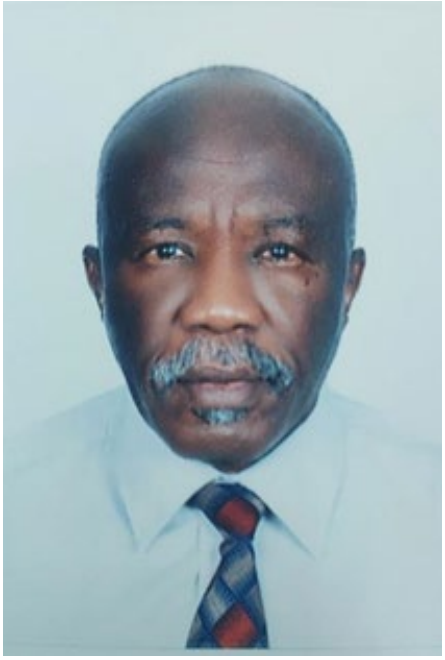
EDITORIAL

Sustainable Pest Management in Date Palm: Current status, challenges, and future directions

The date palm *Phoenix dactylifera* is a valuable tree that has economic, social, cultural, and ecological significances. Beside production of highly nutritious edible dates and numerous byproducts, the tree acts as an important sink for sequestration of atmospheric carbon dioxide, thus mitigating the impact of climate change. Moreover, date palm sector contributes largely to food security, livelihood of rural communities, and environmental sustainability.

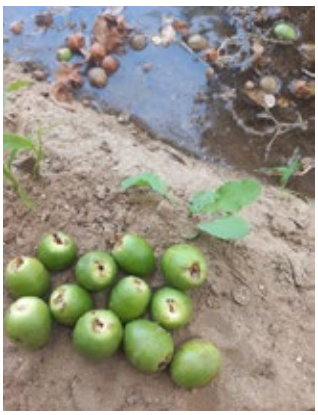


The date palm agroecosystem comprises diverse groups of animals including insects, mites, birds, reptiles, and mammals. There are so many arthropod pests of date palm, which might exceed 135 species, however, a few ones, wreak havoc on date palm and cause economic damage that necessitate management action. The date palm pests could be classified according to the affected parts of the palm into roots, trunk, fronds, inflorescence, and fruit pests. Pests that cause injury to the roots, trunk, and frond midrib include the red palm weevil *Rhynchophorus ferrugineus*, the longhorn borer *Jebusaea hammerschmidti*, different species of termites, frond borer *Phonapate frontalis*, and the rhinoceros beetles *Oryctes* spp., while dubas bug *Ommatissus binotatus*, scale insects, and mealy bugs inflict serious damage on leaves. Major preharvest pests that attack inflorescence and premature fruits include the lesser date moth *Batrachedra amydraula* Meyerick, the greater date moth *Aphomia* (*Arenipses*) *sabella*, the carob moth *Ectomyelois* (*Apomyelois*) *ceratoniae*, the date stone beetle *Coccotrypes dactyliperda*, the inflorescence (spathe) weevil *Derelomus* sp and the old world date mite *Oligonychus afrasiaticus*.

On the other hand, major postharvest pests include the almond moth, *Cadra cautella*, and the saw-toothed grain beetle, *Oryzaephilus surinamensis*. The impact of date palm pests on the environment, biodiversity, and food security is overwhelming. Moreover, the date palm ecosystem includes numerous natural enemies (predators and parasitoids) that play a key role in checking the populations of harmful insects and mites. This unique ecosystem should be considered a living entity when considering the control of major pests.

Any unbalanced intervention may lead to a resurgence of minor pests or even the emergence of new species that are difficult to manage. Currently, date palm pest management depends largely on using chemical insecticides applied through spraying, soil drenching, trunk injection, and fumigation. Additionally, regulatory control, agronomic practices, light and pheromone traps, mechanical control, biological control are deployed. Likewise, microbial insecticides and botanicals are applied to a






limited extent. The main challenges facing sustainable pest management in date palm include, but are not limited to, conservation of natural enemies, insecticide resistance, finding an optimized combination of management components, and climate change

For sustainable management of date palm pests, an integrated holistic intervention strategies that are environmental-friendly should be followed. This intervention approach should consist of the following steps i) proper identification of pests and beneficials ii) preventive practices iii) surveillance and monitoring of pest populations iv) specifying of action threshold v) making action decision to initiate control measures, and vi) evaluation and follow-up of management programs against specific performance indicators. Pest management activities may focus on the use of monitoring, semiochemicals (pheromones and repellents), botanical, biological agents, and microbial pesticides, which are green, climate-resilient, sustainable and environmental friendly. Good agricultural practices (GAP) should be relied upon as one of the most important preventive methods to curb the seriousness of date palm pests. Both mico-and macrosymbionts of date palm pests represent potential biocontrol agents that could be used in biological control against these pests. Before deployment in wide-area pest management, their efficacy, ease of use, and field stability should be enhanced with an emphasis on identifying local strains that can withstand high temperatures and varying environmental factors prevailing in date palm ecosystems.

Infestation by many date palm preharvest fruit pests does not require the application of insecticides. For example, applying insecticides and measurements taken against the date stone beetle or the lesser date moth during April-May could prevent serious injury by the spring generation of the greater date moth *Aphomia sabella*. Additionally, treatments applied during September-October against other fruit moths and sap beetles may also reduce GDM populations and their damage. On the other hand, bunch covering with Agribon™ bags, field sanitation, and early harvesting of certain varieties can sufficiently manage many preharvest insect and mite pests without the need for pesticide application or deployment of other means of control.

This synchronization of control is applicable for trunk borers such as the red palm weevil, longhorn beetle and bunch borer, which could effectively be managed through palm trunk injection using emamectin benzoate or other systemic insecticides.

Setting economic and action thresholds is essential in integrated pest management (IPM) and should be given top priority. The adoption of action thresholds helps in reducing the frequency of insecticide application as well as enhancing management programs for insecticide resistance. Simple action thresholds, which are adaptable to the farmers, should be used to make decisions and initiate control actions. In this respect, prediction models for major date palm pests should be developed. Monitoring of pest population is an important component of IPM, upon which decision-making related to control programs are made. A good example is the SusaHamra App, which is a digital system for monitoring and early warning for red palm weevil. The system was developed by Food and Agriculture Organization of UN (FAO) and contains a cloud platform for processing, analyzing, and mapping the RPW collected data. Area-wide management programs for major date palm pests depend largely on big data and synchronization of control operations and coordination among farmers and stakeholders. Smart digital traps that can send real-time field data (7x24) are commercially available, at least for some pests, could be deployed in the date palm plantations for population monitoring and evaluating the efficacy of any management program. Early detection of the date palm infestation by the major insect

pest such as the RPW is considered the cornerstone of management, which can significantly mitigate the economic damage and enable timely and effective IPM programmes deployment. A persistent, remote surveillance system that combines the features of multi-spectral imaging, chemical sensing, and persistent autonomous measurement and machine learning for data analysis can be used as an innovative tool future date palm pest management. Unmanned aerial vehicle (UAV)-based surveillance and machine learning for pattern recognition and analysis can overcome the limitations of existing early detection approaches. This approach of using IoT and digitalizing date palm pest management will improve governance effectiveness and increase transparency with respect to validity of field data that lead to the success of the control programs.

Reviewing the management technologies adopted against major date palm insect and mite pests, during the last 40 years, reveals many gaps and challenges that need to be adequately addressed in order to keep the pest populations below levels that cause economic damage and to achieve sustainable management. Therefore, to address some of these challenges and to bridge the gaps, the existing management practices need to be improved. Future management technologies should be effective, applicable, cost-effective, socially acceptable, and environmental-friendly.

The genomes of many major date palm insect pests have been released and the essential genes were sequenced and deposited in the global GenBank. Silencing of some of these essential genes through RNA interference technology (RNAi), offers a great chance for innovative method of control of these pests such as vitellogenin-based dsRNA feeding and alpha amylase dsRNA delivery. Precision-guided sterile male technique (pgSMT), incompatible insect technique (IIT), and releasing of insects with dominance lethal "RIDL" technology, which has been tried, with success, in some insects could be used for the management of date palm pests in the future. The use of sterile males in dispersing entomopathogenic fungi (infect-release technique) represents innovative alternative for pest management in date palm in the future. Regulatory measures, capacity building of agricultural engineers, and raising the farmers' awareness about date palm pests and their management, through farmers field schools (FFS), are essential supporting components of a successful sustainable pest management package.

Conclusion

Currently the date palm pest management depends overwhelmingly on the use of insecticides. Effective combination of the different management components need to be optimized. Future directions should seek and apply innovative technologies such as smart pest detection and monitoring devices, RNAi, pgSMT to achieve sustainable, climate-resilient, and smart pest management. Capacity building of agricultural engineers and stakeholders as well as training of farmers should be given a great consideration.

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