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A review of research on diseases and pests of almonds in Morocco

M. Boulif

Plant Protection Department, National School of Agriculture,
BP S/40, Meknès 50001 (Morocco)

Abstract. In Morocco, almonds cover 151 Kha producing 19.8 Kt of shelled nuts. This makes almonds rank 2nd after the olives in terms of area covered. Due to its rusticity, the almond tree is found in various ecological zones throughout Morocco, generating additional income to small farmers operating on marginal lands. The major diseases attacking almond orchards in Morocco are Monilia blossom blight (*Monilia laxa*), leaf curl (*Taphrina deformans*), anthracnose (*Gleosporium amygdalynum*) and shothole (*Coryneum beijerinckii*) while crown gall (*Agrobacterium tumefaciens*), nematodes (*Meloïdogyne* spp.) and *Phytophthora* root rot may occur in almond nurseries. The most prevalent pests on almonds remain the mites (*Tetranychus* spp., *Briobia rubrioculus*), the aphids (*Myzus persicae*, *Brachycaudus amygdalinus*, *Hyaloperus pruni*) that attack the foliage of almond, older and stressed almonds trees are subject to the attack of the Flat-headed Root Borer (*Capnodis tenebrionis*) and the bark beetles (*Scolytus amygdali*). While fungal diseases can be easily controlled through appropriate fungicidal sprays during critical periods, the flat-headed root borer and the bark beetle remain uncontrolled because of lack of registered appropriate pesticides that are cost effective to be used by the farmers. The Green Morocco Plan (Plan Maroc Vert) initiated in 2008 to enhance agricultural production in Morocco and ensure food security of the country, has opted for extending almond plantations to valorize marginal lands, thereby increasing farmers income while preserving soils from erosion in these areas. To ensure the success of the new plantations, certified disease and pest-free almond nursery stocks are promoted within the Green Morocco Plan.

Keywords. Almond – *Prunus amygdalus* – Morocco – Pests – Diseases – IPM – Breeding.

Révision des recherches menées sur les maladies et les ravageurs de l'amandier au Maroc

Résumé. Au Maroc, les amandiers sont cultivés sur 151 Kha et produisent 19,8 Kt de fruits décortiqués. Ceci place les amandes au deuxième rang après les olives en termes de surface. En raison de sa rusticité, on rencontre l'amandier dans diverses zones écologiques à travers le Maroc, permettant un revenu additionnel aux petits agriculteurs exploitant des terres marginales. Les principales maladies qui attaquent les vergers d'amandiers au Maroc sont la moniliose (*Monilia laxa*), la cloque de l'amandier (*Taphrina deformans*), l'anthracnose (*Gleosporium amygdalynum*) et la criblure (*Coryneum beijerinckii*) tandis que la galle du collet (*Agrobacterium tumefaciens*), les nématodes (*Meloïdogyne* spp.) et la pourriture des racines due à *Phytophthora* peuvent survenir en pépinières. Les ravageurs prévalents de l'amandier sont les acariens (*Tetranychus* spp., *Briobia rubrioculus*), les pucerons (*Myzus persicae*, *Brachycaudus amygdalinus*, *Hyaloperus pruni*) qui attaquent le feuillage de l'amandier ; les amandiers plus vieux et stressés font l'objet d'attaques du capnode (*Capnodis tenebrionis*) et du scolyte (*Scolytus amygdali*). Tandis que les maladies fongiques peuvent être facilement contrôlées par des nébulisations fongicides appropriées pendant les périodes critiques, les capnodes et scolytes restent incontrôlés en l'absence de pesticides enregistrés appropriés qui soient d'un bon rapport coût-efficacité et puissent être utilisés par les agriculteurs. Le Plan Maroc Vert, démarré en 2008 pour encourager la production agricole au Maroc et assurer la sécurité alimentaire du pays, a opté pour accroître les plantations d'amandier afin de mettre en valeur les terres marginales, augmentant ainsi le revenu des agriculteurs tout en protégeant les sols de l'érosion dans ces zones. Pour s'assurer du succès des nouvelles plantations, des porte-greffes d'amandier de pépinières, certifiés indemnes de maladies et de ravageurs, sont favorisés dans le cadre du Plan Maroc Vert.

Mots-clés. Amandier – *Prunus amygdalus* – Maroc – Ravageurs – Maladies – IPM – Amélioration.

I – Introduction

Due to their rusticity, requiring little care as compared to other fruit crops, their drought tolerance and adaptation to diverse environments, the almonds conquered large areas in Morocco, ranking 2nd after the olive tree (Anonymous, 2012). Historically, the almond cultivation has known 2 main expansions after independence in 1956: the first one was in the 1960's when the Government of Morocco decided to expand almond plantations along those of olives, to protect land from erosion especially in hilly and mountainous areas, and the 2nd since the advent of the Green Morocco Plan (Plan Maroc Vert, GMP) in 2008, with objective of diversifying farmers' income. At present, the almond insures 1 millions work days and generates a commercial value of 750 Million Dh.

In Morocco, the Almond sector is structured in 2 sub-sectors:

1. The Traditional sub-sector where trees propagated through seeds, are grown in uneven patterns on shallow soils, limited water and nutrients supply, non optimal crop husbandry practices, mostly intercropped with other plants especially in small-holding farms.
2. The Modern sub-sector where almonds are planted in rows, in more fertile soils with adequate crop husbandry techniques including irrigation, fertilizing and plant protection programs. Even though the modern sector covers only 50% of the national almond area, it contributes by 80% to the total national production.

As can be expected, almonds in Morocco are subject to the attacks of a number of diseases and pests some of which are known worldwide. The importance of these diseases and pests and their impact on almond production and quality vary according to the varieties used, the local environment and the crops husbandry techniques used.

It goes without saying, that the traditional almond sub-sector using no plant protection means harbors a diversity of diseases and pests that cause great damage to the almond orchard. In fact, under these condition land owners are practicing a "gathering" type production system; they harvest whatever is left after the pests and diseases have taken their shares. In this respect we can say that the traditional almond production in Morocco is organic.

In the Modern sub-sector, where almonds are grown in rows of more performing varieties, generally introduced in accordance with modern markets' objectives, pests and diseases can cause heavy losses too when the environment is favorable to the pests and diseases and no control is practiced.

II – Major diseases of almond in Morocco

Research and observations carried out during the past 40 years showed that blossom blight (*Monilia laxa*), anthracnose (*Gleosporium amygdalinum*), leaf curl (*Taphrina deformans*), shot hole (*Coryneum Beijerinckii*) and crown gall (*Agrobacterium tumefaciens*) are very common in almond orchards in Morocco. Several other studies have reported the occurrence of virus diseases on almonds in Morocco.

1. Fungal diseases

While fungal diseases go unnoticed in extensive almond plantations, in mountainous and semi-arid areas, they were very importance in the 1970's in intensive almond production orchards using more performing varieties originating from California, southern Europe and Tunisia, like Abiod, Nec + Ultra and others. In a monitoring study conducted in 5 modern almond farms in the Meknes area in the 1970s, Lamnoui (1976) found that blossom and twig blight (*Monilia laxa*) and anthracnose (*Gleosporium amygdalinum*) were the most devastating fungal diseases on selected varieties,

while leaf curl (*Taphrina deformans*) and Shot hole (*Coryneum beijerinckii*) were of lesser importance. Because of the gradual occurrence of the diseases during the growing season, farmers applied from 5 to 7 fungicidal sprays to protect their orchards.

In a subsequent study focusing on the 2 most susceptible varieties Abiod and Nec+Ultra, Aber (1977) found that 3 to 4 sprays of the associations Methylthiophanate + maneb and Captan + mancozeb, applied at bud break, flowering, fruit set and fruit development, greatly reduced the incidence of both *Monilia* blossom blight and fruit anthracnose in the treated orchards.

2. Crown gall

Even though it has been detected in several localities in the country, Crown Gall is a serious threat in the Meknes area where most of the stone fruit nurseries are located. The disease is especially important in nurseries where it can reduce the quality of young trees produced. Older trees seem to tolerate the disease.

Crown gall was intensively investigated by BENJAMA (1997) who studied the pathotyping of Moroccan isolates of *A. tumefaciens* and tested their sensitivity to the antagonistic strain K84. He showed that Moroccan strains were sensitive to pure extracts of strain K84 cultures suggesting that this possibility may be used in the field. Even though the method proved to be successful in other countries in North America and Europe, it did not gain wide use in Morocco where prophylactic measures are preferred.

3. Viral diseases

Fisher and Baumann (1977) have already indicated the wide occurrence of virus infection in zones of intense cultivation of almond, but almost un-existing in areas of extensive almond production. In graft transmission experiments all examined virus containing samples revealed to be infected by various strains of *Prunus necrotic ringspot virus* (PNRV). For intensive almond production, Fisher and Baumann recommended the indexing of varietal collections on imported certified virus-free rootstocks before the distribution of healthy bud wood to authorized private nurseries for further multiplication. For areas of extensive almond production they recommended the indexing of the varietal clones adapted to the specific ecological zones and their propagation on virus-free rootstocks.

In a more recent study, Koutou (2000) examined 156 samples originating from 24 almond orchards in the Meknès-Fes area, using the ELISA technique. He detected PNRSV in all almond orchards surveyed. The incidence of PNRSV varied from 17 to 30% among orchards and localities. With the aim of refining the technique of viral detection, EL JADD (2011) compared ELISA vs. RT-PCR techniques for detecting and extracting of RNA viruses (PNRSV, ACLSV, PDV) infecting stone fruits in Morocco. Both techniques detected PNRSV infection in 12 samples out of the 304 samples of almond leaves tested. Concerning PDV and ACLSV, samples with doubtful viral infections using ELISA technique were found to be virus-free by the RT-PCR technique, suggesting the joint usage of these 2 techniques for reliable viral detection in almond samples.

III – Major pests of almond in Morocco

Of the pests found on almonds, the flat-headed root borer (*Capnodis tenebrionis*) became a serious threat to all stone fruits during the droughty years in the early 1980s, especially in the Meknes region where almonds were heavily attacked along with apricots and prunes. This led to the pulling out of many devastated orchards. The larvae of this beetle attack the roots and crowns of trees that have been weakened by drought or disease. Hmimina (1989) has described the life cycle of this insect. Once eggs have been laid, control becomes difficult because of the subterranean

development of the larvae. Thus, baits containing hexachlorohexane (HCH) were applied to the soil 50cm around the almond stem base during the oviposition period. With the banning of this product in the 1990 due to environmental concerns, growers were urging for a substitute product that was as effective as HCH but less expensive (Moussaoui, 1995). Subsequently, new products came to be experimented, but their markets did not develop accordingly.

The bark beetle (*Scolytus amygdali*) was intensively investigated by Benazoun (1984) in two locations: Tafout and Beni Mella. Although some natural predators were found at that time, none was effective in controlling the bark beetle. A single spray of delta-methrin was partially effective when applied during spring emergence of adults (Benazoun and Schvester, 1989). Beyond the cost and environmental issues, the farmers were reluctant to apply pesticides fearing to damage crops grown in association with almonds. With the bark beetle becoming a serious threat not only in stressed orchards, but also in orchards that are well cared for, and considering the specificity of its biology, other methods including mass trapping using pheromones, will contribute to the integrated pest management of this insect.

Aside from the 2 major pests cited above, almonds may be attacked by various species of mites and aphids during the growing season (Benazoun, 2001; Boutaleb-Joutei, 2011).

IV – Integrated pest and disease management in almond in Morocco

1. Prevention through regulatory methods

In order to ensure the success of new plantations, Morocco has promulgated in 2004 a decree approving standards for the production, control, packaging, storage and certification of seeds and nursery stocks of rosaceous stone fruit trees including almonds and their rootstocks. The diseases and pest concerned are Crown gall, Verticillium, nematodes (*Meloidogyne*, *Xiphinema*, *Longidorus* and *Trichodorus*) and the flat-headed root borer *Capnodis tenebrionis*. Nursery stocks found or suspected to harbor one of the pre-mentioned diseases and/or pests will not be certified. Heavily attacked lots of plants or seeds are destroyed by incineration. Table 1 presents the standards required for virus diseases.

Lots found to harbor viruses and/or other pathogens or pests are simply incinerated.

With the advent of the GMP in 2008, institutional reforms of the Ministry of Agriculture and Marine Fisheries led to the creation of the National Office of Sanitary Safety of Food products (ONSSA) in 2010. This Office invested with the mission of controlling nursery and seed stocks among other things works diligently on updating regulatory texts to make them match the international standards.

Table 1. Standards required by ONSSA before nursery stocks and seeds stocks can be certified

Virus	Category		
	Pre-base	Base	Certified
Prunus Necrotic Ring Spot Virus (PNRSV)	0%	0%	1%
Prune dwarf virus (PDV)	0%	0%	1%
Apple Chlorotic Leaf Spot Virus (CLSV)	0%	0%	1%
Total	0%	0%	2% [†]

[†] Cumulative total of virus-infected plants by species.

2. Pesticides

Active ingredients presently registered for use on almonds are *Ziram*, *Thiram* and *Maneb* as fungicides. *Propargit* is registered for mite control (AMPP, 2015; Anonymous, 2015). No pesticide is labeled for aphid control on almond. While the use of chemical pesticides almost absent in the tra-

ditional almond sub-sector, it is a necessity in semi-intensive and intensive almond production. However, the list of pesticides registered for almonds is progressively shrinking. This will undoubtedly stimulate research to develop alternative methods for controlling pests and diseases.

3. Cultural practices

It goes without saying that appropriate crop husbandry practices such as adequate irrigation and fertilization of almond orchards is of paramount importance in preserving the good health of trees and therefore their productivity. Furthermore, the prevention of early development of diseases and pests relies heavily on sanitation practices, including pruning of affected branches and eliminating dead wood and fruit mummies. Attacked trees and colonized wood should be incinerated on the spot.

4. Breeding

During the last 40 years, researchers of INRA (National Institute for Agricultural Research) have surveyed the local almond populations and collected germplasm of importance to the almond breeding program. Foreign germplasm was also introduced from California, Europe and Tunisia. In total, the current almond collection consists of 245 accessions that are maintained in INRA's experiment stations where active breeding efforts led to the selection late flowering almond varieties to avoid the risk of spring frost along with other qualities required by almond markets. The selection of late flowering varieties will undoubtedly contribute to reduce the risk of *Monilia* infection by avoiding the coincidence of flowering with the wet winter periods. This explains why the association 'Ferragnes'- 'Ferraduel' composed of the two late flowering varieties that are auto-incompatible has become popular since the advent of the 21st century. The number of nursery stocks produced of these 2 varieties increased from 1.45 million plants in 2008 to 3.2 million in 2012, thereby accounting for almost half of the Moroccan almond orchard. More recently, continuous breeding efforts have led to the selection of 2 almond varieties that are late flowering but self-fertile, 'Lauranne' and 'Mandaline'. Nursery stocks of these 2 varieties increased from 78,000 plants sold in 2010 to 110,000 in 2012, representing à 41% increase in a 2 year laps time (Anonymous, 2012).

It is hoped that the study of the genetic diversity of Moroccan almond populations will help identify almond varieties with highly desirable characteristics both agronomically and technologically. It is essential that plant protection specialists work hand in hand with breeders, agronomists and industry professionals to breed future almond cultivars that are resistant or tolerant to pests and diseases to dispense the framers from using chemical pesticides and help preserve consumer's health and the environment.

V – Conclusion

This paper gives a brief review of the research carried out during the last 40 years in Morocco on diseases and pests of almond and their control. It appears as if almond diseases and pests were not as intensively investigated as those of other fruit crops such as apple. This may be explained by the fact that almonds are still grown more extensively in the country. With the more recent option taken by the government to expand plantations and improve almond production in the frame work of the Green Morocco Plan, research on almond protection from pest and diseases will receive inevitably more attention. It is only hoped that the research to be conducted will help develop alternative methods for controlling almond pests and diseases while protecting consumer's health and the environment.

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