

Integrated Pest Management in Chickpea

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1. Introduction

Chickpea (*Cicer arietinum* L.) is one of the most popular vegetables in many regions of the world. Pulses are important sources of protein for vegetarian population. Chickpea (*Cicer arietinum* L.) commonly known as gram is an important pulse crop. In Tunisia, the cultivated area and production have significant instability and decrease, the chickpea crop was affected by biotic and abiotic constraints. The major diseases affecting chickpea are *Ascochyta rabiei*, *Fusarium oxysporum* f. sp. *ciceri*, *Botrytis cinerea* and *Rhizoctonia solani*. *R. solani* is an important component of the disease complex that causes seedling blight and root rot on pea; it also causes root rot in plants of many pulse crops when they are weakened by other stress factors (Singh & Mehrotra, 1982). The pod borers, *Helicoverpa armigera* (Hubner), sap-sucking pests [especially *Aphis craccivora* Koch (*Hemiptera: Aphididae*)] and bruchid beetles belonging to the genus *Callosobruchus* (*C. chinensis* Linnaeus, *C. maculatus* Fabricius, *C. analis* Fabricius) cause some damage to chickpea. The presence of *Orobanche* spp. in some chickpea growing areas is considered as a limiting factor to the expansion of the crop. Genetic resistance is considered the most desirable control method since it is more cost effective and environment friendly than the use of chemicals. In this chapter we review developments in integrated management of insect pests, of parasitic broomrape plants, of the main disease-causing fungi, and of root-lesion and stem nematodes on chickpea.

2. Diseases caused by fungi

2.1 Organisms

Chickpea (*Cicer arietinum* L.) is the third most important cool season grain legume in the world. Its seed are important source of proteins to human and animals. Low yield of chickpea attributed to its susceptibility to several fungal, bacterial, and viral diseases. In general, estimates of yield losses by individual insects and diseases range from 5% to 10% in temperate regions and 50–100% in tropical regions (Van Emden et al., 1988). The blight caused by *Didymella rabiei* (Kovachevski) v. Arx, (anamorph *Ascochyta rabiei* (Pass.) Lab.) is one of the major diseases of chickpea in cool and humid climates of the world (Nene & Reddy, 1987; Khan et al., 1999; Chongo et al., 2003). The disease under favorable climatic

conditions can cause 100% yield losses and plants are susceptible to infection at any stage of crop growth (Reddy & Singh, 1990). Though conidia of *D. rabiei* penetrate the host directly through the cuticle after formation of appressorium like infection structures, the mechanical forces are not considered to facilitate host penetration, rather hydrolytic enzymes produced by the fungus were suspected to aid penetration (Kohler et al., 1995). In Tunisia *D. rabiei* was found for the first times during the 2001-2002 growing season, on chickpea debris overwintering on the soil surface at different chickpea growing locations. *D. rabiei* pseudothecial formation varied significantly in frequency according to the location and the sampling time (Rhaïem et al., 2006).

Several workers have described the symptoms of the disease as it occurs in different countries. The descriptions are remarkably similar. All above ground parts of the plant are attacked. On leaflets the lesions are round or elongated, bearing irregularly depressed brown dots, and are surrounded by a brownish red margin. On the green pods the lesions are usually circular with dark margins and have pycnidia arranged in concentric circles. Often the infected seeds carry lesions. On the stem and petiole, the lesions are brown, elongated (3–4 cm), bear black dots and often girdle the affected portion. When lesions girdle the stem, the portion above the point of attack rapidly dies. If the main stem is girdled at the collar region the whole plant dies. As the disease advances, patches of diseased plants become prominent in the field and slowly spread, involving the entire field (Akem, 1999).

Botrytis gray mold (BGM) of chickpea caused by *Botrytis cinerea* Pers. Ex. Fr. is a destructive foliar disease of chickpea (*Cicer arietinum* L.) in temperate countries and in some subtropical countries (Davidson et al., 2004). BGM is the second most important foliar disease after ascochyta blight (*Ascochyta rabiei* (Pass.) Lab.). The area sown to chickpea in many regions of the world has reduced in recent years. This reduction is primarily attributed to the yield instability caused by BGM (Rahman et al., 2000). Under prolonged cold and higher humidity the fungus first infects the lower leaves and thereafter, progresses upwards causing defoliation, rotting of tender branches and shriveling of grains within the pods (Haware et al., 1996). Chickpea is susceptible to the BGM fungus at all growth stages but flowering and podding stages are most vulnerable to the infection. The disease at these stages may lead to a complete failure of the crop.

Wilt caused by *Fusarium oxysporum* f. sp. *Ciceris* (FOC) Matuo and K. Sato is considered one of the limiting factors for its low productivity (Haware & Nene, 1982). Other species and formae speciales of *Fusarium* also cause wilt in chickpea and produce mycotoxins (Di Pietro et al., 2003; Gopalakrishnan & Strange, 2005; Gopalakrishnan et al., 2005). FOC may survive in soil and on crop residues as chlamydospores for up to six years in the absence of susceptible host, and spread by means of both soil and infected seed (Haware et al., 1978). *Fusarium* wilt is prevalent in almost all chickpea-growing areas of the world, and its incidence varied from 14% to 32% in the different states of India (Dubey et al., 2010). This disease causes yield losses up to 100% under favorable conditions in chickpea (Anjaiah et al., 2003; Landa et al., 2004).

Rhizoctonia solani is an important component of the seedling blight and root rot disease complex in chickpea (Hwang et al., 2003a). Root rot limits plant vigour and ultimately seed production by reducing the number of roots available for nutrient and water uptake and for symbiotic nodulation. The pathogens that cause root rot are also responsible for seedling blight

in younger plants (Wellington, 1962). This can reduce canopy density and uniformity in growth stage. Early injury to the roots can result in thin, uneven stands that are more prone to weed invasion and have a low yield potential. Therefore, where root rot is severe, yield losses in pulses can be high (Xi et al., 1995). Previous studies indicated that the level of root rot was influenced by genetic resistance, soil temperature and the timing of seeding (Degenhart and Kondra, 1981; Hwang et al., 2000a, 200b), and seeding depth (Duczek & Piening, 1982). Populations of pathogenic *R. solani* are expected to increase in the soil, along with losses due to disease, as chickpea acreage increases and the crop is grown repeatedly in the same fields.

2.2 Diseases management methods

2.2.1 Agronomic practices

Successful disease management requires planning well in advance. This disease is most effectively managed with the integration of several different strategies. Since only chickpeas are susceptible to *A. rabiei*, several cultural practices such as rotation with non-host crops, not growing chickpeas more frequently than every 3–4 years, and not planting new crops near previous blighted fields, the use of disease free seeds and destruction of plant diseased debris, will all help to reduce inoculum level and inhibit severe epidemics (Gan et al., 2006). Tillage practices like burial of infected residue and controlling volunteer chickpeas will also be beneficial (Navas- Cortes et al., 1995). Burning of chickpea stubbles in certain environment can also reduce the inoculum build up but may not be favoured because of negative effects on soil health due to loss of organic matter and essential nutrients. Solarization of soil and advanced sowing date are some of the measures usually employed to control Fusarium wilt in chickpea, but with limited success (Haware et al., 1996; Navas-Cortes et al., 1998). It has been demonstrated that some cultural practices, such as planting date proved to be very effective in reducing fungal attack to plants, but they are insufficient under high disease pressure, especially when weather conditions are particularly conducive to disease development (Abdel-Monaim, 2011). The use of resistant cultivars appears to be the most practical and economically efficient measure for management of root diseases of chickpea and is also a key component in Integrated Disease Management programs.

2.2.2 Chemical control

In view of the economic importance of chickpea, as well as the seriousness of the disease and associated yield loss, farmers apply fungicides to control the disease. Research has indicated that foliar fungicide applications are not cost effective when *Ascochyta* blight severity is very low. One or more applications of a foliar fungicide during flowering, or even early podding, can increase seed yield and quality. Timely application of fungicide is especially important if the forecast calls for rain. Host plant resistance provides the cheapest and most sustainable disease control (Malik et al., 2006). Most resistance begins to break down shortly after flowering and pod formation. Alternative measures should be considered if conditions favor disease development after this time. Some fungicides reduce losses and their use is not economical if disease pressure is high. In addition to the use of fungicides, follow good agronomic practices to keep crop healthy and do not grow chickpea outside of the area of best adaptation.

Different fungicides and soil fumigants are currently used to control *R. solani*. However, many of these compounds proved to be quite toxic to the environment and to the ground water.

Methyl bromide is a good example for a very efficient soil fumigant that has a great impact on the environment and has been recently phased out due to the public concern and international agreements. Yet pesticide application does not always prove economic (Lindbeck et al., 2009). In addition, chemicals have various limitations and pose risk of health hazard and environmental contamination (Ndoumbè-Nkeng & Sache, 2003). Use of FOC-free seed and fungicide-treated seed are some of the measures usually employed to control Fusarium wilt in chickpea, but with limited success (Haware et al., 1996; Navas-Cortes et al., 1998).

2.2.3 Biological control

Biological control may emerge as an alternative to chemicals, and offers economically viable and ecologically sustainable management of BGM disease. *Trichoderma* spp. and *Pseudomonas fluorescens* are important biocontrol agents of plant pathogenic fungi (Papavizas, 1985). The antagonistic activity of *Trichoderma harzianum* has been reported against BGM on chickpea foliage in controlled environments (Mukherjee & Haware, 1993). Spray of *Trichoderma viride* (10^{7-8} spores/ml of water) managed the BGM on chickpea and increased the grain yield (Chaurasia & Joshi, 2000/2001).

Currently, biological control of this soil and seed-borne plant pathogenic fungi has been addressed using bacterial and fungal antagonists. Strains of *Pseudomonas* spp., *Bacillus* spp., *Trichoderma* spp. and non-pathogenic isolates of *F. oxysporum*, isolated from the rhizospheres of crop plants and composts, were shown effective not only to control plant pathogens but also in helping the plants to mobilize and acquire nutrients (Glick, 1995; Postma et al., 2003; Khan et al., 2004; Perner et al., 2006). Such novel microorganisms, with plant growth-promoting and biocontrol traits, are found in much higher levels in forest, pasture soils and herbal compost than in arable soils (Torsvik et al., 2002; Tinatin & Nurzat, 2006). There is a growing interest in the use of secondary metabolites, such as toxins, proteins, hormones, vitamins, amino acids and antibiotics from microorganisms, particularly from actinomycetes, for the control of plant pathogens as these are readily degradable, highly specific and less toxic to nature (Doumbou et al., 2001). It is a well-known fact that actinomycetes are found most common in compost and play an important role not only in the decomposition of organic materials but also in their ability to produce secondary metabolites of pharmacological and commercial interest.

The use of antagonistic microorganisms against *R. solani* has been investigated as one of the alternative control methods. Both *Trichoderma* spp. and *Bacillus* spp. are wide spread throughout the world and have been recognized as the most successful biocontrol agents for soil borne pathogens. Several modes of action have been described, including competition for nutrients, antibiosis, induced resistance, mycoparasitism, plant growth promotion and rhizosphere colonization capability (Hassanein et al., 2006; Siddiqui and Akhtar, 2007 & Bailey et al., 2008). The species of *Trichoderma* have been evaluated against the wilt pathogen and have exhibited greater potential in managing chickpea wilt under glasshouse and field conditions, but its effectiveness is not similar in all areas (Kaur & Mukhopadhyay, 1992).

3. Broomrapes

3.1 Orobanche species

Chickpea (*Cicer arietinum*) is a host of three different species of broomrapes, namely crenate broomrape (*Orobanche crenata* Forsk.), fetid broomrape (*O. foetida* Poir.) and Egyptian

broomrape (*Phelipanche aegyptiaca* (Pers.) that suffers little damage in the traditional spring sowing, but there is concern that the continued spread of the practice of winter sowings might lead to an outbreak of broomrape infection in chickpea (Rubiales et al., 2003). *Orobanche* is considered an important agricultural parasite in chickpea in Beja region of Tunisia (Kharrat et al., 1992). The main *Orobanche* species in Tunisia include *O. crenata*, *O. foetida* and *O. ramosa* (Kharrat & Halila, 1994). The estimated levels of *Orobanche* incidence was indicated that about 5 000 ha out of 70 000ha planted to food legumes might have *Orobanche* infestation and Yield losses are approximate from 20 to 80%.

Orobanche species are holoparasites, i.e. lack chlorophyll and entirely depend on hosts for nutrition. *O. crenata* has been known to threaten legume crops since antiquity. It is of economic importance in the Mediterranean Basin and Middle East in chickpea but also in other grain and forage legumes (lentil, pea, vetches, grasspea) and members of Asteraceae, such as safflower, and Apiaceae, such as carrot. It is characterized by large erect plants, branching only from their underground tubercle. The spikes may reach the high of up to 1 m, bearing many flowers of diverse pigmentation, from yellow, through white to pink and violet. *O. foetida* is known as a weed of faba bean and chickpea in Tunisia, but the species is common in native habitats in other North African countries and Spain. The plant has unbranched stems that bear red or purple flowers that release an unpleasant smell. *P. aegyptiaca* parasitizes faba bean, chickpea and lentil and also many other crops belonging to various families, including Asteraceae, Brassicaceae, Cucurbitaceae, Fabaceae, and Solanaceae.

It is widely distributed in eastern parts of the Mediterranean, in the Middle East and in parts of Asia. A healthy broomrape plant can produce 200,000 seeds and in exceptional cases, half a million. These seeds principally remain dormant until a chemical exuded by the host root indicates the vicinity of a host. Their seeds germinate and produce a germ tube that must create a contact with the host root or die. Once the parasite attaches to the host, materials are transferred from the source (crop) to the sink (parasite) through straw like penetrations, called oscula. Affected plants usually grow slowly and, dependent on the severity of infestation, biomass production is lowered. Crop damage is often very significant and depends on crop variety, soil fertility, rainfall pattern and level of infestation in the field. The loss caused by *Orobanche* spp. is often directly proportional to its biomass (Sauerborn et al., 2007).

3.2 Broomrape management methods

In dry land agriculture, intensity and type of weed pressure depend upon the rainfall pattern during the crop season. Clearly, water supply can limit crop yield and there are few management options to try and improve this. The effectiveness of conventional control methods is limited due to numerous factors, in particular the complex nature of the parasites, their tiny and long-lived seeds, and the difficulty of diagnosis before the crop is irreversibly damaged. The intimate connection between host and parasite hinders efficient control by herbicides. Managing these weedy root parasites requires an integrated approach, employing containment and sanitation, direct and indirect measures to prevent the damage caused by the parasites, and finally eradicating the parasite seedbank in soil.

3.2.1 Agronomic practices

Manual weed control

Hand pulling, hoeing and tillage are the traditional methods practiced for a long time in West Asia, North Africa, the Indian-subcontinent and other parts of the world (Saad Eldin, 2003; Sharara et al., 2005; Solh & Palk, 1990; Wortmann, 1993). The major advantage is that it usually requires no capital outlay when cash is not readily available and labour is provided from the farmer's immediate family or through non-cash exchange. Hand pulling and hoeing have become increasingly expensive because of scarcity of labour in rural areas. Where crops are not normally planted in rows, hand pulling is a time-consuming task. Furthermore, investigations in Tunisia demonstrated that continuous hand weeding of *O. foetida* spikes did not significantly increase grain yield of the susceptible faba bean cultivar Aguadulce, proving that the underground stages are clearly detrimental (Kharrat & Halila, 1992).

Intercropping

Intercropping is a method facilitating simultaneous crop production and soil fertility building. There is a renewed interest in intercropping linked to the need for reducing nitrogen cost and soil erosion. Recently it has been demonstrated that intercrops with cereals or with fenugreek can reduce *O. crenata* infection on chickpea, faba bean and pea due to allelopathic interactions (Fernandez-Aparicio et al., 2007, 2008). This has been confirmed in a subsequent study, in which trigoxazonane was identified in the root exudates of fenugreek which may be responsible for the inhibition of *O. crenata* seed germination (Evidente et al., 2007).

Crop rotations

Rotation with non-host crops is usually suggested. The use of trap crops offers the advantage of preferentially stimulating broomrape suicidal germination. Flax, fenugreek and Egyptian clover are established to be successful trap crops for *O. crenata* (Fernandez-Aparicio et al., 2007). There are claims that a reduction in infestation has been reported in rotations with rice, due to water flooding, however, this has not been substantiated. The incorporation of resistant legumes in crop rotations may also maintain broomrape infestation at low levels (Schnell et al., 1996).

Soil solarization

Solarization by covering of moist soil with a layer of polyethylene under high-temperature conditions can control broomrapes efficiently. *O. aegyptiaca* (Jacobsohn et al. 1980), *O. crenata* and *O. ramosa* (Braun et al. 1987) infestations have been reduced by 90 to 100% using solarization. However, this is only economically applicable in small acreages: the cost of solarization for extensive crops is not affordable by farmers (Foy et al., 1989).

Nutrient management

During their evolution, parasitic plants have acquired the ability to obtain nutrition from host plants and have adapted to prefer less fertile soil conditions (ter Borg, 1986). Some studies have shown that nitrogen in ammonium form negatively affects broomrape germination (van Hezewijk and Verkleij, 1996) and/or elongation of the seedling radicle

(Westwood & Foy, 1999). Ghosheh et al. (1999) have shown that addition into the soil of jift (a solid by-product of olive oil processing) from European olive (*Olea europaea*) cultivation suppresses broomrape infection in chickpea and other crops.

3.2.2 Chemical control

Chemical strategies have been used to control broomrapes by reduction or destruction of broomrape seed reserves in the soil, prevention of or negative influence on the germination of broomrape seeds and attachment to the host root. Measures such as soil fumigation, germination stimulants, and certain preplant or preemergence herbicides act directly on broomrape.

Soil fumigation

Methyl bromide has been recognized as an effective soil fumigant. It has been routinely used to control localized populations of *O. ramosa* before planting tomato (Wilhelm et al., 1959). There are several limitations that restrict use of methyl bromide over a large scale. The costs of the chemical as well as the polyethylene sheet needed to cover the treated soil are prohibitively high. A well tilled soil that has been kept moist at 70% field capacity and temperature above 10 C are required for productive results after methyl bromide application. Safety gear is recommended for application personnel due to extreme toxicity of the gas. Parker and Riches (1993) caution regarding the risk of bromine residues in produce from methyl bromide treated areas.

Germination stimulants

Since broomrape seeds must attach to a host root shortly after germination to survive, any means that would cause seed germination in the absence of a suitable host has potential as a control strategy. This stimulation of seed germination in the absence of a susceptible host is called 'suicidal germination' (Eplee, 1975). Strigol was isolated from cotton (*Gossypium hirsutum* L.) roots and identified as a germination stimulant of parasitic weed seeds (Cook et al., 1966, 1972). Certain synthetic analogs of strigol have also been produced (Johnson et al., 1976, 1981; Pepperman et al., 1982). Application of strigol or its synthetic analogs did not provide practical control of broomrape due to their short stability in the soil. Both the activity and stability of the germination stimulants is dependent on the soil pH and moisture conditions. Foy et al. (1989) reviewed several other compounds including herbicides that have been used to stimulate as well as inhibit germination in broomrape seeds.

A number of other chemicals including cytokinins and sodium hypochlorite, which are not related to the natural stimulants, promote germination of parasitic weeds (Parker & Riches, 1993). However, the effectiveness of ethylene in some areas in Africa has been less than expected. For example, *Alectra vogelii* is unresponsive to ethylene (Parker & Riches, 1993). Recently, much attention has been focused on the isolation and identification of novel metabolites including those isolated from plant root exudates and fungal metabolite. The fungal metabolite cotylenins and fusicoccins have been reported to induce over 50% seed germination of *O. minor* even at very low concentrations (Yoneyama et al., 1998). Germination stimulants, both natural and synthetic, have good potential as effective tools of management of broomrape, but much remains to be learned about their structure, activity, and stability in the soil.

Preemergence herbicides

In vitro application of chlorsulfuron, triasulfuron, and rimsulfuron inhibited germination of *O. aegyptiaca*. Those effective as pre-emergent herbicides for non-parasitic weed control in chickpea are alachlor, chlorobromuron, cyanazine, dinoseb amine, methabenzthiazuron, metribuzin, pronamide, prometryne and terbutryne (Solh & Palk, 1990). Among those used for controlling weeds in faba bean, Igran (terbutryne), Fusilade (fluazifopbutyl), Basagran (bentazon), Gezagard (prometryn), Amex (butralin) and Topstar (oxadiargyl) are the most prominent. Gezagard (prometryn) was used as pre-emergence herbicide in the control of a wide range of weeds in legumes (Singh & Wright, 2002). Some researchers have reported increased growth characters, yield and yield attributes of faba bean plants when prometryne was applied (Singh & Jolly, 2004). The selectivity and efficacy of these soil-acting herbicides is usually limited to specific agro-ecological conditions because of differences in soil type, moisture availability, temperature, and weed flora. Therefore, recommendations differ from one agro-climatic zone to another (Solh & Palk, 1990).

Postemergence herbicides

Any herbicide that can translocate, without being metabolized, through a host plant into broomrape attached to the host roots has potential for use in broomrape control. Post-emergent herbicides have limited effectiveness particularly for broad-leaf weeds. Post-emergent applications need great care with respect to stage of growth and air temperature to avoid phytotoxicity. For non-parasitic weed control in legumes, dinosebacetate, fluazifop-butyl and fenoxprop-ethyl have been reported to be effective (Solh & Palk, 1990).

3.2.3 Biological control

Biological control is used here in its broader sense; including natural control as well as classical biological control. Biological control is particularly attractive in suppressing parasitic weeds in annual crops because the intimate physiological relationship with their host plants makes it difficult to apply conventional weed control measures (Sauerborn et al., 2007). Both insects and fungi have been isolated that attack parasitic weeds.

The predominant fungal isolates reported to be pathogenic to *Orobancha* spp. are *Fusarium* spp., particularly strains of *F. oxysporum*. Advantages of *Fusarium* spp. relate to their hostspecificity and longevity in soil (Fravel et al., 1996). However, to date only *F. oxysporum* f. sp. *orthoceras* are under investigation as potential candidates for the control of *O. cumana* on sunflower crops (Thomas et al., 1999a, 1999b; Muller-Stover et al., 2004). Further success of mycoherbicides in agricultural applications is largely dependent on the development of an appropriate formulation which effectively incorporates storage, handling and successful application of the fungal propagules (Muller-Stover & Sauerborn, 2007). Linke et al. (1992) and Muller-Stover & Kroschel, (2005) observed pathogenicity of *Ulocladium atrum* and *U. botrytis* towards *O. crenata* tubercles in vitro and disease symptoms on shoots of crenate broomrape after the application of *U. atrum* under field conditions in Syria. *Myrothecium verrucaria* isolated from faba bean roots has been found to inhibit germination of *O. crenata* seeds due to the production of the macrocyclic trichothecene, verrucaric acid (El-Kassas et al., 2005).

Phytomyza orobanchia Kalt., an agromyzid fly, is monophagous on broomrape and the feeding of the larvae within the capsules markedly diminishes seed multiplication of the parasite (Klein and Kroschel, 2002). *Phytomyza orobanchia* is widely distributed in broomrape infested areas, and consumes a substantial quantity of seeds (Rubiales et al., 2001). Naturally occurring communities of *P. orobanchia* are probably insufficient however to reduce broomrape infectivity in heavily infested areas. Nevertheless, bio-control with *P. orobanchia* may be helpful in reducing further dissemination and infestation in less infested areas, and could be incorporated into an integrated control approach to reduce the seed bank in heavily infested soils (Rubiales et al., 2001).

Recently it has been demonstrated that some *Rhizobium leguminosarum* strains decrease *O. crenata* infections in peas by inducing systemic resistance (Mabrouk et al., 2007a). Induced resistance against broomrape in the nodulated pea was shown to be associated with significant changes in rates of oxidative lipoxygenase (Lox) and phenylpropanoid/isoflavonoid pathways and in accumulation of derived toxins, including phenolics and pisatin (pea phytoalexin). In parallel, the nodulated roots displayed high Lox activity related to the overexpression of the *lox1* gene. Similarly, the expression of phenylalanine ammonia lyase (PAL) and 6a-hydroxymaackiaian 3-O-methyltransferase (Hm6a) genes were induced early during nodule development, suggesting the central role of the phenylpropanoid/isoflavonoid pathways in the elicited defence (Mabrouk et al., 2007b, 2007c, 2010).

4. Insect pests

4.1 Organisms

Chickpeas are damaged by a large number of insect species, both under field conditions and in storage (Clement et al., 2000). Amongst the many insect pests damaging food legumes, the pod borers, *Helicoverpa armigera* (Hubner), sap-sucking pests especially *Aphis craccivora* Koch (*Hemiptera: Aphididae*) and bruchid beetles belonging to the genus *Callosobruchus* (*C. chinensis* Linnaeus, *C. maculatus* Fabricius, *C. analis* Fabricius) are the most devastating pests of chickpea in Asia, Africa, and Australia (Van Emden et al., 1988).

Helicoverpa armigera

The legume pod borer is one of the largest yield reducing factors in food legumes. Its serious pest status has mainly been attributed to the high fecundity, extensive polyphagy, strong dispersal ability, and a facultative diapause. The larval preference for feeding on plant parts rich in nitrogen such as reproductive structures and growing tips results in extensive crop losses (Fitt, 1989).

Sap-sucking pests

Sap-sucking pests infesting chickpeas reach pest status mainly due to the fact that they act as virus vectors. Aphids, especially *A. craccivora*, are known to transmit a large number of viral diseases in chickpea (Kaiser et al., 1990). The most important is a strain of the bean leaf roll luteovirus, the main cause of chickpea stunt, which is transmitted in a persistent manner by *A. craccivora* (Brunt et al., 1996). Another chickpea disease is caused by the chickpea chlorotic dwarf virus (Horn et al., 1995), a tentative mastrevirus (Fauquet & Stanley, 2003).

This virus is transmitted in a persistent, non-propagative and circulative manner by the leafhopper *Orosius orientalis* (Matsumura) (Hemiptera: Cicadellidae) (Brunt et al., 1996).

Bruchids

The members of the family Bruchidae have long been reported to destroy the seeds of leguminous plants. They also feed on seeds and flowers of non-leguminous plants belonging to the families Compositae, Malvaceae, Convolvulaceae, Anacardiaceae, Rosaceae, Umbelliferae, Papavaraceae, and Palmae (Arora, 1977). Among the several species of bruchids attacking edible legumes, *Callosobruchus maculatus* and *C. chinensis* are most destructive, and attack almost all edible legumes, including chickpea.

4.2 Management methods

4.2.1 Agronomic practices

Cultural control options such as manipulation of plant spacing, time of sowing, intercropping and soil operations such as ploughing have also been shown to have some potential to reduce the damage caused by *H. armigera* (Reed et al., 1987). Chickpea germplasm with resistance to insect pests has been identified, but the sources of resistance have not been used extensively in breeding programs (Clement et al., 1994, Sharma & Ortiz, 2002). Since 1976, more than 14,000 chickpea germplasm accessions and breeding lines have been screened for resistance to *H. armigera* at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) under open-field, pesticide-free conditions. Entomologists and plant breeders have experienced difficulties in screening and selecting for resistance to target pests, in part, because of the lack of uniform insect infestations across locations and seasons. In addition, it is difficult to rear and multiply some of the insect species on synthetic diets for artificial infestation. Several genotypes with low to moderate levels of resistance were identified (Lateef & Sachan, 1990). Most of the resistant/tolerant lines were found to be susceptible to diseases, particularly to Fusarium wilt and Ascochyta blight (Lateef & Sachan, 1990).

4.2.2 Chemical control

A wide variety of insecticides have been used to control *H. armigera*, and in many areas, several applications are needed to contain this pest (Reed et al., 1987). Intensive insecticide application to control *H. armigera* on various crops (especially cotton) has resulted in the development of resistance to the major classes of insecticides such as chlorinated hydrocarbons, organophosphates, synthetic pyrethroids and carbamates (Armes et al., 1996). Aphids are generally not controlled in the chickpea crop. While pesticides have been reported to be effective against *A. craccivora* (Sharma et al., 1991), their application is expected to be of limited value since the aphids would still transmit the virus before dying, therefore preventing only secondary virus spread (Reed et al., 1987). In addition, *A. craccivora* has already developed some levels of resistance to a number of common insecticides (Dhingra, 1994). In chickpea storage chemical methods such as fumigation with phosphine, methyl bromide, or dusting with primiphos methyl and permethrin are effective against bruchids (Lal & Dikshit, 2001), but have certain disadvantages such as increased costs, handling hazards, pesticide residue, and possibility of development of resistance.

4.2.3 Biological control

There is voluminous information on parasitism, and to a lesser extent on predation of insect pests on different food legumes. The egg parasitoids, *Trichogramma* spp. And *Telenomus* spp. destroy large numbers of eggs of *H. armigera* and *H. punctigera*, but their activity levels are too low in chickpea and pigeonpea because of trichome exudates. The ichneumonid, *Camponotus chloridae* Uchida is probably the most important larval parasitoid of *H. armigera* on chickpea (Pawar et al., 1986). Tachinids parasitize late-instar *H. armigera* larvae, but result in little reduction in larval density. Six species of parasitoids have been recorded from field-collected *Helicoverpa* pupae (Fitt, 1989). Potential biocontrol agents for *B. pisorum* have been documented (Baker, 1990). The most common predators of insect pests of food legumes are *Chrysopa* spp., *Chrysoperla* spp., *Nabis* spp., *Geocoris* spp., *Orius* spp., *Polistes* spp., and species belonging to Pentatomidae, Reduviidae, Coccinellidae, Carabidae, Formicidae and Araneida (Romeis and Shanower, 1996).

The entomopathogenic fungus *Nomuraea rileyi* (Farlow) Samson resulted in 90–100% larval mortality, while *Beauveria bassiana* Balsamo resulted in 6% damage on chickpea compared to 16.3% damage in untreated control plots (Saxena & Ahmad, 1997). Spraying *Bacillus thuringiensis* (*Bt*) (Berliner) formulations in the evening results in better control than spraying at other times of the day (Mahapatro & Gupta, 1999). The activity of *Bt* d-endotoxins increases with an increase in pH from 8 to 10, but declines at a pH more than 10 (Behle et al., 1997). The acid exudates from chickpea are highly acidic in nature (Bhagwat et al., 1995), and this might influence the biological activity of *Bt* toxins toward *H. armigera*. Food consumption by the third-instar larvae of *Spodoptera litura* (Fab.) decreases gradually on *Bt* treated food when exposed to increasing the pH from 6 to 10 (Somasekhar & Krishnayya, 2004). Much remains to be done to develop stable and effective formulations of biopesticides for the control of *H. armigera* and other insect pests on food legumes. Vegetable oils, neem oil and karanj oil provide effective protection against bruchid damage in pulses (Reddy et al., 1996). To limit the effect of pH level on *Bt* endotoxin activities some researchers develop an appropriate strategies for deployment of *Bt* genes in transgenic chickpea for controlling *H. armigera* (Surekha et al 2011).

5. Nematode pests

5.1 Organisms

Chickpea production is limited by root-knot nematode infections, particularly in the Mediterranean Basin and Indian subcontinent. Root-knot nematodes of the genus *Meloidogyne* encompass more than 90 nominal species distributed worldwide, is known to cause serious yield loss (Siddiqui & Mahmood, 1993). Parasitism by root-knot nematodes is characterized by the establishment of permanent feeding sites comprised of multinucleate giant cells in the root cortex, endodermis, pericycle, and vascular parenchyma of host plants. The feeding sites act as sinks for plant photosynthates and impair plant growth and development. In addition, deformation and blockage of vascular tissues at feeding sites limits translocation of water and nutrients in the plant, further suppressing plant growth and crop yield. Tissues surrounding the feeding sites of root-knot nematodes usually swell, giving rise to large, characteristic galls on the roots of infected plants. However, infection of

chickpea roots by *M. artiellia* (Ma) only gives rise to very small galls surrounding the feeding sites (Volvás et al., 2005).

5.2 Management methods

5.2.1 Cultural practices

Numerous cultural practices can be beneficial by reducing population densities of plant-parasitic nematodes. Organic soil amendments are now widely recognized as 'non-conventional' nematode management options (Muller & Gooch, 1982). Plant products are receiving greater attention as an effective means of control for nematode pests mainly because of their presumed safety to non-target organisms. Plant-parasitic nematodes generally occur with other soil nematode communities, including predacious and free-living nematodes. Following the addition of organic and inorganic fertilizers to soil, populations of free-living microbivorous nematodes can increase rapidly and densities of plant-parasitic nematodes may decline (Tomerlin & Smart, 1969). Some researchers suggested that free-living nematodes accelerate the decomposition of organic soil amendments and increase the mineralization of nitrogen and phosphorus (Abrams & Mitchell 1980) and Griffiths 1986).

5.2.2 Chemical control

Chemical nematicides, though effective in providing rapid kills of nematodes are now being reappraised concerning their environmental hazardousness, high cost and limited availability in many developing countries. Attention of nematologists is now focused on alternative control strategies, including cultural and biological methods.

5.2.3 Biological control

Interest in using predatory nematodes, e.g. *Dorylaimus* sp. for suppressing plant-parasitic nematodes in the soil is receiving attention. Recently, a few studies have investigated predatory nematodes as control agents in the soil (Lal et al., 1983; Sayre and Walter, 1991). Rhizobacteria and arbuscular mycorrhizal (AM) having important roles in the management of parasitic nematodes on various crops (Siddiqui & Mahmood, 1999). Use of *Pseudomonas fluorescens* with *G. mosseae* was more useful in improving plant growth and reducing galling and nematode reproduction. This was probably do to better positive interaction of both organisms which is indicated by greater root colonization by *P. fluorescens* and *G. mosseae* (Siddiqui & Mahmood 2001).

6. Conclusions

The area and the production of legumes in Tunisia have not increased in the last years. Diseases and pests have been reported as recurrent problems in Tunisia (Kharrat et al., 1991). The chickpea (*Cicer arietinum* L.) is grown widely under a range of climatic conditions from temperate to subtropical and it hosts a wide variety of regional, native and exotic cosmopolitan insect pests, fungal pathogens and parasitic weeds so a generalized integrated management strategy is unlikely to be realized. Chemical, agronomic and biological methods developed help in management some pathogens but can not immune the chickpea against all severe conditions and pest. Genetic resistance is available but for some fungi,

nematodes and broomrapes, and cultivars with single resistances are not on the market in many countries. High yield and resistance/tolerance to both biotic and abiotic stresses are the prime objectives across chickpea breeding programmes.

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8. References

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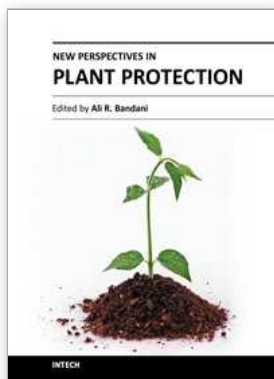
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Crop losses by pests (insects, diseases and weeds) are as old as plant themselves but as agriculture are intensified and cropping patterns including the cultivation of high yielding varieties and hybrids are changing over time the impact of the pests becoming increasingly important. Approximately less than 1000 insect species (roughly 600-800 species), 1500 -2000 plant species, numerous fungal, bacterial and nematode species as well as viruses are considered serious pests in agriculture. If these pests were not properly controlled, crop yields and their quality would drop, considerably. In addition production costs as well as food and fiber prices are increased. The current book is going to put Plant Protection approaches in perspective.

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