of anti-hail nets is very costly, even though it is a long-term investment.

APPLE DISEASES

Worldwide, apples are subject to numerous diseases caused by pathogenic fungi, bacteria, oomycetes and viruses. As a matter of fact, diverse fungal diseases include root rots, leaf spots, leaf blights, blossom blights, fruit decay, fruit spots, defoliation, trunk, branch and twig cankers (Grove *et al.*, 2003). Apple scab caused by *Venturia inaequalis* is considerably one of the most important diseases of apples worldwide (MacHardy, 1996). Powdery mildew caused by *Podosphaera leucotricha* is also common in all apple producing nations. Bacterial diseases such as fire blight, blister spot, blister bark, crown gall and hairy root affect apple (Grove *et al*., 2003). Fire blight caused by *Erwinia amylovora* is a serious bacterial disease which affects the entire tree and can lead to significant tree loss (Grove *et al*., 2003). Oomycetes, *Phytophthora spp*., causing crown and root rot are serious soil-borne diseases associated with moist soil conditions and may be responsible for tree death (Jackson and Palmer, 1999).

Apple scab

Apple scab, caused by the ascomycete fungus *V. inaequalis* (Cooke) G. Wint., is the most economically damaging pathogen in humid apple-producing regions world. Economic losses due to this disease can increase up to 70 % of the production value in case of insufficient control (Belete and Boyraz, 2017, MacHardy, 2000).

Apple scab can be detected on sepals, leaves, fruits, petioles, blossoms and even twigs of the tree, with symptoms commonly observed on the leaves and fruits (Vaillancourt and Hartman, 2000). A lesion first appears as an area which is a lighter shade of green than the surrounding leaf. The lesion is usually circular and as it increases in size it becomes olive-coloured and velvety due to production of asexual spores (conidia). Lesions on the leaves and fruit are generally blistered and scabby in appearance, with a distinct margin (Figure 4) (Belete and Boyraz, 2017).

Disease cycle of apple scab

V. inaequalis is a hemibiotrophic fungus, which means that it does not only grow on/in living leaves, but also has a necrotrophic phase. The scab fungus overwinters on fallen leaves in the orchard; ascospores produced in these leaves are primary inoculum for leaf and fruit infections in the spring. Conidia produced on living leaves re-infect host tissues throughout the season (Earles *et al*., 1999b). There is thus a remarkable synchronisation between the main ascospore releases and the most sensitive stages in the phenological development of the host plant (MacHardy *et al*., 2001).

In the early spring, the ascospores inside pseudothecia begin to mature and during favorable weather conditions, when leaves on the orchard become wet after the rain, spores are forcibly ejected into the air (Belete and Boyraz, 2017). The optimal temperature for the formation of ascogonia and maturation of the ascospores is 8-12°C and 16-18°C, respectively (Turechek, 2004).

The life cycle of *V. inaequalis* can be categorized into two phases: sexual or primary phase and asexual or secondary phase (Figure 5). The primary phase mainly takes place in winter and the secondary in summer (MacHardy, 1996).

Apple scab management

Management practices used for apple scab control are mainly by disrupting three reproductive strategies (MacHardy *et al*., 2001). According to Jamar (2011), two basic practices have been used to disrupt or halt *V. inaequalis*' three reproductive strategies: preventive practice, aiming to reduce the ascospore dose in the saprophytic phase and to make use of the apple tree's natural resistance; and defensive practice, aiming to protect the tree from ascospore and conidial infection. Preventive tactics include chemical, biological and physical methods for either attacking the fungus in the leaf litter or decomposing or removing the leaf litter, coupled with selecting cultivars with disease resistance characteristics. Defensive tactics include fungicidal treatments from bud break, in spring, until summer and sometimes until harvest.

Cultural techniques can help reduce disease infection through elimination of primary inoculum, which include removal or destruction of leaves on the orchard floor. Flail mowing or application of urea fertilizer in November and April is used to

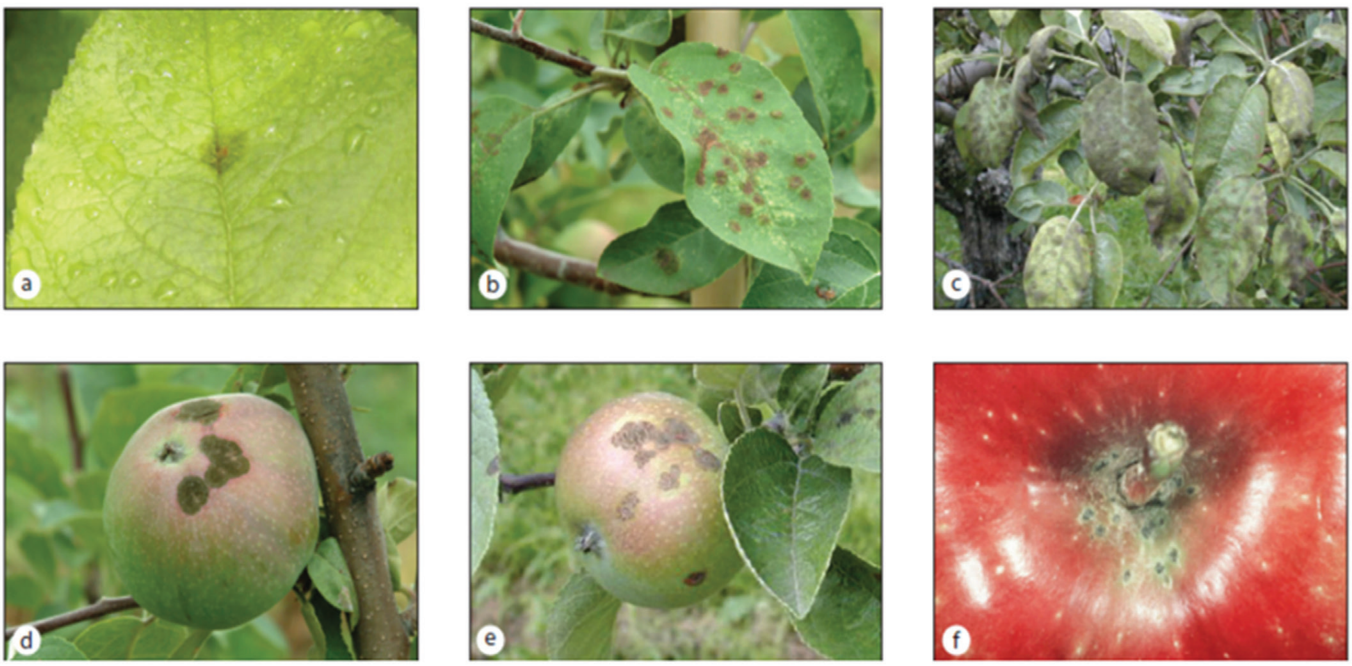

Figure 4: a) Apple scab lesion in the early stage of development; (b-c) secondary scab lesions on leaves; (d-e) scab lesions on fruits; and (f) pin-point scab (Gessler et al., 2006, Carisse and Jobin, 2012)

destroy leaf litter and the scab pseudothecia they contained. These methods achieve reductions in scab risk by 80-90 % and 50-66 %, respectively (Sutton *et al.,* 2000).

Scab-resistant apple cultivars are very useful. Hence, they often require minimum fungicide application and reduce the need for weather monitoring (Ellis *et al.,* 1998). However, the immunity of some species of wild Malus or certain cultivated genotypes can break down if new scab races appear (Bénaouf and Parisi, 2000). One good example is 'Golden Delicious', which was regarded as relatively scab resistant at the beginning of 20 century and has now become extremely susceptible (Gessler *et al.*, 2006, Jamar, 2011). Table 1 represents the susceptibility of selected apple cultivars grown in Morocco to apple scab.

Potential biological control method is not commercially available yet. The cultural and potential biological practices would have to be used in combination with a fungicide spray program and are not solely sufficient for management of apple scab to commercially acceptable levels (MacHardy, 1996). Fiss *et al.,* (2003) showed that several fungi (*Auerobasidium botrytis*, *Cladosporium spp*) and several epiphytic yeast strains from the apple tree phyllosphere inhibit *V. inaequalis* germination and mycelial growth on apple tree plantlets by up to 80 %. On susceptible apple cultivars, apple scab is primarily managed through the application of fungicides (Table 2). Strategies to delay the development of resistance to the different classes of fungicides under field conditions rely on restricting the number of applications per season of fungicides in each class and mixing or alternating fungicides of different classes (Bowen *et al.*, 2011).

Apple powdery mildew, *Podosphaera leucotricha*

P. leucotricha ((Ell. and Evherh.) E.S. Salmon)) is an ascomycete fungus in the Erysiphaceae family and is found in all apple-producing regions (Marine *et al.*, 2010).

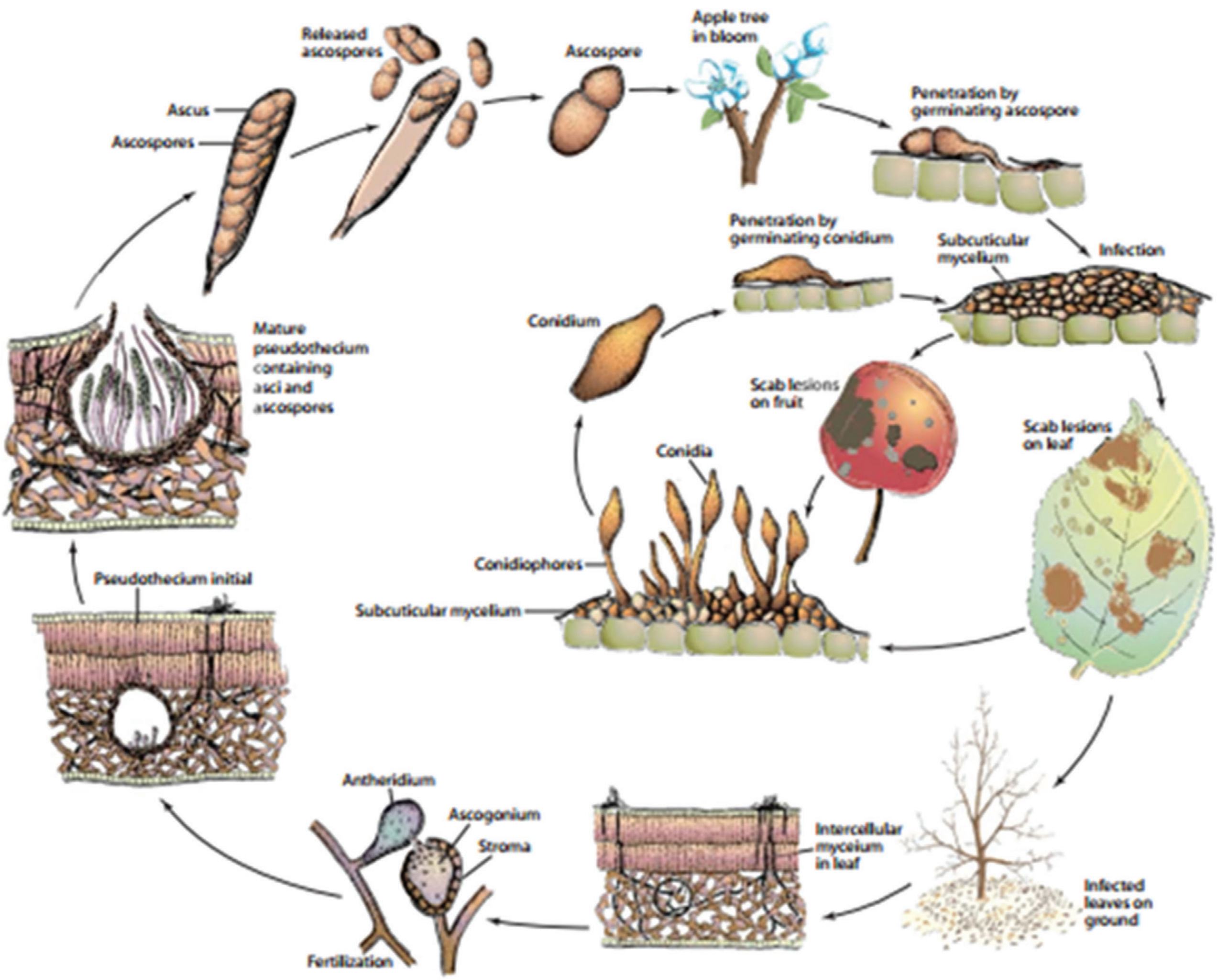

Figure 5: Disease cycle of apple scab caused by V. inaequalis (Agrios, 2005)

Table 1: List of apple varieties reaction to apple scab (Jamar, 2011; Jha *et al.*, 2010)

Very resistant	Resistant	Susceptible	Very susceptible
Gold Rush, Prima, etc.	Akane, Grimes Golden, Pinova, Jolibois, Honey Gold, etc.	Fuji, Early McIntosh, Delicious (Red), Jonagold, Idared, Reinette Clochard, etc.	Golden delicious, Ginger Gold, Gala, Royal Gala, Sunrise, Jerseymac, Reine, etc.

Symptoms

Powdery mildew of apple produces symptoms on young shoots, leaves, blossoms, and fruit. In general, symptoms are most noticeable on the leaves and fruits which can cause russeting of fruit and considerable crop loss (Marine *et al.*, 2010), have a silver-gray appearance and may exhibit defoliation, stunted growth, and die-back (Figure 6).

Disease cycle and epidemiology

Overwintering of *P. leucotricha* occurs as mycelium in dormant flower and shoot buds infected the previous year (Burchill, 1978). In spring, the infected buds break dormancy and the fungus resumes growth, colonizing the developing shoots and young leaf tissue. From these primary infections, asexual conidia are produced on conidiophores and dispersed by wind. Conidia will germinate at high relative humidity (greater than 70 %, which is commonly available in the microclimate of the lower leaf surface) at temperatures between 10 and 25°C; in contrast to most foliar fungal pathogens, leaf wetting is a deterrent to infection. The youngest leaves are the most susceptible, but become increasingly resistant as they mature (Marine *et al.,* 2010).

Management of apple powdery mildew

The use of less susceptible apple cultivars (Table 3) is perhaps the most effective means of preventing mildew. Primary infections can be controlled by removal of the primary inoculum sources (Marine *et al.*, 2010).The whole-field sanitation practice is performed by removal of infected fallen leaves. Pruning significantly reduces leaf scab incidence (Holb and Kunz, 2016). Secondary infections and fruit infections can be controlled by foliar fungicide applications (Marine et al., 2010). There are about fifteen registered active ingredients (Table 4) used to control apple powdery mildew in Morocco (ONSSA, 2017). Copper-based products and elemental lime sulphur are considered the most effective compounds against apple scab and powdery mildew (Holb, 2009). Reduction of primary inoculum and timely application of effective fungicides, such as sulphur, benzimidazole and sterol biosynthesis inhibitors, are the principal methods of disease control in the field (Reuveni *et al.*, 1998).

Apple tree root rot

Phytophthora diseases exist in the form of collar rot, crown rot and root rot and each refers to specific plant part infected. They are common and destructive diseases of fruit trees throughout the world (Ellis, 2008).This disease may be caused by any one of three species of *Phytophthora (P. cactorum, P. cinnamomi* and *P. cambivora*).

Diseased trees are commonly found in poorly drained areas of the orchard (Ellis, 2008). Seemingly, symptoms vary between tree species, but generally include reduced tree vigor and growth, yellowing or chlorosis of leaves, and eventual collapse or death of the tree. Symptoms of tree root rot in apples trees appear in the spring and are heralded by a delay in bud break, discolored leaves, and twig dieback.

The disease is prevalent in nurseries and orchards in wet or poorly drained areas. Consequently, infected trees wither and suddenly collapse. As the disease progresses to the base of the trunk and crown, purple canker can form at the base of affected trees (Ajaanid, 2016a).

Table 2: Fungicides used to control apple scab disease (ONSSA, 2017)

	Chemical class	Active ingredient
Contact fungicides	Inorganic	Copper fungicides: copper hydroxide, copper oxychloride, copper sulphate, copper oxide, etc.
	Dithiocarbamates	Ziram
		Thiram
		Maneb
		Mancozeb
	Phtalimides	Captan
	Guanidine	Dodine
Systemic fungicides	Anilinopyrimidines	Cyprodinil
	Benzimidazoles	Carbendazime
		Thiophanate-methyl
	Pyrimidines	Fenarimol
	Strobilurins	Kresoxim methyl
		Pyraclostrobin
	Triazoles	Difenoconazole
		Myclobutanil

Table 3: Apple cultivar susceptibility to mildew (Marine *et al.*, 2010)

Resistant	Susceptible	Highly susceptible
Delicious, Braeburn, Britegold, Enterprise, Fuji, Gala, Jonafree, Nittany and Winesap	Empire, Golden Delicious, Liberty and McIntosh	Cortland, Ginger Gold, Granny Smith, Idared, Rome Beauty

Fruit tree root rot caused by this fungal disease can survive in the soil for many years as spores. These spores are resistant to drought and to a lesser extent, chemicals. Fungal growth explodes with cool temperatures (around 56°F. or 13°C.) and ample rainfall. Hence, the highest incidence of fruit tree rot is during blossom time in April and during dormancy onset in September.

This disease is difficult to control and once infection is discovered, it is usually too late to treat, so choose rootstock with care. In fact, no rootstock is completely resistant to crown rot (Table 5). Dwarf apple rootstocks should be avoided since they are particularly susceptible. The most used rootstock in Morocco, MM106, is susceptible to *Phytophthora* spp. (Walali and Skiredj, 2003).

Sites that drain slowly or poorly or are subject to periodic flooding should be avoided. Irrigation management is obviously important in reducing the incidence of the disease. Infection is favoured if the amount of water applied exceeds losses through transpiration, evaporation and drainage.

Fosetyl-aluminium could completely control the disease, and increase growth and fruit yield (Utkhede and Smith, 1995). When applied alone, the protection provided by metalaxyl and by fosetyl-Al, and *Enterobacter aerogenes* in combination with metalaxyl, suggest the potential treatments for long-term field control of crown and root rot of apple trees (Utkhede and Smith, 1993).

Fire blight of apple

The disease is caused by the bacterium *Erwinia amylovora*, which is capable of infecting blossoms, fruits, vegetative shoots, woody tissues, and rootstock crowns (Norelli *et al.*, 2003). *E. amylovora* is a member of the family Enterobacteriacae. *Erwinia* are the only plant pathogenic bacteria that are facultative anaerobes (Agrios, 2005).

Symptoms of fire blight can be observed on all above ground tissues including blossoms, fruits, shoots, branches and limbs, and in the rootstock near the graft union on the lower trunk (Johnson, 2000). During periods of high humidity, small droplets of bacterial ooze form on water-soaked and discolored tissues. *E. amylovora* overwinters in a small percentage of the annual cankers that were formed on branches diseased in the previous season (Johnson, 2000). Various insects, such as bees, flies, and ants, are attracted to the sweet, sticky, bacteria-filled exudate, become smeared with it, and spread it to the

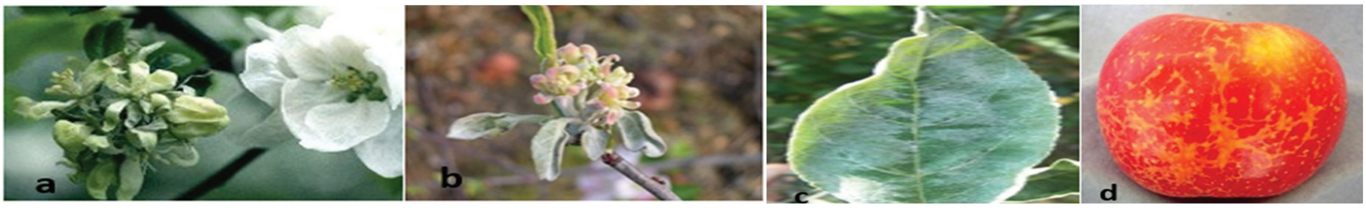

Figure 6: Signs and symptoms of apple powdery mildew (P. leucotricha) on (a and b) blossoms, (c) leaf and (d) fruit (Marine et al., 2010)

Table 5: Susceptibility of rootstocks to *Phytophthora* spp (Ellis, 2008)

Relatively resistant	Moderately susceptible	Susceptible	Very susceptible
M-9, M-2, and M-4	M-7 and MM-111	M-26 and MM-106	MM-104

Table 4: Fungicides used to control powdery mildew, *P. leucotricha* (ONSSA, 2017)

	Group	Active ingredient
Contact fungicides	Inorganic	Sulphur
	Phenol derivatives	Meptyldinocap
	Benzene derivatives	Chlorothalonil
Systemic fungicides	Anilinopyrimidines	Cyprodinil
	Benzimidazoles	Carbendazime
		Thiophanate-methyl
	Pyrimidines	Nuarimol
		Triadimenol
	Triazoles	Tetraconazole
		Mycobutanil
		Meptyldinocap
		Penconazole
		Difenoconazole
	Strobilurins	Kresoxim methyl
		Trifloxystrobin

flowers they visit afterward. In some cases, bacteria are also spread from oozing cankers to flowers by splashing rain (Agrios, 2005).

Effective management of fire blight is multi-faceted and largely preventative. The grower must utilize a combination of sanitation, cultural practices, and sprays of chemical or biological agents to keep the disease in check (Johnson, 2000). Some cultivars exist that are moderately resistant to the disease (e.g., Red and Golden Delicious).

Sanitation practices aiming at reducing the inoculum in a field by removing and burning infected plants or branches, and at reducing the spread of bacteria from plant to plant by decontaminating tools and hands after handling diseased plants, are very important (Agrios, 2005).Management strategies also include the application of copper sprays at the silver- or green-tip growth stage to reduce primary inoculum in the orchard and the pruning of early season infections after bloom to reduce the amount of inoculum available for shoot infection (Van Der Zwet and Beer, 1992). Other active ingredients like fosetyl-aluminium, acibenzolar-S-methyl, prohexadione-calcium and laminarine help reduce the primary inoculum (ONSSA, 2017)

Brown rot

A fungal disease of fruit trees caused by two species of *Monilinia* spp. (Figure 5A). The fungus causes similar symptoms on all hosts, flower blight, fruit rot and cankers on stems (Ajaanid, 2016a). The disease is manifested by dryness of the flowers, drying out, then appearance of a canker patch on the branches, and a development of brown rot from a fruit injury in the orchard or in storage (Alaoui, 2005).

The pressure of *Monilinia* spp. in an orchard can be greatly reduced by the systematic elimination of mummified fruits and infected twigs. Knowledge of the degree of resistance of apple varieties can help in making decisions about the variety chosen. Fungicides are currently available to limit the damage of the fungus (Ajaanid, 2016a).

Postharvest diseases of apple

Fungal disease cause a vast wastage of long-stored apples. In addition, they speed up considerable postharvest losses of apple, depending on cultivar, season and production area among other factors (Valiuškaitė *et al.*, 2006). Infection by fungi and bacteria may occur during the growing season, at harvest time, during handling, storage, transport and marketing, or even after purchase by the consumer. Prominent postharvest diseases of apple caused by fungi include blue mould caused by *Penicillium expansum*; brown rot by *Monilinia sp., Alternaria sp.,* gray rot by *Botrytis cinerea*, and *Gloeosporium* rot by *G. albumand* and *G. Frugtigenum* (Valiuškaitė *et al.*, 2006).

Blue mold

Blue mold, *P. expansum*, can grow at temperatures as low as -3ºC and conidia can germinate at 0 ºC. Spores of Penicillium species are present in the soil, on the fruit surface, in the air of the store etc. Its preferred hosts are pomiferous fruits. This species is responsible for blue mould rot, a major postharvest disease of apples worldwide (Schovankova and Opatova, 2011).

Blue mold originates primarily from infection of wounds such as punctures, bruises and limb rubs on the fruit (Figure 7B). Blue mold can also originate from infection at the stem of fruit. The decayed area appears light tan to dark brown. The decayed tissue is soft and watery and the lesion has a very sharp margin between diseased and healthy tissues(Sugar and Spotts, 1999).

In the orchard, *Penicillium spp.* survives in organic debris on the orchard floor, in the soil, and perhaps on dead bark on the trees. Conidia are also present in the air and on the surface of fruit. In the packinghouse facility, DPA- or fungicide-drench solutions, flume water and dump-tank water are common sources of Penicillium spores for fruit infection during the handling and packing processes. Spores of *P. expansum* are also commonly present in the air and on the walls of storage rooms(Sugar and Spotts, 1999).

Alternaria rot on apples

Alternaria rot, caused by *Alternaria alternata* (Fr.) Keissl, occurs on apple fruit (*Malus* × *domestica* Borkh) worldwide. Initial infections can occur in the orchard prior to harvest, or during cold storage, and appear as small red dots located around lenticels. The symptoms appear on fruits within a 2 months period after placement into cold storage. *A. alternata* has been documented as a pre- and postharvest pathogen on *Malus* spp (Aldwinckle and Jones, 1990).

Growth of fungal mycelium within the locules but not the mesoderm of the fruit is characteristic of moldy core. Dry core is defined as a slow dry and corky rot that affects the tissue around the core (Figure 7C). Wet core rot generally

Figure 7: Decays symptoms of Monilinia fructigena (A), Penicillium expansum, and both Alternaria sp. and P. expansum (C) on apple fruit

develops more in storage but is an aggressive wet rot that may cause partial or complete fruit rot. External symptoms are generally rare and in some cases can be confused with coddling moth damage (Sutton *et al.*, 2014).

Gray mold on apples

Gray mold caused by *Botrytis cinerea* is a common postharvest disease of apples worldwide. The disease originates primarily from infection of wounds such as cracks at the stem-bowl area of apple fruit and punctures and bruises that are created at harvest and during postharvest handling. The decayed area is spongy and diseased tissue is not readily separable from the healthy tissue, but after an extended storage, advanced decayed fruit may become soft. Under high relative humidity, grayish spore masses and/or fluffy white to gray mycelium may appear on the decayed area. Except that a mild cider-like odor may be associated with gray mold decayed apple fruit, generally there is no detectable distinct odor from gray mold decayed fruit (Xiao and Kim, 2008).

Management of postharvest diseases

Prophylaxis

Bruised or wounded fruits are susceptible to postharvest diseases. While harvesting, fruits must be handled with care when picking and transferring fruit from bag to bin to avoid bruising or wounding. Moreover, the more mature a fruit, the more susceptible it is to storage diseases. Harvesting must be done at proper maturity.

Inoculum sources for rot pathogens cause diseases in storage and come from plant and soil debris. Use clean bins and minimize the amount of soil and plant debris brought in on bins. Warm temperatures also encourage pathogens to grow. Keep fruit cool after harvest. If delivering to a packinghouse, minimize time between harvest and delivery of fruit.

Biological control

Biological control using microbial antagonists such as bacteria and yeasts has emerged as one of the most promising of these alternatives. Emphasis is given to the attempts to introduce effective biological control agents (Table 7) able to reduce fruit losses by an improvement in their formulation.

Chemical control

Fungicides applied at bloom may reduce incidence of moldy core. Fungicides used for scab and powdery mildew during bloom generally keep these diseases in check. In the USA, there are four fungicides currently labelled for controlling *P. expansum* with postharvest application: captan, thiabendazole (TBZ), fludi-oxonil and pyrimethanil (Rosenberger, 2009).

The intense use of fungicides in the postharvest phase has contributed to the appearance of resistant isolates, widespread in packinghouses. Nowadays, fungicide resistance is frequently reported for the main fungal pathogens such as *Penicillium, Monilinia, Botrytis*, etc. Although the use of synthetic chemical fungicides remains a primary method of controlling postharvest diseases, the global trend appears to be shifting towards reduced use of fungicides, substituting them with alternative methods like biofungicides (Table 6) (Mari *et al*., 2014).

MAJOR INSECT PESTS OF APPLE AND THEIR MANAGEMENT

A large number of insect pests attacks to apple crops. Insect pests found in apple orchards can be classified into two groups depending upon plant parts which they attack. Direct pests are insects that feed on apple fruits while indirect pests are those that attack leaves, trunk and other parts of the tree. Examples of direct pests are maggot, codling moth and other internal fruit feeders (Sherwani *et al*., 2016). Nevertheless, an insect can be simultaneously direct and indirect pest.

The pest damage caused to apple trees in Morocco is mainly due to codling moth *Cydia pomonella* L. (Lepidoptera, Tortricidae), aphids, especially *Aphis pomi* De Geer (Homoptera: Aphididae), and mites represented by *Panonychus ulmi* Koch (Acari: Tetranychidae) and *Tetranychus urticae* Koch (Acari: Tetranychidae) (Vicente *et al.*, 2003).

The codling moth, *C. pomonella* L.

The codling moth, *C. pomonella* L. (Lepidoptera: Tortricidae), is the key pest of apple production worldwide (El Iraqui and Hmimina, 2016, Witzgall *et al*., 2008, van der Geest and Evenhuis, 1991). This species is widespread in all growing regions of pome fruits. It can develop in the orchards of the mountain massifs reaching 1,800 m of altitude. *C. Pomonella* occurs in four generations in Morocco (Hmimina, 2007).

Eggs are laid singly on leaves, blossoms and fruits. The freshly hatched caterpillars feed on leaves for a while, then burrow inside the fruits and feed on the pulp. The entry holes become quite conspicuous as these are filled with dry

Table 6: Microbial antagonists registered or in progress of registration for postharvest phase (Mari *et al*., 2014)

Microorganism	Product name	Pathogen target	Country
Bacillus subtilis	Avogreen	Collectotrichum glorosporiodes	South Africa
Aureobasidium pullulans	Boniprotect	*Penicillium expansum, Botrytis cinerea, Monilinia sp*	Germany
Candida sake	Candifruit	*P. expansum, B. cinerea, Rhizopus sp*	Spain
Pantoea agglomerans	Pantovital	*P. expansum, B. cinerea, Monilinia sp*	Spain
Pseudomonas syringae	Biosave	*Penicillium sp., B. cinerea, Mucor sp*	USA
Cryptococcus albidus	Yield plus	*Penicillium sp., B. cinerea, Mucor sp*	South Africa
Candida oleophila	Nevy	*B. cinerea, Penicillium sp*	Belgium

brown frass and are surrounded by a dark reddish ring. The infested apples become brighter in color than those that are not infested and also ripe prematurely. The fruits that are attacked early in the season often drop down before the crop is ready for harvest (Paul, 2008). The economic losses can reach 100 % of the total production (El Iraqui and Hmimina, 2016).

An integrated approach to codling moth control can help to manage insecticide resistance. Scouting and weather monitoring can be used to discern key emergence times for precision pesticide applications (Sisson, 2009, Croft and Riedl, 1991, Earles *et al*., 1999a, Lacey and Unruh, 2005). All the debris and weeds should be removed from old trees and orchard to prevent the hibernating larval to find shelter Band the trees with grass ropes or sac (Jute) cloth (Sherwani *et al*., 2016). In Morocco, chemical control is the main strategy used to protect orchards against codling moth. A wide range of insecticides (azinphos-methyl, chlorpyriphos-ethyl, diflubenzuron, thiacloprid, methoxyfenozide, spinosad, deltamethrin, etc.) are used to control the neonate larvae. The action threshold was usually exceeded, leading to an intensive chemical control, with an average frequency of 9 to 13 days (Hmimina, 2007). Codling moth has become resistant to many insecticides (Witzgall *et al.*, 2008).

The principle of sexual trapping is to attract male butterflies into a sticky trap using female sex pheromones. It allows knowing the dynamics of codling moths. A visual inspection should be performed on a sample of 1000 fruits by August 15 before the fall of the attacked fruit to determine the infestation rate of apple orchards (Ajaanid, 2016b). In Morocco, codling moth develops two complete generations and a third made partial by larval diapauses in spring.

Spiders mites

The European red mite, *P. ulmi Koch*, and the two-spotted spider mite, *T. urticae Koch*, both belonging to Acari family Tetranychidae, are the most common mite pests of apple. One of the reasons could be the capability of this polyphagous species to develop resistance to pesticides (Van Leeuwen *et al*., 2010). *T. urticae* is a polyphagous pest on a variety of annual and perennial crops (Naher *et al*., 2005). It disperses by ambulatory means (crawling) and aerial one by wind mostly in adult female stage (Naher *et al*., 2005, Jung, 2005). *P. ulmi* over winter as diapausing eggs laid on the bark of trees or smaller branches and spurs. During heavy infestation, areas of bark may even appear red due to the presence of many eggs.

European red mite injuries the tree by feeding on leaves destroying chlorophyll, and increasing respiration. This is accomplished by insertion of the mite mouth parts into the leaf cells to withdraw the contents. All motile stages feed on the foliage, preferably on lower surface of leaves, but both leaf surfaces are attached when populations are high. A characteristic of brown foliage, starting as a subtle cast to the green leaf which becomes bronze in severe cases, results from heavy mite feeding (Sherwani *et al*., 2016). Both of these species infest leaves and suck fluids from the cells. Large populations desiccate leaves, cause reduced fruit growth and yield, and may defoliate trees (Hoyt *et al.*, 1979, Beers, 1993).

Management of spider mites can be difficult because they have a short generation time, high reproductive potential, and rapidly acquire resistance or tolerance to acaricides (Tanigoshi *et al*., 1983, Beers, 1993).

According to the “Arthropod Resistance to Pesticides Database”, *T. urticae* has shown resistance to 94 active ingredients while *P. ulmi* has shown resistance to only 48 (Whalon *et al*., 2011) . Management of spider mites in orchards relies primarily on removal of branches carrying eggs of mites in autumn when leaves fall and activities natural enemies, especially predaceous mites in the family Phytoseiidae (Tanigoshi *et al*., 1983, Beers, 1993).

The biology of the two species is totally different. Therefore, the control strategy is not the same for the two species of spider mites.

European red mite

The control of “winter eggs” is done by observing 50 two-year-old branches with one branch per tree (in January-February) and if the threshold exceeds 60 % of infested organs, it is necessary to use an acaricide (ovicide). Dormant spray is applied to control the overwintering forms of apple pests (mealybugs, red mites and aphids). Full vegetation treatments from March or April depending on the year, is recommended to observe 100 leaves at the rate of 2 leaves/tree and to intervene with an acaricide if 40 to 50 % of leaves are infested.

Two-spotted mite

It is recommended that 100 leaves be examined at 2 leaves /tree and be treated with an acaricide if 40 to 50% of leaves are infested. The choice of the product is related to the population structure.

Aphids

Aphids (Homoptera: Aphididae) are small sap-sucking insects infesting both aerial and subaerial parts of a variety of plant species. They are cosmopolitan but are most abundant in temperate climates. The major species found in apple orchards are woolly aphid (*Eriosoma lanigerum* Hausmann), green apple aphid (*Aphis pomi* Degeer) and rosy apple aphid (*Dysaphis plantaginea* Passerini) (Singh and Singh, 2016).

Aphids directly damage the plants by sucking their nutrients, causing curling and twisting of tender shoots and general devitalization of plants. The inflorescence may fail to open fully when the part of the plant is heavily infested by either *Aphis pomi* or *Dysaphis plantaginea*. Sometimes fruits fail to develop normally and may also show various malformations, like twisting of pods, impaired developments of seeds, etc.(Singh and Singh, 2016). In gall-making aphids like *Eriosoma lanigerum*, direct injury is caused by making different types of leaf and stem galls which start with woolly formation between the nodes (Figure 8) and these galls subsequently serve as temporary abodes for those aphids.

The physical presence of a large number of aphids can be a cause for concern, and the honeydew they excrete promotes the growth of black sooty molds, which in turn reduce the crop's photosynthesis as well as its aesthetic value (Singh and Singh, 2016).

Figure 8: Woolly apple aphid (Eriosoma lanigerum) shoot colonies (Beers et al., 2010)

The development of resistant varieties of crops is the most practicable approach to tackle aphid problems (Smith, 2005). Regular monitoring and assessment of an orchard helps reduce the infestation of aphids. Other practices like pruning and application of dormant spray are preventative measures.

Predators and parasitoids are the most common bioagents used to control other insects. Predators such as ladybird beetles devour prey insects and usually consume many prey in their lifetimes. Parasitoids are a type of parasite that often do not prey on other insects as adults, but instead deposit their eggs inside (internal parasitoid) or on (ectoparasitoid) a host insect. After hatching, the immature form, i.e., the larvae, consumes the living host from within. All the hymenopteran parasitoids belong to the families Braconidae (subfamily Aphidiinae) and Aphelinidae). The woolly aphid population can also be effectively checked by an exotic parasitoid, *Aphelinus mali* Hald (Paul, 2008).

Chemical control is carried out with foliar spray of 20% of imidacloprid @ 50 cc/hl helps control green aphids, 500g/kg of flonicamid @ 14 g/hl against green aphids and rosy apple aphids, and 480g/l of thiacloprid @ 30 cc/hl all with a 14-day preharvest interval (PHI) (ONSSA, 2017).

Conservation of natural resources (air, soil, and water) is essential and hence management strategies should aim at developing the approaches which do not lead to degradation and/or depletion of these gifts from nature.

Table 7: active ingredients to control San José scale, *Quadraspidiotus perniciosus* (Comstock) (ONSSA, 2017)

Active ingredient	Dose (cc/hl)	Developmental stages	Mode of application	PHI (days)
480g/l of chlorpyrifos-ethyl	150 cc/hl	Mobile stages	Foliar spray	30
420 g/l of methylation	150 cc/hl	Adults	Foliar spray	30
Vaseline oil	2l/hl	Overwintering	Dormant spray	-

Table 8: Host plant species making up the herbaceous stratum in the apple plots

Botanical family	Species
Amaranthaceae	**Amaranthus albus* L.
Asteraceae	*Senecio vulgaris* L., *Silybum marianum* L., *Calendula arvensis* L., **Anacyclus clavatus* (Desf.) Pers., *Sonchus asper* (L.) Hill, *Sonchus oleraceus* L., **Chrysanthemum coronarium* L.
Borraginaceae	**Cynoglossum cheirifolium* L.
Brassicaceae	*Capsella bursa-pastoris* L., *Sinapis arvensis* L.
Caryophyllaceae	*Stellaria media* (L.)Vil, *Silene cucubalus* Wibel
Chenopodiaceae	*Chenopodium album* L.
Convolvulaceae	*Convolvulus arvensis* L.
Cruciferaceae	**Thlaspi arvense* L., *Diplotaxis tenuifolia* (L) DC.
Cuscutaceae	**Cuscutae pithymum* L.
Euphorbiaceae	*Euphorbia segetalis* L.
Fabaceae	**Lathyrus articulatus* L., *Vicia pannonica* Crantz, *Melilotus sulcata* Des., *Medicago hispida* Gaertn.
Fagaceae	**Astragalus boeticus* L., *Muscari comosum* L.
Geraniaceae	*Erodium moschatum* (L) L'Hér.
Graminaceae	**Sorghum halepense* (L.) Pers.
Labiaceae	*Lamium amplexicaule* L.
Lamiaceae	*Mentha pulegium* L.
Malvaceae	*Malva neglecta* W., *Malva nicaeensis* L.
Papaveraceae	*Fumaria vaillantii* Loiselier, *Papaver rhoeas* L.
Polygonaceae	**Rumex crispus* L.
Solanaceae	*Datura stramonium* L.
Urticaceae	*Urtica urens* L.

*: species which is not found in the plot of 'Golden' apple cultivar

San Jose scale, *Quadraspidiotus perniciosus* (Comstock)

San Jose scale, *Q. perniciosus* (Comstock) (Hemiptera: Diaspididae), insect is widely distributed in all the apple growing countries of the world. The insects are active from April to December. There are 6-7 overlapping generations in a year (Sherwani *et al.*, 2016).

The tiny insects suck the sap continuously resulting in weakness and ultimately death of young plants in the nursery. The leaves, twigs and fruits sometimes even the entire bark may be seen covered with ashy-grey scales which can be easily scraped off exposing the orange colored individuals beneath. The fruits present pink colored (Figure 9)areas around the scales and the market value of such fruits is depreciated (Sherwani *et al.*, 2016).

Figure 9: Apple fruit infested by San Jose scale (early season)(Beers, 1993)

Infested nursery plantation, buds, graft materials should be avoided. Shade trees especially willow, poplar etc. should not be planted in and around fruit orchards. Pruning of heavily infested branches during dormant period and their burning helps in preventing the build-up of the pest. Dormant spray is applied during late dormant stage (before green tip stage) in order to ensure the suppression of scale (Sofi, 2017, Paul, 2008).

The parasite, *Encarsia perniciosi* Tower, may also be released to check the overwintering population and have proved effective in controlling this insect pest (Sherwani *et al.*, 2016). Table 7 shows some active ingredients certified for chemical control of this pest.

WEED MANAGEMENT IN APPLE ORCHARDS

Weeds and other flora compete with apple trees for nutrients and water, especially in newly established orchards(Walsh *et al.*, 1996). The dominant species in Moroccan apple orchards could be *Sinapis arvensis*, *Malva neglecta*, *Mentha pulegium* and *Malva nicaensis* according to weed sampling in a Golden apple cultivar and Anna cultivar plot Table 8 (Vicente *et al*., 2003).

Mulching is a common way to control weeds and reduce resource competition in orchards (Merwin and Stiles, 1998). Weed seeds are prevented from germinating and growth of emerging seedlings is suppressed by covering the soil surface with mulch (Bond *et al.*, 2003). Mulching in the orchard understory can have several additional positive impacts, including enhanced soil fertility and organic matter, conserved soil moisture, and increased tree growth (Granatstein *et al.*, 2003, Merwin, 2004).Another downside is that, when perennial weeds appear, they cannot be managed effectively by using mulches(Bond *et al.*, 2003).

The sandwich system (living mulch within rows of apples trees, combined with mechanical weed control between rows) and to a full covering of short-clipped grass on the entire surface (Tahir *et al.*, 2015) is a sustainable approach. This method is reported to show the lowest costs for practical weed control without any negative effect on tree performance and yield (Stefanelli *et al*., 2009). The sandwich system can also decrease pests and diseases and increase biodiversity (Schmid and Weibel, 2000).

Weeds are often controlled by sprays of synthetic chemical herbicides in strips beneath the orchard canopy (Yao *et al*., 2005). Glyphosate, diquat, oxadiazon and Oxyfluorfen are some of the active ingredients used in an apple orchard (ONSSA, 2017).

CONCLUSION

Apple production represents 20% of the cultivated area of rosaceous fruit trees, making it the largest rosaceous trees planted in Morocco. The main production areas are located in the mountainous areas of the Middle and High Atlas. However, apples are subject to plant diseases, insect pests and weed infestation. Meteorological conditions are important environmental factors affecting apple quality. Adverse weather conditions cause water shortage, low chilling requirement, hail and frosts. As a result, fruit quality is compromised by physical injury and reduced leaf area. In addition, the risk of pathogen penetration via injury is greater.

Conventional management of apple pests is generally achieved by the application of chemical pesticides on a calendar-based schedule. Increased pathogen and pests insensitivity to synthetic pesticides, coupled with public demand to reduce pesticide use stimulated by greater awareness of environmental and health issues, has placed more emphasis on alternative pest control strategies. Conservation of natural resources (air, soil, and water) is essential and hence management strategies should aim at developing the approaches which do not lead to degradation and/or depletion of these gifts from nature.

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