Chapter 1
Date Palm Production and Pest Management Challenges

Waqas Wakil, Jose Romeno Faleiro, Thomas A. Miller, Geoffrey O. Bedford, and Robert R. Krueger

Abstract Date palm, *Phoenix dactylifera*, is a monocotyledonous species belonging to the palm family (Arecaceae or Palmae) which is perennial and dioecious and cultivated mostly in the arid regions of the world. Date palm is important to the agrarian economy of several countries, with the ability to withstand severe abiotic stresses prevalent in the world's arid regions, including hot and dry climatic conditions, water stress and salinity. A recent report on the arthropod fauna of date palm lists 112 species of insects and mites associated with it worldwide, including 22 species attacking stored dates. In several date producing countries, the monoculture type of date palm cultivation, climate change, unrestrained use of chemical insecticides and extensive international trade is likely to impact the pest complex and its natural enemies in the date agroecosystems. Considering the significance of date palm, we summarize the biology and sustainable management of major insect and mite pests addressing related challenges and future research areas. The emerging role of semiochemicals in date palm IPM is described including new strategies in

W. Wakil (✉)
Department of Entomology, University of Agriculture, Faisalabad, Punjab, Pakistan
e-mail: waqaswakeel@hotmail.com; arid1972@yahoo.com

J.R. Faleiro
Food and Agriculture Organization of the United Nations (UTF/SAU/043/SAU), Date Palm Research Center, Al-Ahsa, Saudi Arabia
e-mail: jrfaleiro@yahoo.co.in

T.A. Miller
Department of Entomology, University of California, Riverside, CA, USA
e-mail: thomas.miller@ucr.edu

G.O. Bedford
Department of Biological Sciences, Macquarie University, NSW 2109, Australia
e-mail: geoffrey.bedford@mq.edu.au

R.R. Krueger
USDA-ARS, National Clonal Germplasm Repository for Citrus and Dates, Riverside, CA, USA
e-mail: robert.krueger@ars.usda.gov

W. Wakil et al. (eds.), *Sustainable Pest Management in Date Palm: Current Status and Emerging Challenges*, Sustainability in Plant and Crop Protection,
DOI 10.1007/978-3-319-24397-9_1

mating disruption, “attract-and-kill” and “push-pull” technologies. Also phytoplasma diseases and their insect vectors are discussed, besides innovative methods for managing storage pests of dates.

1.1 Introduction

Date palm, *Phoenix dactylifera* L. (Arecaceae, or Palmae) is an important species cultivated mostly in arid areas of the world. It is a perennial and dioecious with female (fruit bearing) and male (pollen bearing) plants growing separately. Date palms were cultivated 6000 years ago in the Mesopotamian region (present day Iraq) (Wrigley 1995; Zohary and Hopf 2000; Johnson et al. 2013). The importance of date palm in the economy of several date producing countries is based on its ability to withstand severe climatic conditions, water stress and salinity ranging up to 2000 ppm. Among the 100 million date palms of the world, 60 % exist in North Africa and Middle East, where it has become important to the life and culture of the people in these regions.

According to Johnson (2011) propagation of superior palm types targeting increased crop productivity and fruit quality is among the early date palm-specific technologies applied. Crop and water management of palms, tree segregation on the basis of sex, artificial pollination, assigning names to cultivars, and characterization of different growth stages of fruit, fruiting seasonality and fruit flesh texture are all other old practices and characteristics that are still important today (Johnson 2011). Among the modern date palm production technologies, plantlets are developed commercially through tissue-culture techniques, a practice that has enabled rapid expansion of planting and replanting of date palm orchards, besides incorporating traits like resistance against insect pests and pathogens, and increasing fruit yields (Johnson et al. 2013).

1.2 Production, Area and Yield

With the major proportion of world’s total date palm production in the Middle East and North Africa, date palms have also been introduced in Australia, India, Mexico, Southern Africa, South America, Pakistan and the USA during the last three decades. Dates are not only a staple food for local populations in many countries, but their production also contributes significantly to the economy, society and environment of those countries (Chao and Krueger 2007).

Date palm has a wide genetic diversity due to extensive out breeding (Popenoe 1992). There are around 3000 cultivars of date palm worldwide (Zaid 2002), but some of the varieties could represent synonyms (Johnson et al. 2013). Though

mainly propagated by offshoots, seedling date palms are the original source of most of the existing established cultivars in several countries. Date palms are cultivated from seeds for two major reasons; (i) germplasm preservation and (ii) conservation of desirable traits (Johnson et al. 2013). Male palms are also an important genetic resource that provides valuable pollen to pollinate the female cultivars, which is carried out artificially either manually, by inserting pollen strands in individual female flowers, or mechanically by using pollen dusters so as to ensure fruit setting and to sustain yields (Al-Wusaibai et al. 2012).

The date fruit is classified as a drupe exhibiting high variation in color, texture, shape and chemical composition that mainly depends on prevailing environmental conditions, cultivar genotype and practices as well as growing season. Date varieties are usually characterized by the fruit attributes (El-Hadrami and Al-Khayri 2012). The fruit development on the palm is categorized mainly into four stages using Arabic terms viz. Kimri, Khalal, Rutab and Tamar stages, where the averages for moisture content is around 80 %, 60 %, 40 % and 20 %, respectively (Fayadh and Al-Showiman 1990; Al-Shahib and Marshall 2002). The most desirable character in dates after production is a large fruit size (Johnson et al. 2013). According to the Food and Agriculture Organization (FAO) of the United Nations, the global date production has increased from 1.8 million tons in 1962 to nearly 8 million tons in 2012. Egypt, Saudi Arabia and Iran are the current top three date producing countries (FAOSTAT 2012) (Fig. 1.1).

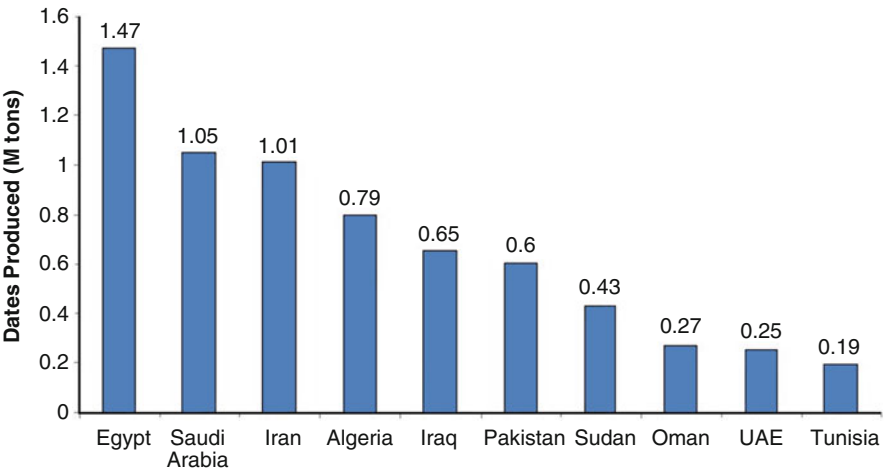

Fig. 1.1 Production of dates (million tons) in top ten producing countries during 2012 (Source: FAOSTAT 2012)

1.3 Date Palm and Global Food Security

Dates contain high amounts of essential nutrients: minerals (Mg, Ca, Fe, K), carbohydrates (total sugars 44–88 %, glucose and fructose 65–80 % of dry weight) (Al-Shahib and Marshall 2003; Chandrasekaran and Bahkali 2013), vitamins (niacin, B1, B2), dietary fibers (6.4–11.5 %), fatty acids and proteins. They could play an important role in emergency food relief programs. In certain cultures dates are considered to have several medicinal qualities viz. antifungal, antibacterial, antiulcer, immuno-modulatory and antitumor properties. Also, some date cultivars have antioxidant activity due to phenolic compounds (Vayalill 2002; Al-Farsi et al. 2005; Baloch et al. 2006; El-Hadrami and Al-Khayri 2012). Efficient utilization of raw dates and date seeds is expected to generate a number of new products by bioprocessing, especially through the exploration of these technologies on commercial scale by the pharmaceutical and food industries (Chandrasekaran and Bahkali 2013). Date seeds are also used in animal feed due to their high protein, fat and dietary fiber contents (Besbes et al. 2004). About 11–18 % of date fruit weight is from the seed, where a recent report suggests that the antioxidant content of date seed oil is comparable to that of olive oil (Abdul Afiq et al. 2013).

Increasing global production of dates will significantly improve the livelihood among rural communities of date farmers in several date producing countries, leading to increased internal and external trade of dates and date-based products. Trade of dates especially in the USA and EU is governed by international marketing norms. In North Africa, the international standards and CODEX norms are available for standardization of dates for the date varieties, like Medjool and Deglet Noor, and widely used by date importing and exporting countries. Besides the standards recommended by CODEX, standards set by the EU, USDA and date exporting countries of North Africa (Morocco and Tunisia) are also important. Dates with standardized color, size, texture, resistance against insect pests and less number of infested fruits are well accepted internationally (Anonymous 1985).

The CODEX limit for dates is 6 % of defective fruits, whether the damage is visual or contamination is due to the incidence of dead insects or presence of body parts of insects or mites, their exuvia or excreta. Currently, absence of internationally accepted standards for marketing dates is adversely impacting the date industry in several countries, especially in the Gulf Cooperation Council countries (Saudi Arabia, United Arab Emirates, Oman, Kuwait, Bahrain, Qatar) of the Middle East which accounts for around 30 % of the global date production. This important issue in the date palm industry was highlighted in the International Dates Council (IDC) establishment meeting, recently organized by Ministry of Agriculture, Saudi Arabia and FAO in Riyadh in December, 2013. Jaradat and Zaid (2004) studied quality parameters of dates in reference to consumers' preference and found that fruit size, ripening, shape and their associated interactions were primarily important, together with fruit color, softness and consumption stage accounting for most of the variability in the economic value.

1.4 Climate Change, Desertification and Date Palm

Climate change is adversely impacting human societies. The Intergovernmental Panel on Climate Change (IPCC) has estimated that by 2100 the global mean surface temperature will increase by 1–3.5 °C from the 1990 level (Cannon 2004). According to FAO over one third land area of the world is desert which mainly occurs due to prevailing weather patterns and over-exploitation by inappropriate land use. Lal (2001) indicated that dry lands of the world occupy 6.31 billion ha or nearly half of the earth's land area. This situation leads to overgrazing, deforestation and faulty irrigation practices that in turn could cause deterioration in the soil fertility and crop productivity.

The major threat to biodiversity conservation is given by desertification, particularly in the dry regions of the world. Desertification is a persistent land degradation characterized by reduced water bodies, vegetation and wildlife as a result of climate changes and human activities, thus converting a relatively dry region into arid land. Factors like climate change, land degradation, loss of biodiversity, desertification and water shortage are affecting over one billion people worldwide. Several parts of the world including the Indian sub-continent, North Africa, China, Saudi Arabia, Eastern Australia, Central Asia, Egypt, parts of Southern Africa, Northern Mexico and Southwestern USA are already experiencing water shortages. Water availability for agriculture is becoming limited with greater demands from other sectors (increased urbanization of farming regions, for example). The relationship between desertification and climate change, combined with biodiversity loss, degradation of land and water shortage makes farming in the dry lands of the world increasingly difficult and challenging.

In this context, the date palm is very useful, with its ability to withstand adverse climatic variations, in addition to providing an environment with a micro-climate for farmers to grow a variety of crops. It can also be used for bio-ethanol production as a bio-energy crop. In several countries date palm constitutes an important economic factor that provides income to a large number of farming communities particularly those residing in the arid regions. Moreover, according to FAO, the ability of date palm to tolerate harsh climatic conditions and salinity renders it a significant potential resource in holding back or combating desertification.

1.5 Insect Pests of Date Palm: Current Status, Challenges and Future Priorities

Integrated Pest Management (IPM) requires information on pest biology, ecology, sampling and monitoring, for developing action and identifying thresholds. Fully integrated pest management approaches combine elements of plant resistance, chemical, semiochemical, biological and microbial control. In this context an assessment of the pest complex and associated biological control agents is essential.

The earliest report on the insect pests of date palm goes almost one hundred years back when Buxton (1920) documented the insect pests of date palm in Mesopotamia (present day Iraq). Later, Carpenter and Elmer (1978) listed 54 species of insect pests and mites on dates and date palms. A comprehensive report from Israel on the arthropod pest complex of date palm and their management lists 16 major and 15 minor insect pests (Blumberg 2008). Recently, El-Shafie (2012), listed 112 species of mites and insects worldwide associated with date palm, including 22 species attacking stored dates. Of the arthropod pests listed in this report, only ten are considered major. This review also lists 45 predators and parasitoids associated with the insect pest complex of date palm.

Management of palm pests usually starts with the application of insecticides, but gradually progresses into the IPM mode, mainly due to the negative aspects of insecticide-based control programs. Scale insects (Hemiptera: Coccidea) cause heavy infestations in date palms, but the indiscriminate use of organophosphates against this and several other pests led farmers in Israel to gradually adopt IPM based programs. Preliminary IPM trials in date palm were aimed at controlling fruit pests and scale insects and also tissue borers like red palm weevil (RPW) in Israel (Soroker et al. 2005; Blumberg 2008).

In Iraq, Al-Jboory (2007) emphasized the importance of biological control for pests attacking date palm. Sustainable IPM programmes implemented by the Ministry of Agriculture in Iraq along with international collaborators in area-wide programs between 2009 and 2012, targeting stem borers, lesser date moth and dubas bug resulted in 90.5 %, 80 % and 96.7 % decrease in infestation levels, respectively. IPM interventions included solar light traps and hand collection of borers, application of neem based (azadirachtin) sprays against dubas and biological control of the lesser date moth employing treatments with *Bacillus thuringiensis* (http://www.icarda.org/bio-control-date-palm-pests).

Geographic Information System (GIS) based techniques and threshold based sampling plans could serve as vital tools to assess the performance of area-wide IPM programs in date palm. Massoud et al. (2012) used GIS tactics to determine the spatial-temporal distribution of RPW in food baited pheromone traps installed in vast stretches of date plantations in Al-Ahsa, Saudi Arabia, during 2009 and 2010. The fluctuation in spatial activity of RPW revealed lower weevil incidence in 2009 than in 2010, while maximum weevil activity was observed during early summer and late spring in 2009 and 2010. Furthermore, threshold based sequential sampling plans revealed that during 2011, the pheromone based IPM program against RPW in the same date palm oasis of Saudi Arabia was controlling the pest (infestations below 1 %) in the east of the oasis while needing minor adjustments (infestations approaching 1 %) in the centre of Al-Ahsa, and required major reinforcement (infestations above 1 %) in the north (Faleiro et al. 2010; Al-Shawaf et al. 2012). In Israel, the overall improvement in controlling insect and mite pests of date palm through the IPM approach involving mechanical and biological control, use of botanicals and semiochemicals together with crop management procedures enabled reduction in the use of synthetic insecticides with significant preservation of natural enemies (Blumberg 2008).

Monoculture of date palm in several growing countries, coupled with global warming, unrestrained use of chemical insecticides and extensive international trade affect the pest complex and its natural enemies. Changes are observed in the date palm agroecosystem in terms of species diversity and density of individual species per unit area. During the last two decades, there has been a significant increase in the area under date palm cultivation (FAOSTAT 2012) with several new plantations cultivated in vast monoculture stretches that offer an ideal ecological niche for biotic stresses, including insect pests and diseases. Between 1992 and 2012 the Maghreb region of North Africa (comprising of Algeria, Morocco, Tunisia, Libya and Mauritania) and the Gulf Cooperation Council (GCC) countries of the Middle East (comprising of Saudi Arabia, UAE, Sultanate of Oman, Bahrain, Kuwait and Qatar) showed a significant increase in new date plantations (Fig. 1.2).

At a plant density of 100 palms · Ha^{-1} (Zaid 2002) the new plantations in the Maghreb and GCC countries are estimated to account for around 25 million date palms (Faleiro et al. 2012). These young plantations are prone to attacks by several insect pests especially RPW, which prefers to infest date palms less than 20 years old (Abraham et al. 1998). Besides RPW, farmers will face new challenges arising either from new introductions or minor pests becoming major threats. Thus, they will have to rely on sustainable IPM techniques as proposed by Blumberg (2008) for date palm farmers in Israel, which integrates semiochemical mediated mating disruption or "attract-and-kill" methods, improved monitoring systems, deployment of biocontrol agents and inundating releases of egg parasitoids.

Recent genome sequencing in date palm indicates that stress resistance genes are present in the chromosomal regions where the density of single-nucleotide polymorphisms is comparatively low (Al-Mssallem et al. 2013). Advanced techniques like gene silencing or RNA interference (RNAi), aiming at delivering durable multiple resistance traits towards important date palm pests through the development of genetically improved resistant transgenic palms, represent potential strategies for future management approaches.

Novel IPM approaches using species-specific and environment-friendly management options of insect pests include: mating to control insects by rearing, sterilizing and releasing large numbers of insects (sterile insect technique: SIT) or release of insects with dominant lethal gene (RIDL). These strategies could be pursued in the context of area-wide sustainable IPM programs. The pheromone/semiochemical-based IPM strategy most widely adapted in date palm is the one used to manage RPW (Faleiro 2006). Use of semiochemicals for behavioral manipulation involves lower risks of resistance development in target pest species, a main disadvantage associated with the use of traditional insecticides (Miller et al. 2006). Furthermore, unlike conventional insecticides where the entire crop is sprayed posing a hazard to non-target organisms, semiochemicals are deployed selectively. As new pheromones and repellents are identified and deployed against more insect pests of date palm, semiochemical-based IPM strategies will have an increasing role to play in future IPM programs.

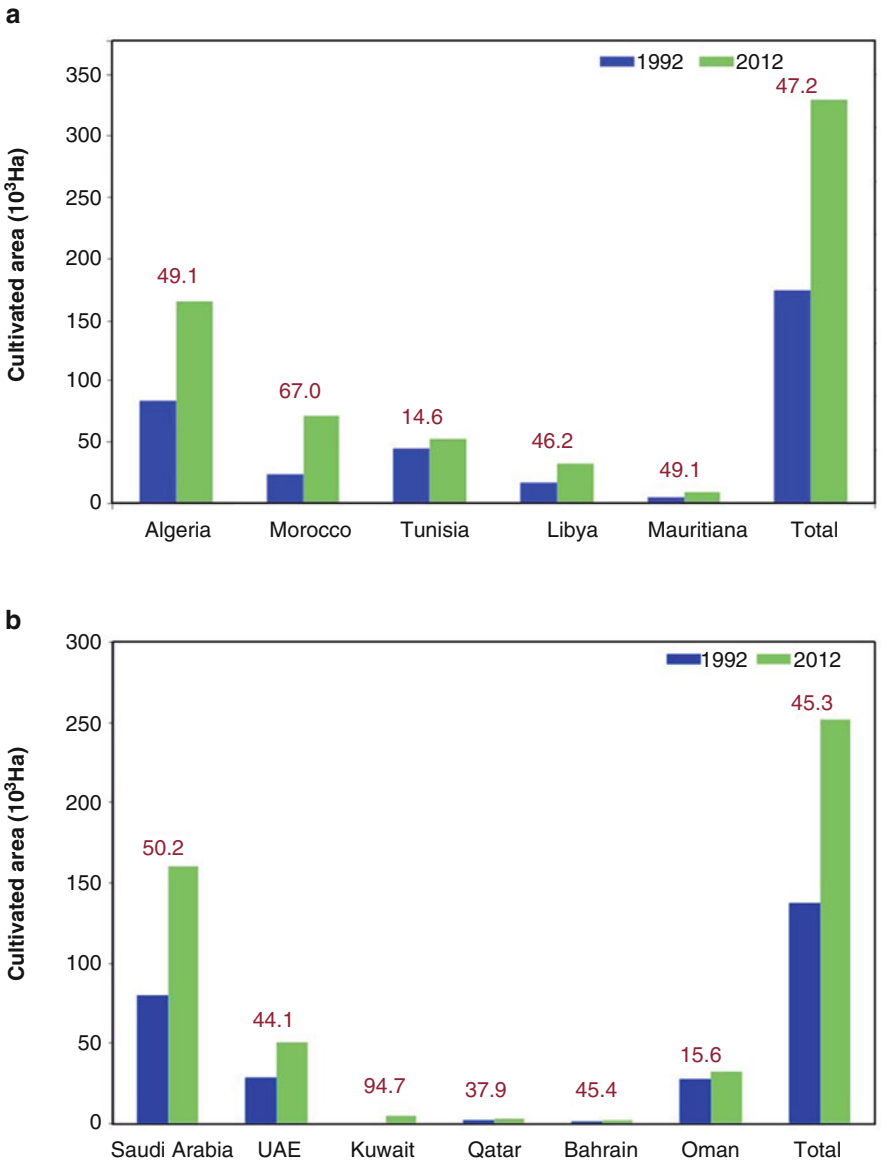

Fig. 1.2 Changes in the area under date palm cultivation (with % increase shown in *red*) in the Maghreb region of North Africa (**a**) and the GCC countries of the Middle East (**b**), between 1992 and 2012 (Source: FAOSTAT 2012)

According to the report of IPCC, the increase in mean temperature of earth surface could likely result in an increased abundance of several insects, with far reaching consequences on the way IPM strategies will evolve. According to Porter et al. (1991), climatic variations may bring changes in geographical distribution,

crop-pest synchrony, inter-specific interactions, increased over-wintering, elongation of development times, increasing number of generations and increased chances of invasive pest species episodes. Furthermore, Cannon (2004) reported that as temperatures increase, insects become more abundant through various inter-related processes, such as phenological changes and range extensions, as well as population growth, development, over-wintering and migration. Consequently, the monitoring and evaluation of insect pests and their natural enemies is becoming increasingly an imperative.

The adaptation of RPW – a tropical weevil from its warm and humid speciation area in South and Southeast Asia where it is regarded as a key pest of coconut – to the arid and hot regions of the Middle East on date palm, provides a classical example of how some expected changes may affect distant agroecosystems. Large scale and rapid movement of infested planting material has resulted in the abundance of RPW population in Middle East on date palm, and also on its adaptation to the Canary Island palm, *Phoenix canariensis* Chabaud in the Mediterranean basin countries and the transfer of *Oryctes agamemnon arabicus* from the Middle East and its establishment in Tunisia.

In view of the importance of date palm as an emerging crop of the future, and of the need to develop and adopt ecologically sound and socially acceptable IPM techniques, this volume aims at anticipating the issues related to the sustainable management of major insect and mite pests on this crop, by reviewing the current IPM strategies available and addressing emerging challenges and future research priorities. The book provides an overview of the biology (life cycle, damage, losses, geographical distribution, host range) and management (monitoring, action thresholds, cultural practices, physical and mechanical measures, use of semiochemicals, biopesticides and botanicals, biological and chemical control) of major insect pests of date palm from the orders Coleoptera (RPW, long horn beetle, dynastid beetles, frond borer, sap beetles), Hemiptera (dubas date bug, issid bug, scale insects, mealy bug) and Lepidoptera (lesser date moth, carob moth, raisin moth), together with other pests like mites. Issues pertaining to the role of semiochemicals in date palm IPM involving new strategies revolving around “attract-and-kill” and “push-pull” technologies, phytoplasmas, their insect vectors and innovative methods for managing storage pests of dates are also addressed.

References

Abdul Afiq, M. J., Abdul Rahman, R., Che Man, Y. B., Al-Kahtani, H. A., & Mansor, T. S. T. (2013). Date seed and date seed oil. *International Food Research Journal, 20*(5), 2035–2043.

Abraham, V. A., Al Shuaibi, M., Faleiro, J. R., Abozuhairah, R. A., & Vidyasagar, P. S. P. V. (1998). An integrated approach for the management of red palm weevil *Rhynchophorus ferrugineus* Oliv. – a key pest of date palm in the Middle-East. *Sultan Qaboos University Journal of Scientific Research (Agricultural Science), 3*, 77–83.

Al-Farsi, M., Alasalvar, C., Morris, A., Barron, M., & Shahidi, F. (2005). Compositional and sensory characteristics of three native sun-dried date (*Phoenix dactylifera* L) varieties grown in Oman. *Journal of Agricultural and Food Chemistry, 53*, 7586–7591.

Al-Jboory, I. J. (2007). Survey and identification of the biotic factors in date palm environment and its application for designing IPM-program of date palm pests in Iraq. *University of Aden Journal of Natural and Applied Sciences, 11*, 423–457.

Al-Mssallem, I. S., et al. (2013). Genome sequence of the date palm *Phoenix dactylifera* L. *Nature Communications, 4*, 2274. doi:10.1038/ncomms3274. 1–9 pp.

Al-Shahib, W., & Marshall, R. J. (2002). Dietary fibre content of 13 varieties of date palm (*Phoenix dactylifera* L.). *Journal of Food Science and Technology, 37*, 719–721.

Al-Shahib, W., & Marshall, R. J. (2003). The fruit of the date palm: It's possible use as the best food for the future? *International Journal of Food Sciences and Nutrition, 24*, 247–259.

Al-Shawaf, A. M., Al-Abdan, S., Al-Abbad, A. H., Ben Abdallah, A., & Faleiro, J. R. (2012). Validating area-wide management of *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) in date plantation of Al-Hassa. *Indian Journal of Plant Protection, 40*(4), 255–259.

Al-Wusaibai, N. A., Ben Abdallah, A., Al-Husainai, M. S., Al-Salman, H., & Elballaj, M. (2012). A comparative study between mechanical and manual pollination in two premier Saudi Arabian date palm cultivars. *Indian Journal of Science and Technology, 5*(4), 2487–2490.

Anonymous. (1985). Codex standards for dates. CODEX STAN. 6 p.

Baloch, M. K., Saleem, S. A., Ahmad, K., Baloch, A. K., & Baloch, W. A. (2006). Impact of controlled atmosphere on the stability of Dhakki dates. *Swiss Society of Food Science and Technology, 39*, 671–676.

Besbes, S., Blecker, C., Deroanne, C., Bahloul, N., Drira, N. E., & Attia, H. (2004). Date seeds: Chemical composition and characteristic profiles of the lipid fraction. *Food Chemistry, 84*, 577–584.

Blumberg, D. (2008). Review: Date palm arthropod pests and their management in Israel. *Phytoparasitica, 36*(5), 411–448.

Buxton, B. A. (1920). Insect pests of date and date palm in Mesopotamia and elsewhere. *Bulletin of Entomological Research, 11*, 287–303.

Cannon, R. J. C. (2004). The implications of predicted climate change for insect pests in the UK, with emphasis on non-indigenous species. *Global Change Biology, 4*(7), 785–796.

Carpenter, J. B., & Elmer, H. S. (1978). *Pests and diseases of the date palm* (Agricultural Research Service Handbook. No. 527; 42 pp). Washington, DC: United States Department of Agriculture.

Chandrasekaran, M., & Bahkali, H. A. (2013). Valorization of date palm (*Phoenix dactylifera*) fruit processing by-products and wastes using bioprocess technology – Review. *Saudi Journal of Biological Sciences, 20*, 105–120.

Chao, T. C., & Krueger, R. R. (2007). The date palm (*Phoenix dactylifera* L.): Overview of biology, uses, and cultivation. *Horticulture Science, 42*(5), 1077–1082.

El-Hadrami, A., & Al-Khayri, J. M. (2012). Socioeconomic and traditional importance of date palm. *Emirates Journal of Food and Agriculture, 24*(5), 371–385.

El-Shafie, H. A. F. (2012). Review: List of arthropod pests and their natural enemies identified worldwide on date palm, *Phoenix dactylifera* L. *Agriculture and Biology Journal of North America, 3*(12), 516–524.

Faleiro, J. R. (2006). A review of the issues and management of the red palm weevil *Rhynchophorus ferrugineus* (Coleoptera: Rhynchophoridae) in coconut and date palm during the last one hundred years. *International Journal of Tropical Insect Science, 26*, 135–154.

Faleiro, J. R., Abdallah, B. A., & Ashok, K. J. (2010). Sequential sampling plan for area-wide management of *Rhynchophorus ferrugineus* (Olivier) in date palm plantations of Saudi Arabia. *International Journal of Tropical Insect Science, 30*(3), 145–153.

Faleiro, J. R., Ben Abdallah, A., El Bellaj, M., Al-Ajlan, A. M., & Oihabi, A. (2012). Threat of red palm weevil, *Rhynchophorus ferrugineus* (Olivier) to date plantations of the Maghreb region in North Africa. *Arab Journal of Plant Protection, 30*, 274–280.

FAOSTAT. (2012). Food and agricultural commodities production. Available at: http://faostat.fao.org/site/567/default.aspx#ancor. Accessed on 29 Apr 2015.

Fayadh, J. M., & Al-Showiman, S. S. (1990). Chemical composition of date palm (*Phoenix dactylifera* L). *Journal of the Chemical Society of Pakistan, 12*, 84–103.

Jaradat, A. A., & Zaid, A. (2004). Quality traits of date palm fruits in a center of origin and center of diversity. *Food, Agriculture and Environment, 2*(1), 208–217.

Johnson, D. V. (2011). Date palm biotechnology from theory to practice. In S. M. Jain, J. M. Al-Khayri, & D. V. Johnson (Eds.), *Date palm biotechnology* (pp. 1–11). Dordrecht: Springer.

Johnson, D. V., Al-Khayri, J. M., & Jain, S. M. (2013). Seedling date palms (*Phoenix dactylifera* L.) as genetic resources. *Emirates Journal of Food and Agriculture, 25*(11), 809–830.

Lal, R. (2001). Potential of desertification control to sequester carbon and mitigate the greenhouse effect. *Climatic Change, 15*, 35–72.

Massoud, M. A., Sallam, A. A., Faleiro, J. R., & Al-Abdan, S. (2012). Geographic information system-based study to ascertain the spatial and temporal spread of red palm weevil *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) in date plantations. *International Journal of Tropical Insect Science, 32*(2), 108–115.

Miller, J. R., Gut, L. J., de Lame, F. M., & Stelinski, L. L. (2006). Differentiation of competitive vs. non-competitive mechanisms mediating disruption of moth sexual communication by point sources of sex pheromone (Part II): Case studies. *Journal of Chemical Ecology, 32*, 2115–2143.

Popenoe, P. (1992). The pollination of the date palm. *Journal of the American Oriental Society, 42*, 343–354.

Porter, J. H., Parry, M. L., & Carter, T. R. (1991). The potential effects of climatic change on agricultural insect pests. *Agricultural and Forest Meteorology, 57*(1–3), 221–240.

Soroker, V., Blumberg, D., Haberman, A., Hamburger-Rishard, M., Reneh, S., Talebaev, S., Anshelevich, L., & Harari, A. R. (2005). Current status of RPW in date palm plantations in Israel. *Phytoparasitica, 33*, 97–106.

Vayalill, P. K. (2002). Antioxidant and antimutagenic properties of aqueous extract of date fruit (*Phoenix dactylifera* L. Arecaceae). *Journal of Agricultural and Food Chemistry, 50*, 610–617.

Wrigley, G. (1995). Date-palm (*Phoenix dactylifera* L.). In J. Smartt & N. W. Simmonds (Eds.), *The evolution of crop plants* (2nd ed., pp. 399–403). Essex: Essex Longman.

Zaid, A. (2002). *Date palm cultivation* (FAO Plant Production and Protection Paper No. 156, Revision 1). Rome: Food and Agriculture Organization of the United Nations.

Zohary, D., & Hopf, M. (2000). *Domestication of plants in the old world: The origin and spread of cultivated plants in west Asia, Europe, and the Nile Valley* (3rd ed.). Oxford University Press Inc., New York, USA. 328 pp.