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REVIEW ARTICLE

Integrated management for major date palm pests in Iraq

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ABSTRACT

Date palm has been considered for centuries as the most important fruit tree (economically, socially and environmentally) in Iraq and other date producing countries. Dates and other palm trees products are contributing to both national economy and farmer income as well. Date palm plantations are an integral component of the citrus agro-ecosystem in irrigated regions in the central and southern of Iraq. Both date palm productivity and dates quality has been deteriorated mainly due to pests attack and other environmental and social factors. Date palm trees and fruits are affected by many principle insect pests such as Dubas bug *Ommatissus lybicus* De Berge*.,* borers *Oryctus* spp*., Jebusae* spp and Lesser Date Moth *Batrachedra amydraula* which cause serious and significant reductions in date palm productivity and quality. Conventional insecticides have become inefficient to reach a satisfactory solution against date palm pests in addition to their negatives consequences on environment and human health. Therefore, efforts were directed towards the application of Integrated Pest Management techniques as a safe affective alternative. Based on this concept, the Iraqi agricultural policy started moving towards safe alternatives in managing epidemic pests. Direct actions were taken to implement the integrated management programs in various agricultural systems in the country. The Harmonized Support for Agricultural Development program (HSAD) in Iraq, funded by USAID and implemented jointly by ICARDA and the Ministry of Agriculture, has devoted much effort in the dissemination of the IPM concept and application in controlling major date palm insect pests in Iraq. As a result of these joint efforts an IPM program was developed and implemented against major date palm pest in the country.

Keywords: Biological control; Borers; Date palm; Dubas; Integrated pest management (IPM); Lesser date palm moth

INTRODUCTION

Date palm plantations have formed over decades a source of livelihood for an important segment of Iraqi farmers since these orchards had been intercropped with another high economic return crop (citrus), contributing self-sufficiency until the late nineties of the last century. This agro-ecological system was introduced by ancestors and maintained by subsequent generations with such high productivity to put Iraq at the top of the list of countries in terms of number of palm trees or date production until the mid-nineties of the last century (Al-Baker, 1972; Hussian and Hreab, 2004). All researchers studies have not made any feasible alternatives in the development of modern cultivation systems of date palm and improvement of palm groves. Date palm cultivation in Iraq has been facing numerous problems and serious constraints; namely that could threaten this vital sector to a great extent.

Data from the Ministry of Planning and Development Cooperation shows that the number of palm trees and their productivity were reduced drastically (from 33 million in the seventies of last century to about 16 million palm trees in 2012). Date production was greatly affected reaching less than 500.000 ton/year. Palm groves are mainly found in central and southern Iraq, especially along the banks of the Tigris, Euphrates, Diyala and Shat El Arab rivers (Al-Baker, 1972; Hussian and Hreab, 2004). There are many constraints that have led to the decline in date production and the most important of which the infestation by many economic pests that can be found wherever date palm trees are cultivated in the world including Iraq. Pest distribution and the severity of infestation vary according to the pest species, tree's variety, age, management program and the dominating environmental conditions (El-Haideri and El-Hafeedh, 1986; Hazirmm and Buyukozturk, 2013; Zaid, 2002). The following pests are classified as key pests because of their wide distribution and the severity of economic damage they can cause to different parts and stages of date palms, dubas bug *Ommatissus lybicus* De Bergevin, the lesser date palm moth (LDM) *Batrachedra amydraula* Meyrick, the long horn stem borer *Jebuseae*

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hammershmitti Riche, Bunch borer, *Oryctes elegance* Prell, frond borers *Phonopate frontalis,* Arabian Rhinoceros beetle *Oryctes agamemnon arabicus* Fairmaire, *dust mite Olygonichus afrasiaticus* (Megregor), storage insects *Ephestia* sp. and inflorescence rot *Maginellia scatae*. Other pests such as scale insects as well as fungal diseases such as Almajnoona (black blight) and inflorescence rot are classified as secondary or less important pests. However, given appropriate environmental conditions, these pests may become principal pests that belong to the major pests category (Abdel-Hussian, 1985; El-Haideri and El-Hafeedh, 1986; Khalaf et al., 2013). Therefore, efforts were directed towards the application of Integrated Pest Management techniques as a safe affective alternative. Based on this concept, the Iraqi agricultural policy started moving towards safe alternatives in managing epidemic pests. Direct actions were taken to implement the integrated management programs in various agricultural systems in the country. The Harmonized Support for Agricultural Development program (HSAD) in Iraq, funded by USAID and implemented jointly by ICARDA and the Ministry of Agriculture, has devoted much effort in the dissemination of the IPM concept and application in controlling major date palm insect pests in Iraq. As a result of these joint efforts an IPM program was developed and implemented against major date palm pest in the country. A comprehensive manual for managing major date palm pests was developed and disseminated as a part of the project (Ali and Hama, 2014).The present article will focus on the main issues of the intended manual and to outline the threats posed by three major pests (dubas bug, LDM, borers) and management measures to control them.

INTEGRATED PEST MANAGEMENT

Traditional control programs of main date palm pests (dubas and humera) in the region including Iraq relied on ground and aerial spraying of broad spectrum chemical pesticides which affected the natural balance between the palm pests and their natural enemies. Misuse of these pesticides for an extended period has caused many negative consequences such as the development of multiple resistances toward various groups of pesticides, adverse effects on natural enemies and other non-targeted organisms, resurgence of secondary pests to the level of principal pests, in addition to the effect on environment and human health. At present, the use of pesticides is not economically and environmentally commendable because of the low efficiency of most pesticides in use (Al-Jboory et al., 1999, 2001, 2007; Al-Samarraie et al., 1988; Ba-Angood, 1978; Ba-Angood et al., 2009; Ali et al., 2010). Less toxic materials which are called environmentally friendly pesticides are considered as safe alternative for controlling date palm pests (Al-Karaki, 2013; Ali and Mohammad, 2014; Al-Khawaja, 1999; Hama et al., 2002; Hama and Abdul-Razzak, 2006; Dhoubi et al., 2007; Al-Bahely, 2004; Mohammad et al., 2011, 2013, 2014; Sayed et al., 2001; 2010; Lysandrou et al., 2010; Gerling et al., 2006). Other means such as light traps were used as monitoring and control tools against date palm pests especially borers (Khalaf et al., 2010).The best solution lies in the development and implementation of an integrated management program that addresses the entire range of date palm pests. In order for this program to succeed, farmers must be willing to accept the idea and to cooperate with specialists and agricultural extension agents in the adoption and dissemination of safe and effective alternative control practices against the date palm pests.

Integrated Pest Management is a comprehensive approach to control pests, which includes the collection of information on the pest's biological aspects (strains) and link them with the governing environmental factors in order to identify available control methods to manage the pest in a more economically and efficient way that is more environmentally friendly and less risky to the human health. Components of IPM were developed for both diseases and insect pests by National and International projects on some economic agricultural crops in various agricultural systems including date palm in Iraq. The Ministry of Agriculture has devoted much effort to encourage the dissemination of the IPM concept and application in controlling major date palm insect pests in the country.

The key elements of the pest management program are as follows:

1. Provide adequate information concerning the identification, biology, life cycle, ecology of the target pests and their natural enemies.
2. Development of an effective decision making tool (monitoring -predication and program evaluation system) to trace pest's population, damage and the role of their natural enemies.
3. Development of a decision-making system using the economic (practically action) threshold as a base to determine proper time of control application.
4. Take suitable decision on what is the best control approach to be implemented.
5. Record the data on all activities implemented in the field, including: Date of sampling, data obtained, the control method used and results of the treatment in terms of reducing pest population or the damages they cause
6. Program evaluation should be conducted annually.

Success of the integrated management program depends mainly on the accuracy of the monitoring process in terms of population density of the pests and their damage.

This would provide the necessary information for the most important pests on the intended dates and therefore provide data for decision making on the suitable timing of intervention method and its application.

In order to make a reliable sampling process, samples should be collected at regular intervals, taking the time of day scouting team into considerations. Representative samples should be chosen randomly or according to the recommended sampling regime, sample size using appropriate sampling techniques and methods. The area of the orchard and growth stage of the trees should also be taken into consideration along with the distribution of infestation, climatic factors, and the borders of the orchards. Sampling process should start with a preliminary survey of the orchard; samples are then taken and examined looking for pest stages, molting skins, and damages on parts of targeted plants. Whenever it is possible insect activity should also be monitored by using light or pheromone traps.

The following IPM programs were successfully implemented against epidemic date palm pests, such as dubas bug, lesser date moth, and date palm borers. These programs have been verified on farm and they were widely accepted by date growers in areas of application.

COMPONENT OF APPLIED IPM PROGRAM AGAINST MAJOR DATE PALM PESTS

Dubas bug

Dubas bug is an endemic pest that has pervaded palm groves in Iraq, for over a century. Infestation varies between regions, governorates, provinces and between locations within the same province. Temporal variation has also recorded for this pest. The level of pest infestation also varies according to variety, cultural practices, and implemented agriculture practices as well as to the surrounding environmental factors, especially temperature, relative humidity and dust storms. Heavy infestation is mainly found in central Iraq, including the provinces of Karbala, Babel, Baghdad, Diyala and Wasit. Infestation in the provinces of the Middle Euphrates and the southern area (Najaf, Diwaniyah, Samawah) are categorized as low to moderate, whereas in the provinces of Salahuddin and Al-Anbar, they are still limited (Al-Khafagi et al., 1995; Ali, 2007, 2011; Jassim, 2007). Dubas bug is also found in many date palm growing countries (Ba-Angood, 2007). This insect has two generations per year, the spring (summer) generation and the fall (winter) generation. The starting date of each generation is influenced by the climatic factors. Nymphs of the spring generation usually start emergence in late March, reaching their peak in April, and may be extended to the beginning of the month of May (Hama and Abdul-Razaq, 2006; Jassim, 2007). The adult stage stays alive till the end of June when females stop laying their eggs which undergo an aestivation period that can last for two months. The Fall generation begin when insect nymphs start emerging by the end of August. Field Surveys conducted by researchers at different scientific institutes indicated that the insect, during all the stages of its lifecycle, hides under different parts of the tree in those particular years when winter is relatively moderate, (no frost). These stages can be seen on date palm leaves early in spring when females may start laying their eggs which indicates a nearly appearance of the pest and additional sources of infestation and other complications. Dubas lifecycle consists of three stages; egg, nymph (five instars) and adult (Fig. 1). Both nymphs and adult stages feed on plant sap and cause serious damage to the trees. Nymphs are considered more important than the adults because of their rapacity which increases as the nymphs develop which consequently inflect tremendous amount of damage (Abdel-Hussian, 1985; El-Haideri and El-Hafeedh, 1986).

Damages caused by Dubas

Nymphs and adults are found on almost all leave rows feed on plant sap, causing direct and indirect damages (Khalaf and Khudhair, 2015). The repetition of infestation twice a year (spring and fall generations) for several subsequent seasons depletes the sap of the infected palm trees which weakens the tree and leads to significant reduction in yield quality and quantity. The infected leaves turn yellow in color (Fig. 2a) and then dry out during subsequent generation continuous. The process of laying eggs in different parts of the fronds causes another direct damage because of the destruction of plant tissue by ovipositor of females. Pathogenic organisms may also be transmitted by Dubas through feeding or egg laying process. The indirect damages are represented by the honey dew excreted by Dubas nymphs (Fig. 2). Mold and dust are accumulated on

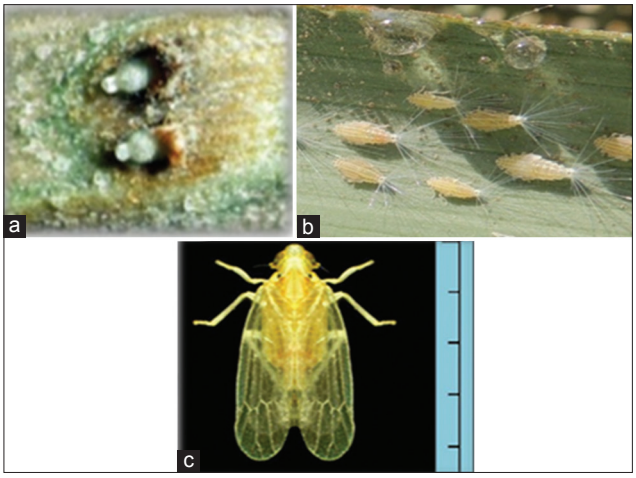

Fig 1. Life cycle of Dubas bug, (a) Egg, (b) Nymph, (c) Adult

the infested trees leading to weakened efficiency of plant parts to functions normally, especially in the process of photosynthesis and distribution of nutrients to the tree. Honey dew can also impede agricultural care processes, including bunch bagging and harvesting of dates because farmers can be affected by this sticky substance which can damage their skin or clothes. Moreover, access honeydew that trickles off of the affected palm tree, will fall on intercropped trees and other trees or surrounding crops planted in the same grove, especially citrus trees(Khalaf and Khudhair, 2015).

Integrated management of Dubas

Integrated management involves using all available control measures, including chemical insecticides–(these can be used as a last resort) to control infestation and reduce the number and damage of pests. Integrated management techniques take into account all biological and ecological aspects of pest control and require the adoption of a reliable monitoring program as a basis for sound decision making. Pest management is also a part of a comprehensive process of crop management (Ali and Hama, 2014). The basic elements for the management program of Dubas, include the following:

1. Agricultural practices, which include cultivation type, removal of old leaves from the lower parts of the tree to eliminate a large percentage of Dubas eggs that are an important source of infestation. Regular irrigation and fertilization should include the use of organic fertilizers (compost) or manure instead of, or in addition to chemical fertilizers. New orchards should be cultivated according to modern designs that require an 8x8 meter space between planted trees to create unfavorable conditions for the pests and facilitate the use of machineries.
2. The development and adoption of a monitoring and early prediction program to detect Dubas level of infestation and identify its natural enemies as a basis for decision making and scheduling of control application.
3. Monitoring and sampling techniques must take into account several important factors, such as the number and distribution of palms per unit area, the target level of leaves and the sample size (number of leaflets/Palm), as well as the adopted sample collecting mechanism.

To determine the level of pest infestation, it is recommended that samples are collected when the pests are in their egg stage because the rapid movement of nymphs or adults can influence the accuracy of population estimation. The process is implemented by taking one or two samples per geographical region/week in order to determine the percentage of egg hatching, developmental stage of the pest and the presence of natural enemies. Based on the above element the following tools proved effective against dubas bug in Iraq(Fig. 3) (Ali and Hama, 2014):

1. Pruning and removal of the lower fronds to eliminate a large portion of Dubas eggs injected in these leaves
2. Using botanical and environmentally safe insecticides
   a) Spraying Dubas eggs or Nymphs (stages 1-3), with 1% Neem (Azadirachtin) at a ratio of 2–3 ml per liter of water, or by mixing 1.5 ml. of neem + 15 ml summer oil, using ground sprayers.
   b) Spraying Dubas eggs or Nymphs (phases 1-3), with the botanical pesticide, Oxymatrine, at a ratio of 2 ml per liter of water.
3. Agricultural soap at a ratio of 2-3%
4. Application of biological insecticides such as the pathogenic fungi *Beauveria,* and *trichoderma* at a ratio of 5 g/l;
5. Using biological control agents such as lace wing (it can be obtained from the mass rearing unit of the MoA or other specialized institutes).

Other groups of natural enemies associated with Dubas in the field, including the lace wing (Chrysopidae), Coccinellid

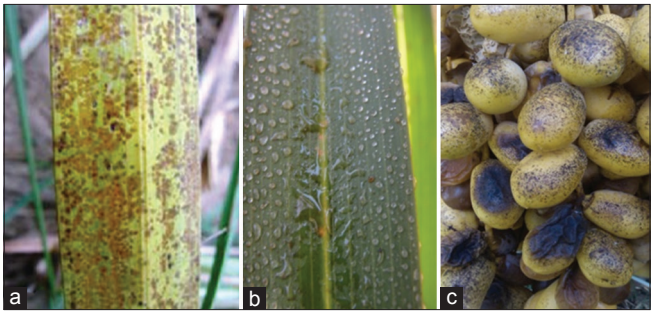

Fig 2. Direct Damages caused by Dubas, (a,b) Honey dew droplets and damage on leaflets, (c) Damage on fruits.

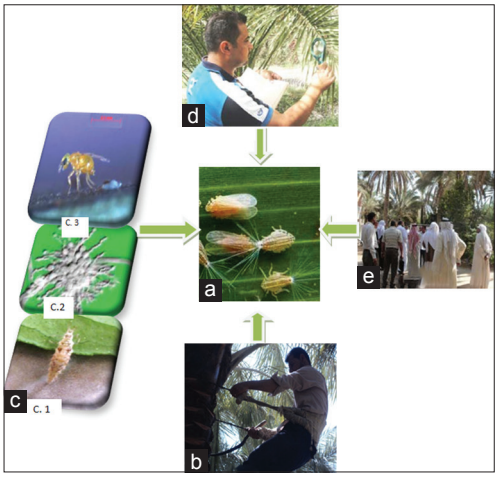

Fig 3. Integrated pest management elements for Dubas bug, (a) Nymphs and adults of Dubas, (b) Good Agricultural Practices (AP), IPM Compatible Insecticides (Green pesticides (Neem, Oxymetrin, and summer oil) (c) Biological control agents (1. Lace wing, 2. Beauvaria, 3. *Oligosita*), (d) Monitoring and Prediction, (e) Farmer's Field School (FFS).

beetles and the egg parasitoid *Oligosita* sp, play an important role in the elimination of large proportions of Dubas stages. These natural enemies may be found in mass rearing laboratories, or they can be conserved by field protection and maintenance. Such practice should include the use of safe pesticides in timed applications and encourage planting crops that are known for attracting and harboring natural enemies.

Lesser date moth (Alhumara)

Likewise Lesser date moth (LDM) is also considered as one of the key pests attacking almost all date palm varieties in Iraq and many other countries in the world. Larvae start attacking the florescence and continue after fruit setting feeding on subsequent fruit stages (Fig. 4). Infested fruits become dry red in color. Most dried fruits drop causing big losses in yield. The starting date of generation emergence and infestation intensity vary according to the region and mostly coincide with the developmental stages of fruits which usually mature earlier in the southern region than the northern sides of the date palm growing region, according to the surrounding environmental factors (El-Haideri and El-Hafeedh, 1986; Al-Fahadawy, 1988; Aziz, 2005; Mohammed, 2011).

Life cycle and description of stages

The periodical activity usually starts in spring when climatic factors become favorable. Females lay their eggs individually on the cap of fruits or on strands close to them. Newly laid eggs are yellowish green in color and turn yellow before hatching. Young larvae are white then turn pink as larvae develop and become older (Fig. 4c). Mature larvae spin a light whitish silky cocoon inside which they later transform into pupae. Duration for adult emergence varies according to climatic factors, especially daily temperature. The adult is a small slim moth, around 12 -15 mm in length, dark in color with a silver abdomen. It has compound brown eyes and Silver antennae with dark spots (Fig. 4a). The front wings of the moth are covered with white scales and very small dark spots. The dorsal wings are narrow and dark, with long, dark bristle edges. After mating, females start laying their eggs on fruits, or nest around them. This insect goes through three overlapped generations during the developmental stages of fruits in most date palm growing regions of the country. However, the beginning and duration of generations vary according to surrounding environmental factors (Aziz, 2005; Mohammed, 2011).

Symptoms of infestation

Larvae start attacking small fruits and borrow through the cap inside the fruits to feed on contents leaving an empty outside wall. During the subsequent generation, larvae attack fruits at subsequent stage of maturities and feed mainly on the soft pith and immature seeds during the chemri stage (a stage of maturation where the date fruits are green and inedible) (Fig. 4d). Infested fruits wilt and turn red in color. Small dried fruits can be seen tied or hanging by silken threads produced by the larvae (Fig. 4b, f). Dropped fruits with insect penetration holes and silky remains close to fruit cap are considered identifying characteristics or signs of infestation by lesser date moth (El-Haideri and El-Hafeedh, 1986; Mohammed, 2011).

Integrated management elements for lesser date moth

The components of date palm pest management may overlap particularly dubas and lesser date moth. However; the main steps suggested for control of lesser date moth are the following (Ali and Hama, 2014):

1. Use of pheromone or light traps at the rate of one trap per/donum(2500 m^2) for monitoring purposes in order to determine the periodic activity of the insect, thedate of adult emergence, and the timing of control practices. Pheromone traps canbe used for both monitoring and control measures against LDM, through male confusion and mating disruption (Fig. 5a). The trap would attract males and reduce the chance of mating which will certainly reduce the level of infestation during the next generations.
2. Dual release of both egg parasitoid *Trichogramma sp.* at the rate of 300–500 individuals/tree, 1-2 release/season

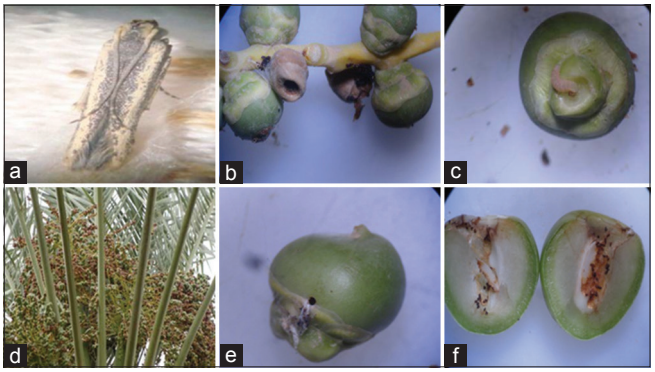

Fig 4. Life cycle and damage of lesser date moth, (a) Adult, (b) Symptoms of infestation on fruits, (e) Larva on fruit cap, (e) Damaged fruits, (e) Larvae penetration place close to fruit cap, (f) Symptoms of infestation on bunches.

Fig 5. Elements applied for the msanagement of lesser date moth (a) Location of Monitoring Traps (Light and Pheromone), (b) *Trichogramma* sp. capsule on the bunch

plus 5 pairs of larval parisitiods *Bracon sp.* Capsules containing the parasitoids are inserted within the fruit bunches or leave base for egg and larval's parasitoids consequently (Fig. 5b).

3. Field's release initiation will be determined by the number of cached males on pheromone traps or number of adults/light traps. It has been recommended to use bio agents against first generation as inoculation release.
4. Application of the biological insecticide Bt.(*Bacillus thuringiensis*) in spray form, at a rate of 3 g/l (6-7 l/tree). Spraying time will be based on data of monitoring traps.
5. Agricultural and sanitation practices to remove the dropped fruits from the orchards because they are considered as a source of infestation for the next generation.

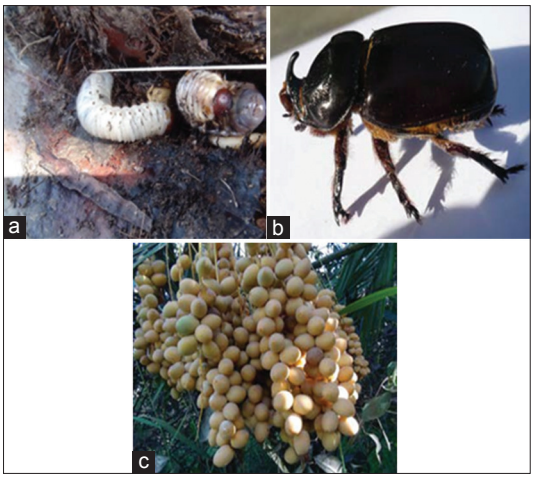

Fig 6. Stages and damages of long horn stem borer, (a) Larvae, (b) Adult male, (c) Symptoms of infestation on bunch.

Date palm borers

Recently, date palm borers have been considered as major pests that cause serious damages to palm trees. Heavy infestation of stem borers would lead to the destruction of stems and collapsing of trees. Infestation debilitates the trees and reduces their productivity and yield. The pests are most damaging when they are at their larvae or adult stage, depending on the feeding behavior of the different species. There are several species of borers that cause direct damages to different parts of palm trees in Iraq(Khalaf et al., 2013; Khalaf and Altaweel, 2015) The distribution of species and intensity of infestation vary according to the region and surrounding environmental factors. However, the most important and familiar species include the following three:

Bunch borer Oryctes elegance

This species main domain is the top of the tree but can be found in almost all stem parts of the aged trees. In middle age trees, larvae of this borer are found at the bases of the frond at the top of the tree.

Life cycle and description of damage

Adult bunch borers emerge in spring and the females start laying eggs after mating. Females prefer to lay their eggs at the base of the upper fronds, at the top of the tree. The white, ovoid-shaped eggs hatch to display arcuate creamy larvae that have three thoracic legs and a well-developed head with strong mandibles (Fig. 6a). Larvae molt three times to become mature. During this period, larvae dig some cavities, using tissues and debris of the stem and fronds, where it then molts to pupa. Larvae molt to pupae which are dark brown in color with lateral brown spots on both sides representing the spiracle of larvae and pupae. Duration of pupa stage differs according to environmental factors. Newly emerged adults are brown and gradually turn into glossy black after few hours of emergence. Females can be differentiated from males by the dorso-frontal horn which is long in male and very short or absent in female (Fig. 6b).The life cycle of the bunch borer species is similar to that of the Arabian rhinoceros beetle; however, they differ in their feeding habits and the damage they cause. The rhinoceros beetle attacks most parts of palm tree creating a network of tunnels which lead to the weakness of the trees and breaking of the stem at any other additional stress such as wind storms. The bunch borer is found at the top of the tree and larvae can be found at the base of fronds without causing significant damage while adults feed on the stalk of the bunch, tunneling inside of it and leading to the rupture of the bunch or the destruction of its tissue. Fruits in such bunch are misshaped and small (Fig. 6c). Infestation of bunch borers is found in all date palm growing regions with increasing intensity towards the middle Euphrates and southern provinces(Ali and Hama 2014; Khalaf, and Al-Taweel, 2015).

Long horn stem borer Jebuseae hammershmitti

Life cycle and symptoms of Infestation

This species (Fig. 7) is considered as a serious palm stem pest. Infestation can be found on all lower and upper parts of the stem. Infestation by this species is intensifying and, in the case of aging trees, it is becoming a more serious threat depending in its severity on the region and variety. Overlapping symptoms of this species with other borer species might occur with the dominance of one over the others (Khalaf et al., 2010). Infestation includes the gummy excretion found on the bases of the fronds at the top of tree. In the event of heavy infestation, the number of holes the pest bores in the stem may exceed 200/m of trunk. Larvae make tunnels inside the trunk in which they spend the winter months. The mature larva is about 5 cm in length, with a small head inserted on the thorax and Legless abdominal segments that are well developed. During spring and when conditions are favorable, the larvae start digging their holes close to the external surface and then molt to pupae inside these holes.

Pupae are white in color and gradually turn into reddish brown. The duration of the pupa stage varies according to climatic conditions (especially daily temperature). The female insect is larger than the male and both are cylindrical in shape, reddish brown in color, with large, compound eyes and antennae that are longer than insect body. After mating, females start laying their eggs individually on stems and on the bases of fronds. Newly hatched larvae start boring in the stem and fronds to move inside and continue their feeding in the tunnel molting to pupae and then to adults. The duration of each stage varies according to climatic factors and the larval stage alone may last more than three months (Ali and Hama 2014; Khalaf and Al-Taweel, 2015).

Frond borer

Life cycle and description of damage

This species is found in many countries in the region infesting grapes, pomegranate and other host plants in addition to the fronds of date palm. Both larvae and adult life stages are considered as harmful. Adults bore tunnels inside the middle rib of the green fronds (Fig. 8). Symptoms of infestation are represented by the presence of the gummy materials excreted from the entrance holes. Infested fronds become bristle and easy to break. This pest also attacks dried fronds which are used for handcrafts industries, and to build traditional roofs of homes in the villages. Symptoms in this case are characterized by the presence of exit holes used by newly emerged adults. Debris in the tunnels are another sign of infestation (Ali and Hama 2014; Khalaf and Al-Taweel, 2015). When the insect attacks the stalk of the bunch, fruits shrivel and dry out. Adult frond borers are medium-size beetles that have elongated, dark brown or black bodies. The first thoracic segment of the insect covers the head, the anterior part of the dorsal plate is the first thoracic segment with thorns, while the posterior edge is smooth and shiny. Female frond borers lay eggs on green or soft fronds and bunches. The newly emerged larvae are creamy in color, legless, arcuate in shape and all stages may be found within the same frond at the same time.

Integrated management tools for date palm borers

Cultural practices

This is one of the most effective components of IPM program against bores particularly bunch and Arabian rhinoceros beetle which are found at the base of the fronds in middle aged palm trees and can be found in all parts of the trunk in old trees. Larvae duration is long and may extend to more than six months. The collection and destruction of larvae is done manually during the annual routine service of palm orchards (pruning and cutting of old fronds) which starts in December and continues until March. This method has proven to be an effective method to control bunch borers and to reduce population density, significantly (Ali and Hama 2014; Khalaf et al., 2010, 2013).

Fig 7. Stages and damages of long horn stem borer, (a) Larva, Pupa, Adult (b) Larvae within stem, (c) Symptoms of infestation(Holes) on stem

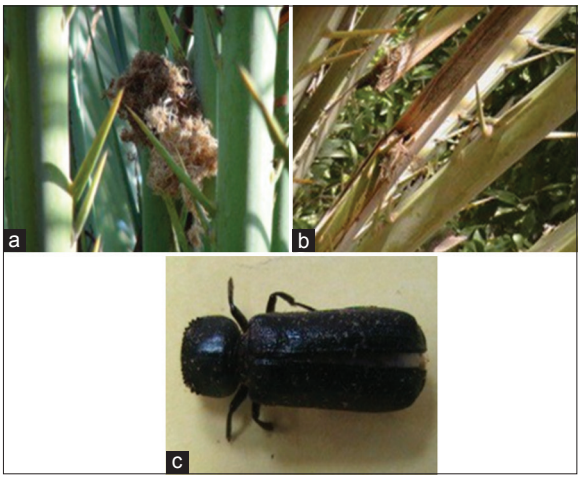

Fig 8. Frond borer, (a,b) Symptoms of infestation on fronds, (c) Adult

Physical and mechanical measures

This method is directed against the adults through the use of solar light traps with a wave length of 320-420 nm (Fig. 9). Light traps proved to be effective against the adult stages of the three species of palm borers (Ali and Hama 2014; Khalaf and Al-Taweel, 2015; Khalaf et al., 2010). Adults start their periodical activity during April-June and continue in summer and fall to disappear in December. The highest population is recorded in the months of June, July and August.

Field studies showed that the implementation of agricultural practices (pruning), physical (light traps) and mechanical measures (collection and destruction of larvae) resulted in 82% and 90% reduction of borers' population during the first and second years of application. Yield increase exceeded 20% and this could be further improved if the application of the program continues during the subsequent seasons.

Fig 9. Light traps used for monitoring and control of date palm borers, (a) Symptoms of bunch borer infestation, (b) Solar light trap, (c) Farmer in process of inspecting the trap, (d) Collection and examination of captured insects

Other practices

The success of the management program against date palm borers should take in consideration the following essential applications (Ali and Hama, 2014):

1. Identifying neglected orchards which produce low yields and that are considered as a source of infestation. Infested trees should be removed and burned if there is no other effective mean to control the pest and rehabilitate the orchard is available. Moreover, there is a need to obtain the necessary supplies for the implementation of agricultural services of palm groves.
2. Using normal or solar light traps to identify the infestation loci (since these traps are effective monitoring tools, in addition to their role as a control measure) to help reduce the population density of date palm pests(Pheromone traps can be used in the same manner especially against *Oryctes spp.*). They can be used to determine the relation between the climatic factors and the distribution of intended pests in order to decide the ecological map for each pest and the associated natural enemies which would be used as a prediction tool for infestation level and suggested control practice.
3. Encouraging the owners of date palm orchards to do the annual agriculture practices and removal of borers' larvae which are considered as a source of subsequent infestations.

CONCLUSION

Date palm is considered as one of the most important fruit trees contributing in a big share of farmer income in the central and southern regions of Iraq. Date palm trees and date are subjected to infestation by many economic and principle pests which can be found where ever these trees are cultivated in the world including Iraq. The use of wide spectrum insecticide resulted in many negative consequences on human health and environment in addition to the effect on non target organisms including beneficial insects and natural enemies. Measures, based on bio-pesticides, would cut down the use of chemicals, lessen environmental pollution, and would have minimum or no effect on natural enemies that feed on pests. National and International projects implemented with the cooperation of the MoA devoted much of their activities to improve date palm production and protection with the emphasize on the use of biological agents and other environmentally safe elements for the control of major pests (Dubas bug, LDM, Date palm borers). IPM programs against these pests were developed, tested and implemented at different sites in date palm growing provinces in Iraq. IPM techniques at different sites demonstrated positive results and significant benefits. Biological control agents, biological pesticides and botanical pesticides in addition to light traps proved to be promising alternatives that can be applied as an integrated package against date palm pests in Iraq as a pest management approach safe for both humans and the environment. Using IPM technology is profitable and can increase the household incomes of date palm farmers. This is in addition to the important environmental benefits.

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Author's contributions

Both authors devoted much of their time during the development and implementation of IPM projects in the country. A-S A A represented ICARDA as IPM Officer (Harmonized Support for Agriculture Development (HSAD) Project in Iraq) and team leader, N N H represent Ministry of Agriculture as Plant Protection Expert and team leader. Both authors contributed in writing and reviewing the article.

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