Food and Agriculture Organization of the United Nations

CIHEAM

Current Situation of Red Palm Weevil in the NENA Region

[Current situation of management practices, challenges/weaknesses and available research and technologies for its improvement]

Scientific Consultation and High-Level Meeting on Red Palm Weevil Management, Rome, 29-31 March, 2017

This Document is prepared by the RPW Expert Team with support of FAO, CIHEAM and NEPPO Technical Officers

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List of abbreviations

CIHEAM	International Centre for Advanced Mediterranean Agronomic studies
EPN	Entomo-pathogenic Nematodes
EPPO	European Plant Protection Organization
FAO	Food and Agriculture Organization
FAO-CIO	FAO-Chief Information Officer Division
GIS	Geographic Information System
GPRS	General Packet Radio Service
GSM	Global System for Mobile communication
ISPM	International Standard for Phytosanitary Measures
IPPC	International plant Protection Convention
IPM	Integrated Pest Management
KSA	Kingdom of Saudi Arabia
LIBS	Laser Induced Breakdown Spectroscopy
M&E	Monitoring and Evaluation
MoA	Ministry of Agriculture
NENA	Near East and North Africa
NEPPO	Near East Plant Protection Organization
NGO	Non-Governmental Organization
NPPO	National Plant Protection Organization
NIRS	Near Infrared Spectroscopy
PRA	Pest Risk Analysis
QGIS	Quantum Geographic Information System
RBM	Result Based Management
RFID	Radio Frequency Identification
RPW	Red Palm Weevil
RNAi	Ribonucleic acid-interference
TMS	Trapping Management System
TCP	Technical Cooperation Program
USD	United States Dollar
UAE	United Arab Emirates
UTF	Unilateral Trust Fund

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1. BACKGROUND

Red Palm Weevil (RPW) *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionidae) known also as the Asian Palm Weevil or Indian Red Pam Weevil is indigenous to South and South East Asian Countries. It is one of the world's major invasive pest species and attacks around 40 palm species worldwide. The most important host species of RPW are Date Palms, Coconut Palms, Oil Palms, Canary Island Palms and Washingtonia Palms. RPW was first detected in the Gulf region during the mid-eighties, and has significantly expanded westwards over the last three decades to cover almost all countries of the Near East and North Africa region (NENA) (Figure1).

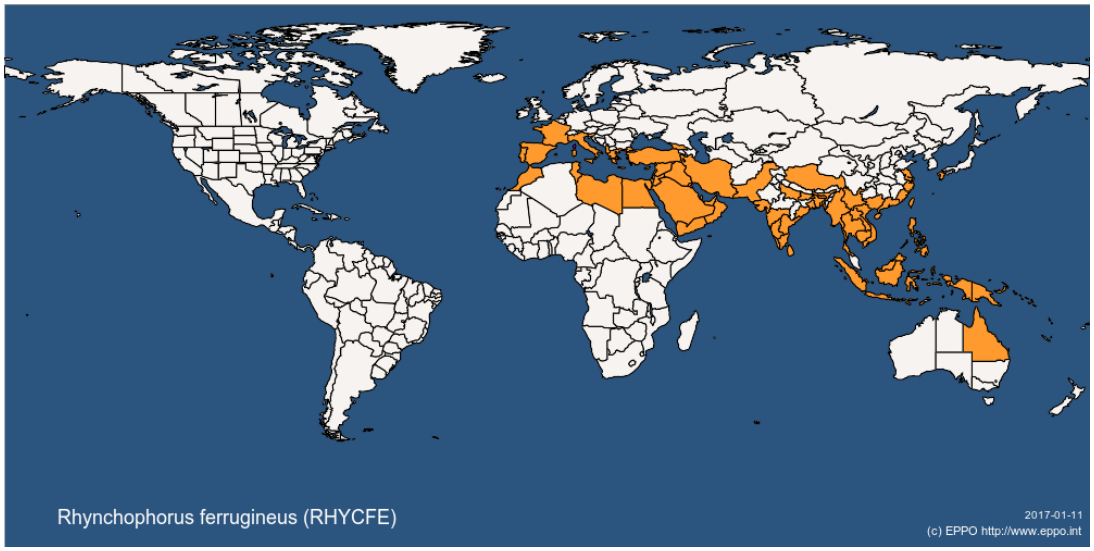

Figure 1: Global distribution of *Rhynchophorus ferrugineus* from the EPPO Global database. The detail records is provided at https://gd.eppo.int/taxon/RHYCFE/distribution

The RPW is spread through the movement of infested plant materials including young or adult palms and offshoots. Weak quarantine procedures and difficulties in the early detection of RPW-infested plant materials have contributed to its rapid spread. Currently RPW is being managed employing pheromone based IPM strategy. There are some evidence based success stories of the eradication of RPW. One of these being the RPW-IPM program of Canary Islands in Spain, where RPW was eradicated as there has been no new infestation reports and no weevil captures in traps for the last three years, since 2013. This success was due to the scientifically based, systematic and well-coordinated program supported by adequate resources.

1.1. Economic impact of RPW

Date palm represents a symbol of life in the NENA region and has a long heritage of sustaining human life in hot and infertile areas, where it is seen as a renewable natural resource. RPW has significant socio-economic impact on the date palm production sector and livelihoods of farmers in affected areas. Although there are no concrete studies of the economic impact of RPW on palms, it is considered as a key pest of palms with immense economic and environmental impacts, with consequences on food security and rural community livelihood in date palm oases. Direct losses due to RPW can be attributed

to the value of the destroyed palms and the loss in yield, in addition to the high cost of the management programs, notwithstanding the expenses incurred on the removal and disposal of infested palms. The indirect costs are also substantial. The most significant of these is the restricted movement of trees, especially their offshoots. These restrictions result in drastic cuts in trade not only among countries but also between different regions of the same country that has also curtailed the expansion of new plantations, besides the adverse impact on the environment and landscape as a result of chemical treatments and removal of the infested palms, respectively.

In the Middle-East, RPW has been the most destructive insect pest of date palm and is designated as category-1 pest by FAO. The annual loss during 2009 in the Gulf region of the Middle-East due to removal of severely infested palms has been estimated to range from 1.74 to 8.69 million USD at 1 and 5% infestation, respectively. Recent reports indicate that in the Mediterranean region, palms worth up to 483 million Euros have been destroyed or infested, primarily by RPW. However, this figure remains a significant underestimate of the total economic value of affected palms because no study has accounted for all of the ecosystem services they provide.

In the Spanish region of Murcia over 7 million Euros were spent on various measures to combat RPW mainly on the removal of infested palms. Between 2004 and 2009, in the autonomous community of Valencia around 20,000 palms, mostly *Phoenix canariensis*, were killed by RPW, where losses were estimated to be 16 million Euro.

1.2. Overview of the RPW situation in the NENA region

In the NENA region, RPW was first recorded in Ras-Al-Khaima in UAE during 1985. Thereafter, it has been reported from the entire region, with Iraq being the latest country to report RPW during 2015. Although all the Near East countries have reported RPW during the last three decades, in North Africa there is no report on the incidence of the pest in Algeria. Currently 0.95 million ha are under date palm in the region with an estimated 48 million palms in the susceptible age group of less than 20 years.

Recent country reports on the current status, challenges and recommendations to improve the control of RPW in the region (Egypt, Iran, Iraq, Libya, Morocco, Mauritania, Oman, Palestine, Qatar, Saudi Arabia, Tunisia and Yemen) reveal that RPW arrived in the countries either through infested date palm offshoots, ornamental palms or hitchhiking on moving vehicles. In most of the countries there are phytosanitary (quarantine) laws/decrees to prevent the movement of infested palms, however enforcement and implementation is weak. In Morocco and Mauritania quarantine laws have helped to prevent the spread of RPW. Usually, the source of offshoots is known in most of the countries; however there are no certified nurseries, while tissue cultured palms for several varieties are available in some countries. Lack of awareness, commitment to implement quarantine regulations and difficulties in detecting infested palms are some of the challenges and constraints facing application of quarantine measures in the NENA region. In Egypt, smuggling of offshoots through alternate routes is a constraint in the effective application of quarantine regulations. In Tunisia during 2016, RPW spread to three foci 30-60 km from Tunis where it was detected in 2011, which is indicative of the weakness of the quarantine measures implemented.

Regular inspection of palms, pheromone trapping, chemical insecticide treatments, internal quarantine, are some of the major preventive measures/practices put in place to control RPW by countries in the NENA region. In Mauritania, the preventive measures adopted have been very effective to control RPW, while in Libya the measures adopted have not been effective due to the lack of a planned and structured

RPW-IPM program and also the prevailing security situation. It is pertinent to mention that in Mauritania, a well-structured RPW-IPM national program supported by FAO, was implemented without much delay after the first report of the pest with the active involvement of the farmers, cooperatives, Governmental and non-Governmental agencies, that resulted in containment of the pest with a good potential for its eradication in the infested area.

Early detection, vast stretches of date plantation (Egypt, Iran, Saudi Arabia), topography and heterogeneity of the traditional grooves (Egypt, Iran, Saudi Arabia) physically challenging task (Morocco, Tunisia), prevailing security situation (Libya), presence of neglected gardens and lack of adequate human and financial resources (all countries) are some of the major challenges in implementing the preventive control measures. The number of infested palms is known in countries having a national IPM program to control RPW, where tables, graphs and maps for data in the control program are developed frequently in most of the countries of the region, while in Tunisia infested palms are also geo-located.

Use of pheromone traps in surveillance and mass trapping programs is reported from all the NENA countries infested with RPW where the number of traps deployed in the field is known. These traps are serviced (changes of food bait and water) every 7-14 days and data on weevil captures is maintained and utilized to gauge the success of the strategy employed. The trap density varied from 0.5 trap/ha (Iran) to1.0 trap/ha (Saudi Arabia). In Tunisia pheromone traps are geo-located using GPS.

In countries with a national RPW-IPM program data on palm inspection, preventive and curative treatments are maintained. The socio-economic dimension of the problem is not very well studied in the NENA countries. In general, farmers and other stakeholders are aware of the problem and in some countries garden owners are involved in implementing some of the control measures. In Tunisia, farmers in the date palm oasis in the south of the country have been involved in the drafting of the strategy to prevent the spread of RPW to the southern areas of Tunisia.

Detection of infested palms by periodic visual observations is reported to be moderately to very effective by countries of the region and is linked to captures in pheromone traps in Saudi Arabia to prioritize inspection of palms in and around traps capturing weevils. However, in general, lack of effective advanced detection instrument techniques is the main constraint seen in the region. Upon detection of an infested palm, it is either treated (if in the early stage of attack) or eradicated (if in the advanced stage of attack). Efficiency of the control program in most of the countries is gauged on infestation reports and weevil captures in traps. In Mauritania, all infested palms are removed/eradicated.

Weakness of human and financial potentials, absence of biological control, strong heterogeneity of traditional date palm groves, labor intensive control and high cost, lack of farmer's and stakeholder's cooperation are the major challenges/constraints facing the management practices. In most of the countries all the prevention and control operations are carried out by the Government, while in some, inputs for control are supplied free of cost by the Government. As per the country reports, clear policy or strategy to control RPW is in place by most Governments of the region. In UAE, pheromone trapping and treatment of infested palms is outsourced to private agencies under supervision by the Ministry officials.

Extension/Plant Protection services in the region provide training to farmers and other stakeholders on the control of RPW. Advanced innovative technologies using electromagnetic waves, sound waves,

using trained dogs for early detection of the pest have been field tested in Saudi Arabia with limited success, while stem injection (Egypt , Saudi Arabia,), improving trapping efficiency (Morocco) and attract and kill technology (Mauritania, Saudi Arabia,) are other innovative or modern technologies that have been tested/applied in the region.

Detection difficulties, limited efficiency of the on-going management program, regional cooperation and funding, control is challenging physically for workers and is costly, prevailing security situation (Libya), lack of awareness among some farmers and officials, participation of the producers etc. are some of the major challenges and constraints facing the control of RPW in the region.

Raising awareness, applying incentive and punishment system, re-evaluation of the current recommended management practices, effective early detection technique, international and regional level push toward direct coordination, regulation regarding the import and export of offshoots, support to set up surveillance program etc. are some of the major recommendations proposed by member countries of the NENA region to overcome the challenges of RPW management and improve the management programs.

1.3. Previous FAO work and experience in managing RPW in the region

FAO has provided substantial technical assistance to enhance the cooperation and knowledge sharing between the countries in the NENA region, and strengthen the capacities of the countries for the management of RPW to reduce/prevent its spread to non-infested areas within the infested countries and to other non-infested countries. Recently, several projects have been implemented by FAO in the NENA Region especially to assist countries in RPW management. The sub-regional TCP project TCP/RAB/3307 on "Management of Red Palm Weevil in North Africa" has been implemented in 2012-2014 in North African Countries. Technical assistance has been provided to reinforce the ongoing pheromone based RPW strategy in the KSA, testing and validation of new technologies, and to train professionals and farmers on advanced control methods that was provided through the two phases of the UTF project on "Development of an International Date Palm Research Centre in Al Hassa, KSA during (2006-2016). Specific support has also been provided to Yemen under an emergency TCP (TCP/YEM/3404 (E) to control the outbreak of RPW and also in the West Bank and Gaza Strip. More recently FAO supported TCP projects to combat RPW were developed for 'emergency assistance to control RPW outbreak' in Mauritania (TCP/MAU/3505) and to 'support for surveillance and management of RPW' in Iraq (TCP/IRQ/3602).

During 2014, FAO evaluated the ongoing pest management program of date palm pests besides developing a proposal for date palm IPM in UAE with emphasis on the area-wide management of RPW. Furthermore, during 2016, FAO undertook a specialized mission on RPW to Saudi Arabia to review and learn about the current ongoing program being implemented in the Kingdom and provide recommendations to enhance research capacity of the RPW management program.

In addition to the aforementioned projects, FAO has organized many technical sessions in the past few years to facilitate the sharing of experience, knowledge and advanced technologies among the experts and different stakeholders involved in date palm production and RPW management. The most recent workshop was the International Workshop on RPW Management, held in Riyadh in May 2015, organized by FAO and the Ministry of Agriculture of KSA, with participation of 22 invited experts.

2. ANALYSIS OF THE MANAGEMENT PROGRAMME COMPONENTS

2.1. Phytosanitary (quarantine) Measures

- **Current status:**

  In most of the countries there are no clear import regulations for palm trees.

  A. Date Palm:

  In general, several laws and regulations do exist preventing the movement of infested offshoots within the country and also prohibiting import of offshoots from another country. However, enforcement is weak.

  B. Ornamental Palms:

  In general, several laws and regulations do exist preventing the movement of infested palms within the country and also prohibiting import of offshoots from another country.

- **Challenges/weaknesses:**

  1. Reluctance of the farmers to implement the quarantine measures due to lack of awareness on the risk and options available.
  2. Insufficient staff and means in the countries to effectively implement the regulations.
  3. Smuggling of planting material through alternate routes.
  4. Interference in the imports/ movements of planting material by higher officials.
  5. Lack of :
     - Availability of sources of trustful /certified palms within the countries.
     - Enforcement of quarantine measures.
     - Involvement and coordination between all stakeholders/agencies (MoA and law enforcement authorities) for enforcing the internal phytosanitary measures and import regulations.
     - Awareness and coordination among farmers and other stakeholders.
     - Specific guidelines on phytosanitary measures to regulate the palm trade, especially for officials / enforcement authorities at the entry points.
     - Registered nurseries.
     - Traceability (source and subsequent movement) of palms transported.

- **Proposed improvements/recommendations:**

  1. Development of specific regulations with clear requirements for import, movement and nursery certification.
  2. Enforcement of harmonised plant quarantine protocols for phytosanitary treatments and specification of planting material.
  3. Development of manuals on RPW specific quarantine regulations and measures.
  4. Establish certified and registered nurseries that would be entitled to trade RPW free palms.
  5. Support the establishment of tissue culture laboratories for the production and supply of RPW free planting material.
  6. Training of Plant Quarantine Staff and other law enforcement authorities.
  7. Raising awareness on RPW phytosanitary measures among all the stakeholders.
  8. Strengthen the coordination and engagement of all stakeholders (farmers/farmers' cooperatives, NGOs, MoA officials, other law enforcement agencies etc.).

- **Options for improvement of the phytosanitary (quarantine) measures**

Specific regulations and measures should be developed for the import and containment systems. As movement of plant material is the main pathway of introduction of RPW in the country, import regulations should be put in place with clear inspection and treatment procedures.

Prevention is the main tool to deal with RPW for the countries not yet infested. Due to the cryptic biology of RPW, importation of palms plants should be strictly regulated. The importation of date/ornamental palm offshoots and adult trees should be banned from infested countries/areas.

Ornamental palms for planting should have specific requirements, such as the size of palms to be introduced (in tube for tissue culture palms, or less than 5 cm in diameter of the stem at the base for the other palms). Date palm should be imported in tubes produced from tissue culture. Acclimatization should be done at the imported country level. All imported consignment should be inspected.

As the risk of introduction by ornamental palms is probably very high, importers should be registered, and mapped (GIS system) by National Plant Protection Organization (NPPO). They should ensure a traceability and management system to follow up the introduction, the management of nursery and the destination of palms sold. Official annual surveys should be conducted for the absence of RPW and early detection of its presence on plants of palm tree (including all family of palms) in their area.
Guidelines and procedures should be developed for strengthening quarantine inspection at borders and plant protection services within the country (including manual on identification of palms species).

For containment, movement of palms trees should also be regulated within the country mainly from infested area to avoid any potential spread of RPW.

With respect to date palm, nurseries should be authorized and certified by an official institution to ensure their compliance with a certification scheme (variety authentication and free from pests including RPW). In case of detection, the National Plant Protection Organization (NPPO) should define a demarcated area and implement the appropriate measures to contain and suppress RPW such as:

I. destruction or, where appropriate, complete mechanical sanitation of the infested susceptible plants;
II. measures to prevent any spread of the specified organism during the destruction or sanitation actions by application of chemical treatments in the immediate vicinity;
III. appropriate treatment of infested susceptible plants;
IV. where appropriate, mass pheromone trapping in infested areas;
V. stop movement of nursery stock from the infested area.

The NPPOs should also carry out an intensified survey programme in an area of at least 10 km around the infestation foci based on the International Standard for Phytosanitary Measures (ISPM 6) and trace back the related plant material. An action plan based on (ISPM 9) related to pest eradication programmes and (ISPM 14) related to the use of integrated measures in a systems' approach for pest risk management.

Phytosanitary measures should be applied at the farm level or local level where offshoots of date palm are collected, transported to existing gardens or for establishing new farms. Besides, guidelines should be for establishing commercial date palm nurseries. Protocols need to be developed that can be implemented at the field level to treat palms both for farming and ornamental gardening to ensure that the planting material to be transported is free of the pest. One of the suggested protocols for the date

palm offshoots management is described here. Before the offshoots are loaded at the supply farm, a thorough visual inspection has to be done and made sure that there is no infestation. After the offshoots are brought to the farm, a trained dog squad if available may be used for sniffing and any suspicious material may be kept isolated and further checked and only absolutely healthy offshoots are allowed inside farm for transplanting. The offshoots are to be sprayed with a combination of fungicide and insecticide to drench the offshoots. At the time of offloading at the nursery, each offshoot may be dipped in the recommended pesticide. After dipping, the offshoots are planted in the pots or in the field. Depending on the infestations in the neighboring farms, bi-monthly or tri-monthly sprays may be given to the transplanted or potted offshoots. After one month of putting in pot, application of granular pesticide may be useful to give better control. Monitoring of offshoots for any pests and diseases should be continued on regular basis. By following this method the risk of importing the weevil or pest accidentally is minimized and also killing of any hidden pest is ensured.

2.2. Early Detection

- **Current status:**

Visual and manual inspection of palms is currently widely practiced to detect RPW infested palms. In several countries visual detection is carried out generally by trained technical staff.
The other advanced methods of detection (acoustics, thermal imaging, chemical signatures, laser induced breakdown spectroscopy, near infrared spectroscopy, biological and physiological stress indicators, sniffer dogs etc.) are currently under experimentation.

- **Challenges/weaknesses:**
  1. Limited numbers of trained personnel available for visual inspection.
  2. Visual inspection is laborious and costly.
  3. Badly managed date farms with growth of offshoots, weeds etc. are difficult to be inspected visually.
  4. Where infestation occurs in the crown (Canary Island Palm) visual detection needs specific training.
  5. Weak involvement of the farmers and garden owners, municipalities etc. in the periodic visual inspection.

- **Proposed improvement/recommendations:**
  1. Improve farmer/stakeholder involvement by training, farmer-participatory approach, extension agents, giving incentives/fines etc.
  2. Develop a protocol for visual inspection in a simple and easy way, to understand, in languages of the farmer and other support staff.
  3. Enforce clean cultivation especially related to offshoot management and frond removal to facilitate visual inspection.
  4. Urgent need to develop a quick and reliable, cost effective, and easy to handle early detection device for RPW.
  5. Adopt early detection of RPW infested palms using trained sniffer dogs where ever possible.

- **Research and technologies developed for improvement of early detection**

Following platforms, sensors and techniques need to be considered to enhance the efficiency of the detection.

- **Platforms :** Drones, Satellite, Aircraft
- **Sensors:** Visible, Infra-red, Multispectral
- **Techniques:**

- ***Detecting chemical signatures (e-nose, sniffer dogs):***

Using dogs to detect RPW infested date palms is possible, where infestations are recorded between 2m from the ground. Dog-assisted detection could suit well for palm inspection in the field, at nurseries, ports of entry and/or quarantine facilities.

The use of trained sniffer dogs in early detection of infested palms has been established. There were some concerns regarding the adoption of the dogs to high temperature conditions in Gulf regions and other regions. For a few years in private farms, the trained sniffer dogs were effectively used for identifying the early infestations in date palms. This method of early detection is similar to the techniques employed by customs officials at ports, airports and other gateways of importation. Hence, wherever it is possible, especially for the local transport of planting material at border check points, internal regional restricted zones, etc. these sniffer dogs can also be used besides visual inspection to ensure pest free material.

Electronic gas sensors have been used to detect volatile emitted by plants infested by insects. However, these sensors are also highly sensitive to the presence of other different compounds such as alcohols, ketones, fatty acids and esters.

- ***Acoustic detection:***

Acoustic technology measuring the spectral and temporal patterns of sounds produced by feeding and moving larvae has the potential to enable early detection, particularly because the insect sounds often can be distinguished from agricultural or urban background noise by identifying specific groupings (bursts) of broadband impulses produced by insects but not by other animals or machinery. Currently available acoustic systems have seen limited use because they require skilled operators. Simpler, lower-cost automated systems are being developed to increase the capability of early detection efforts. Also, field studies are being conducted to reduce interference from high wind that may induce leaf-tapping noise pulses difficult to distinguish from insects' sounds.

- ***Thermal imaging:***

Infrared cameras have been used to detect temperature increase in infested palms. Currently available literature on this aspect suggests that baseline information on temperature profiles of RPW infested date palms are available for developing a real-time sensor. Thermography is an accurate, quantifiable, non-contact diagnostic technique used to visualize and quantify changes in surface temperatures using high performance infrared cameras. Two models of IR Thermal Cameras were tested in the field in different seasons (summer and winter) to assess their efficacy in identifying the RPW damaged palms. These cameras are portable, sturdy and easy to carry in the field. Several tests were done to accurately identify the damaged palms and precise location of damage site. The RPW larvae make tunnels and bores into the stem causing hollowness of various degrees in the affected tree's stem. When the thermographs of healthy and damaged palms were analyzed in some cases, the differences in the color spectrum was clear

and easy to mark the damage based on temperature differences. However, in some instances it was not easy when the surface temperature and inside temperature were not much different.

It is suggested to carry out further trials with cameras having more refined and sensitive sensors to determine the value of this technique as a tool in the quick and accurate detection of RPW damage in palms.

- ***Near infrared detection:***

Near Infrared Spectroscopy (NIRS) technique has been extensively used for non-destructive analysis and monitoring of biological systems. Numerous studies have been made to measure physiological changes in living organisms. In NIRS, specific chemical composition of an object excites molecules to absorb light in the NIR region and vibrate at unique frequencies. The NIR spectra depend on the number and type of chemical (CH, NH, and OH) bonds in the material being analyzed. For compositional analysis, reflected or transmitted light is collected by a spectrometer that measures energy absorption by the sample. The NIRS is extensively used in the grain industry to determine grain quality. Insect borers cause stress to the plants interfering with transpiration stream by ingesting plant stem tissues. Similarly, when RPW infest date palm, it starts eating internal tissues of the tree and induces stress that can be detected through NIRS technique.
A preliminary study was carried out in Saudi Arabia by measuring absorbance spectra for control, wounded and RPW infested fresh date palm leaves samples through spectrophometry. These preliminary results seem to be quite promising and provide evidence that NIRS can be a potential technique for detection of RPW infestation in palm trees at early stage before the appearance of visual symptoms.

- ***Laser induced breakdown spectroscopy:***

Laser Induced Breakdown Spectroscopy (LIBS) is a type of emission spectroscopy which involves high energy focused laser pulse for the production of plasma from the target. The emitted light from the plasma after cooling is collected with an optical fiber and passed through a spectrograph to record the LIBS spectra. The spectra are analyzed to identify the elemental concentration of the target sample. This technique can be applied on any form of physical state of matter, solid, liquid, or gas.
The LIBS technique was applied on the soil around the roots of the RPW infested date palm for early detection of RPW. Through the analysis of the observed LIBS spectra of different infested and healthy samples, the presence of Ca, Mg, Na, C, K elements, and OH and CN molecules can be detected. The spectra also reveal that with the population growth of the pest, the intensity of Mg and Ca atomic lines in LIBS spectra increases rapidly. Similar trend is observed in the molecular lines of LIBS spectra. Results obtained indicated that LIBS technique can be used for the early detection of RPW infestation without damaging the date palms.

- ***High frequency radar:***

Tree Radars (Tree Radar 2000 MHz and Tree Radar 900 MHz) were used for the detection of RPW infested date palm trees in a date palm orchard at Riyadh, Saudi Arabia, where results indicated greater RPW detection accuracy (80%) with Radar 2000 followed by Radar 900 (66.7%).

- ***X-ray technology:***

X-Ray is a widely used technique for medical imaging, but, its use in agriculture for the detection of insect pest infestation is relatively less. Preliminary studies carried out under laboratory conditions revealed promising results. Results indicated images of the larval stages and the galleries created by

RPW larvae inside the date palm trunk. Further studies are needed to improve the methodology for imaging the tree and devising a system compatible with date palm tree imaging under field conditions.

Near infrared detection experimentation would hasten the use of drone based early detection, if such sensors are made based on results of these experiments. Also, experimentation for the creation of a portable Laser induced breakdown spectroscopy based technology would be a handy tool in the early detection of RPW on ground. Furthermore in this matter, High frequency radar and X-ray technology experiments have some promises based on preliminary experiments.

Furthermore, proteomics strategies have been widely used for detecting infections/diseases among humans; however their uses for plants have been relatively less. A few plant related proteomic studies would encourage the utilization of these methodologies for the early detection of RPW infestation in date palms. The protein molecules displaying modulated response and especially those with up-regulated expression pattern in infested date palm samples would be helpful in developing some diagnostic molecular markers for early detection of RPW infestation. Experiments with proteomics strategies also carry a high potential for developing future kits for early detection.

2.3. Surveillance and Monitoring

- **Current status:**

  In general surveillance and monitoring of RPW is carried out through 1. Visual inspection and 2. Pheromone trapping in both infested and non-infested areas.

- **Challenges/ weaknesses:**
  1. Visual inspections carried out under surveillance and monitoring programme is often inadequate.
  2. Lack of funds to carry out RPW surveillance and monitoring.
  3. Limited information generated by the monitoring tools.
  4. Perception of the farmers that individual monitor traps pose a threat to their farms by attracting the pest to their garden and reluctance of the farmer / stakeholder to participate in this programme.
  5. Lack of involvement of the stakeholders in the programme.
  6. Lack of organization and efficient management of the surveillance and monitoring programme including lack of periodic trap servicing (biweekly change of poisoned food bait & water) and insufficient frequency of inspection.
  7. Inadequate system for mapping, data collection and management.
  8. Non-availability of advanced monitoring tools.
  9. Large number of ornamental palms in parks, municipality areas, and streets are not under the surveillance programme.
  10. Topography of the traditional date palm groves with large number of offshoots in date palm, poorly maintained plantations making visual inspection / monitoring difficult and cumbersome.
- **Proposed improvements/recommendations:**
  1. Carry out a risk assessment of the area adopting visual observation and through pheromone traps.
  2. Implement a GIS aided monitoring system for efficient mapping, data collection, analysis and management of the surveillance and monitoring programme.
  3. Frequency of Visual Inspection :
     - Non-Infested area : Quarterly
     - Infested Area : Bimonthly

4. Biweekly trap servicing (change of food bait and water) in both the infested and non-infested area.
5. Enhanced awareness and frequent communication among all the stakeholders.
6. Trap Density
    - Non-Infested area : Need based after risk assessment
    - Infested Area : 1-2 traps / ha

- **Technologies to be adopted to improvement the surveillance and monitoring system**

- Data base / GIS / Satellite imagery analysis:

A data collection system is desirable that consists of (a) geo-referencing palm trees using Google Earth Engine and remote sensing, (b) use of mobile phones for data entry and transmission and (c) use of GIS for data management and analysis. A custom app should be developed for Android and iOS smart phones that would allow users to record geo-referenced data at the field location on a standard form. Ideally, users should use their own smart phone in order to avoid the procurement, distribution and management of unique devices. The app would use the GSM mobile data service (GPRS) to transmit the data from the field to a centralized national RPW office in real time. A specific procedure would be developed to allow automatic importing of field data into a custom GIS that contains a spatial database at RPW offices. The GIS would be used for the management and analysis of field and smart trap data in order to prepare maps, tables, charts and reports, and take necessary management decisions.

Open-source, non-proprietary software such as PostgreSQL/PostGIS database and QGIS are suggested for the spatial database and GIS respectively. In this way, annual license fees are avoided, the GIS is platform independent (it can operate on Windows, Mac, Linux), and a large pool of available developers and expertise can be utilized to customize the GIS to RPW requirements. The primary base map for the GIS should be a geo-referenced map of palm trees (output from item (a) above). This base map in combination with regularly updated and historical field data can be utilized to assess the current situation of RPW, monitor its incidence and geographical spread, act as an early warning system, make well-informed decisions, and research historical trends in order to better manage RPW.

Automated data flow and a GIS will permit to elaborate various types of maps, tables and graphs at different time periods and spatial resolutions according to the type of requested information. These analytical tools are indispensable for an effective multi-regional, multi-disciplinary programme/strategy to combat RPW at all levels.

The system could be supplemented eventually with the use of drones to assist with inspections and data collection and transmission.

- Improving the trapping system

For developing a Trapping Management System (TMS) by integrating Radio Frequency Identification (RFID), wireless telecommunication technology and GIS technology to enable geo-referencing and the efficient use of human resources in the management of pheromone trapping at the local, national, and regional level. The issues involved are Real-time update of trap catches, locating function, 3D modeling, hardware specification definition and mounting of RFID. This will be useful not only for trapping systems but also locating and follow up action on damaged and rescued trees.

The release rate of pheromone in the dispenser increases during summer due to high temperatures. Therefore, in countries with high temperatures in summer months, the replacement of pheromone lures

has to be undertaken more frequently involving costs towards extra labor, lures and transport. Recently in India, nano-based matrix was developed with loaded pheromone components to extend the life of the lures in the field. This was successfully tested in the buckets for the capture of RPW. It is suggested that such technologies may be adopted in countries with high temperature for prolonged periods especially Gulf countries.

2.4. Agronomic Practices

- **Current status:**

It has been established that agronomic practices like palm density (spacing), irrigation, palm and field sanitation, frond and offshoot removal, influence the intensity of infestation. Also date palm varieties offer varying degrees of resistance to attack by RPW. This IPM component (host plant resistance) has not been exploited to manage RPW.

These agronomic practices that could limit RPW infestation and its spread are generally not adopted especially in traditional grooves. This makes inspection of the palms for early detection and also treatment of palms difficult.

- **Challenges/ weaknesses:**
  1. Farmers do not adopt best agricultural practices that could curtail RPW infestation.
  2. Farmers are not aware of the agronomic practices that influence RPW infestation.
  3. Resistance to change the traditional way of farming at times due to economic constraints and lack of manpower.
  4. High in-groove humidity due to flood irrigation, facilitating RPW infestation.

- **Proposed improvement/recommendations:**
  1. Encourage good agronomic practices especially with regard to, offshoot removal, frond cleaning, palm density and irrigation.
  2. Standards for good agronomic practices that limit RPW attack may be developed and recommended.
  3. Periodic offshoot pruning and / or removal in date palm to facilitate visual inspection.
  4. Protecting of wounds with insecticide immediately after frond pruning and offshoot removal.

It is proposed that studies be carried out to determine the relationship between the above practices/factors and RPW infestation, besides incorporating resistance against RPW in palms either through classical plant breeding programs or advanced molecular protocols using gene silencing (RNAi).

2.5. Control Practices

a. Mechanical sanitation

Palms that are not too deeply infested (terminal bud not infested, trunk not too deeply damaged by the larvae) can be sanitized either by insecticide injection or by mechanical sanitation. The purpose of mechanical sanitation is to eliminate the tissues where the larvae exist as well as to locate and destroy all the cocoons and adults. For tall ornamental palms (Infestation is located in the top leaf bases), researches allowed few years to elaborate a precise and efficient protocol. For date palms, mechanical sanitation is practiced for many years, very simply with hand tools. When the tissues where the larvae present are cut in small pieces, there is no need for a complementary treatment. As, in some places, very complex protocol have often been recommended regarding the issue of wasted infested tissues.

It would be perhaps desirable that very simple experimentation be implemented to confirm the absence of risk presented by larvae or eggs present in wastes cut into small pieces. Some new technologies have been proposed to sanitize infested palms but they don't seem to present any advantage compared with the existing techniques.

b. Preventive Insecticide Applications (Chemical/Natural)

Among several control methods attempted against RPW, chemical control is thought to be a quick and reliable way of controlling and recovering RPW infested date palm trees. Extensive and indiscriminate use of insecticides not only cause environmental pollution but also injurious for plants, animals, and human health.

- **Current Status:**
  1. In several countries routine insecticide sprays are given on preventive basis.
  2. In ornamental palms, stipe injection is used for preventive treatments.

- **Challenges/ weaknesses:**
  1. Often insecticides used in preventive treatments are not tested and registered against RPW in some countries.
  2. Build-up of insecticide residues in the environment and dates due to excessive preventive treatments.
  3. Probability of RPW population developing resistance to different groups of insecticides.
  4. Lack of training on preventive treatment applications.

- **Proposed improvement/recommendations:**
  1. Need based preventive insecticide treatments based on infestation foci and trap capture data.
  2. Need to develop a protocol for the rationale use of preventive insecticide applications.
  3. A range of insecticides may be tested and registered against RPW.
  4. Before authorizing injection for preventive treatments in date palm, trials on residue analysis may be carried out.

- **Options and research to be considered for preventive treatment :**

Preventive treatments consisting of soaking the sites where the females lay their eggs or where the adults hide in general are a frequent component of integrated strategy to control the RPW (usual spraying treatments are inefficient and should be forbidden).The main problem of these treatments is on the one hand their cost as they have to be repeated frequently and, on the other hand, the environmental and human health risks that present these treatments if they are applied for many years. As regards ornamental palms, preventive treatments are also applied by injection. Such treatments can't be used routinely because, in palms, the wounds made in the "trunks" are never closed or covered. For palms grown for date production, researches must imperatively be done to establish the delay before harvest for each type of treatment and each insecticide before authorizing such technique. For soaking treatments, research at the field level must be realized to establish the efficiency and frequency of different treatments; an urgent work on pest residue analysis in date and soil must be also urgently realized as in some places these treatments are applied for many years.

The preventive pesticide treatments should not be given to bearing palms within 45 days of harvest. Thus the residues in fruits can be avoided or brought down to permissible limits. While applying preventive

spraying, care should be taken so that only target areas in the palm are covered and that there is no splashing or unnecessary spread of the pesticide in non-target areas which may cause environmental pollution.

c. Curative Insecticide Treatments (Chemical/Natural)

- **Current Status:**
  1. Currently stem/stipe injection is the curative technique to treat RPW infested palms in combination with insecticide sprays.
  2. In some countries infested palms are sanitised by mechanical removal of the damaged tissue followed by insecticide application to protect the wounded tissue.
  3. A curative treatment in date palm is also carried out with aluminium phosphide treatments.
  4. Several injecting machines (tools) are currently commercially available in the market.
  5. Several natural/organic products are currently available.

- **Challenges/ weaknesses:**
  1. Often insecticides used in curative treatments are not tested and registered against RPW in some countries.
  2. Deleterious effect of high pressure and high dose applications in curative treatments.
  3. Inadequate / insufficient knowledge regarding stem injection.
  4. Lack of training on curative treatment applications using stem injection.
  5. Insufficient evidence to recommend use of natural/organic products is currently available.

- **Proposed improvement/recommendations:**
  1. Need to develop a protocol for the rationale use of curative insecticide applications especially with regard to stem injection.
  2. Natural pesticides should be tested after details on the composition of the product are known.

- **Options and research to be considered for curative treatment**

Instead of mechanical curative treatments, injection techniques are used in several places for long time. Regarding phytosanitary treatments by injection, a lot of fundamental knowledge has been acquired 30 years ago but the good practices that should result from this knowledge are not adequately known. This leads to misuse as for example if the technique based on high pressure injection technique applied in some places. Several new injection equipments are also proposed in the market which advantages are often questionable. An assessment of the different techniques and insecticides to be used has to be made to recommend these techniques.

In collaboration with the Ministry of Agriculture, Riyadh, Saudi Arabia, trials of several chemical control programs were conducted to test the efficacy of several insecticides, their optimum doses and delivery system including spray and date palm trunk injections. The results indicated varying level of success. At present, several insecticides are available in the market that are claimed to be effective against RPW. Therefore, there is a dire need for screening suitable insecticides, their optimum doses and delivery system and to develop a precision-based environment friendly chemical control strategy against RPW.

For treated infested palms stems injections with low pressure or high pressure are available in the market. In Europe several plastic pipes for the delivery of appropriate dose of pesticide are commercially available and are used in Ornamental palms. The high pressure injectors use multiple points on the stem

of a palm and sometimes the results are not good. This technique has to be used in a discretionary way with solid follow up on recovery of trees. In very young palms this technique may have some deleterious effects and hence avoided.

There are always apprehensions whenever holes are made on the palm stem to administer the pesticide solution to control the pest or sometimes as a preventive method. Biodegradable gel pipes are available to plug the hole and then inject the pesticide in to the gel through which it is dissipated in to the palm. Depending on the type of injection this method can also be tried.
Insecticides delivery systems are also in great need of experimenting in field sittings. Experiments to explore the movements of pesticides in palm trunk and other parts of the palm, especially fruits, should be explored.

d. Mass Trapping

- **Current Status:**
  1. Mass trapping using food baited pheromone traps (bucket traps) is used in several RPW infested countries.
  2. Currently black coloured, dome shaped traps are available and more efficient compared to the traditional bucket traps.
  3. Trap and bait free pheromone trapping technology involving attract and kill is currently available.

- **Challenges/ weaknesses:**
  1. Need to periodically service (change food bait & water) in traps is costly and labour intensive.
  2. Logistic support of transportation could often limit the efficiency of the mass trapping programme
  3. Lack of proper system to number and map the location of traps.
  4. Un-serviced traps act as a double edge sword, posing a danger to palms around such traps.

- **Proposed improvement/recommendations:**
  1. In some countries mass trapping could be taken up by lead / trained farmers.
  2. Introduction of attract and kill as an additional component of the RPW-IPM mass trapping programme.
  3. Further evaluate attract and kill technology where ever necessary.
  4. Need to evaluate the dry trap using electro-magnetic technology.
  5. Managing mass trapping through the use of GIS with RFID (Bar coding) of traps.

- **Research and techniques for improvement the effectiveness of mass-trapping system**

The male produced aggregation pheromone (ferrugineol) synthesized during 1993 has been widely used to monitor and mass trap RPW for over two decades using food baited bucket traps. RPW pheromone trap capture only part of the weevil population in the field and is one of the RPW-IPM component. Numbering of every pheromone trap in the field is essential for systematic data collection and processing. This could be realized by geo-referencing the traps and use of the Radio Frequency Identification (RFID).

Recently black colored traps have been reported to record superior weevil captures, while, with regard to trap design, the dome shaped trap records significantly higher captures as compared to the traditional bucket trap. The synthetic kairomone (ethyl acetate) when added as a component to the RPW food baited

pheromone trap is known to enhance weevil captures. Periodic replacement of the food bait and water limits the need of increasing the number of pheromone traps in the field, besides significantly increasing the cost of an area-wide mass trapping program. In this context, service-less options based on 'attract and kill' and use of a dry trap based on 'electro-magnetic radiation' have been found promising in Saudi Arabia. Ferrugineol emission rate can vary in a wide range without significantly affecting RPW response; co-attractants based on fermenting compounds, ethyl acetate and ethanol, are able to improve the attraction level of ferrugineol and could be employed to replace non-standardized natural kairomones in RPW trapping systems after further optimization the proportions and doses. Optimization of control techniques based on use of semiochemicals (mass trapping) with RPW repellents in a push-and-pull strategy.

Due to a very low action threshold, that is almost zero for Canary palms and near to zero for date palm, searching for strong aggregating or repelling substances seems the only route to increase the effectiveness of the semiochemical-based techniques.

To enhance the overall efficiency of a RPW pheromone trapping programs there is a need to evaluate i) a trap numbering system based on RFID ii) smart traps that would automatically record weevil captures continuously iii) integration of smart traps in a GIS, iv) trapping options that do not need servicing based on attract and kill and also electromagnetic radiation, v) other synthetic kairomones like ethyl alcohol, ethyl propionate , pentan-1-ol and vi) continuous evaluation of the commercial pheromone lures.

A semiochemical mediated IPM strategy against RPW could also involve the 'push-pull' technique wherein potential RPW repellents (α-pinene, verbenone, methyl salicylate, menthone) should be tested for palm protection.

e. Biological Control

- **Current Status:**

Several biological control agents reported as natural enemies of RPW have been reported, including EPNs and *Beauveria bassiana* have been extensively evaluated. Currently EPNs are used as a component of the RPW-IPM in some countries.

- **Challenges/ weaknesses:**
  1. As RPW is cryptic/hidden, these organisms have difficulty in reaching the pest stages inside an infested palm when used in curative control programmes and also the arriving adults in preventive treatments.
  2. The efficiency of these organisms is highly dependent on the weather factors, which also limit their efficacy.
  3. Lack of an effective application / delivery technique.
  4. The system is not self-sustaining and needs repeated releases.

- **Proposed improvements/recommendations:**
  1. Further evaluation and testing of the promising organisms in the field.
  2. Development of an efficient delivery system so that the biocontrol agents find the pest.
  3. Identify indigenous strains of EPNs and *Beauveria bassiana*

- **Biological control research and opportunities for control of RPW:**

The intensive use of insecticides against the invaded populations of red palm weevil imparts detrimental effects on non-target animals, environmental pollution, and insecticide residues in the food. Recent reports on the continued low efficacy of insecticides due to the development of insecticide resistance in the most destructive pest of palm, RPW is challenging for farmers, researchers and policy makers. These facts signify the importance of developing eco-friendly bio-control agents especially entomopathogenic nematodes, entomopathogenic fungi and bacteria. In case of nematodes, only two families including *Heterorhabditidae* and *Steinernematidae* received the most attention as biological control agents of RPW. The symbiotic relationship between bacteria and nematodes showed some limited RPW larval field mortality. However, no promising reports are available on the effectiveness and consistency to control RPW. The failure might be because of the host defense mechanism against bacterial bio-control agents. The possibility of using entomopathogenic fungi especially *Beauveria bassiana* found to be a promising future eco-friendly bio-control agent in semi-field conditions against RPW.

The efficacy of *B. bassiana* as a bio-control agent against RPW was studied in detail by several researchers with mixed results. The main reason for the limited success is the very short field life of the fungus besides a weak mechanism of delivery to the target organism.

There are significant advances in nano technology and a company in USA has developed a micro-encapsulation technique for fungal and bacterial pathogens that are used as bio-control agents. The microencapsulated biopesticides with a proprietary UV protection is the answer to overcome the problems faced in the field use of available potential fungal pathogens like *B. bassiana*. This technique will increase the field life of the biopesticide from the normal life of a few hours to about three weeks without losing the efficacy and potency. The patented technologies are known as "eShield" and are having good potential to extend for the development of *B. bassiana*. The advantages of this technique are that these biopesticides have longer life, better UV protection and heat tolerance. It is therefore suggested that potential collaborators may be identified from academic or development organizations in countries to incorporate this as an important component of biological control after conducting the mandatory trials and field tests.

Besides nematodes and fungi, the taxa (bacteria, yeast and acari) reported from Italy, are regularly associated with the weevil and their co-induction with RPW could reduce the fitness of the pest, which needs to be evaluated.

f. Removal and disposal of highly infested palms

- **Current Status:**

1. There are several options for the removal and the disposal of infested palms. However, some of these options/techniques are not applied in the correct manner.
2. In some countries, only severely infested palms are removed and disposed of, while in other countries, with new infestations, they opt for the eradication of all the infested trees to eliminate further spread of the pest.
3. Some countries follow the practice of cutting and burying the infested palms without any pre-treatment of palms.

- **Challenges/ weaknesses:**
  1. Identified palms that are heavily and/or lightly infested that are scheduled for removal often remain in the field for too long.
  2. There is a lack of knowledge for the removal and safe disposal of infested palms, including,
     - proper treatment and safe transportation to the place of disposal, where there are no onsite facilities for disposal.
     - infested palms are left in their places with no action.
  3. No detailed guidelines are available for removal and safe disposal of infested palms.
  4. There is no assessment on the degree of damage in some palms and the risk involved in disposal of such palms.

- **Proposed improvement/recommendations:**
  1. Removal and the disposal of infested palms' procedures should be developed.
  2. It is recommended to assess and dispose of such palms in the site itself.
  3. Explore the possibility of onsite complete incineration/small shredders of the removed palms through mobile incinerating trucks/ mobile shredding machines.

- **Options and considerations for improving the removal and disposal of infested palms:**

The measures adopted to process the severely infested palms are highly variable. In some places, it has been decided that the infested palms had to be cut and totally shredded. The last operation requests the use of huge machines that are available only in few places where the infested palms have to be transported. Such protocol, that is very heavy, complex to be applied safely (to avoid RPW spreading) and expensive has been adopted only in few places. For some years, it has been proposed that the procedure to be adopted is based on a risk analysis approach. Better knowledge of the RPW biology during these last years has allowed establishing a very important point to take into consideration in the risk analysis: the larvae are not *xylophagous* and died very quickly in drying tissue. As, in some places, very complex protocol have often been recommended regarding the issue of wasted infested tissues, it would be perhaps desirable that very simple experimentation be implemented to confirm the absence of risk presented by larvae or eggs present in wastes cut in small pieces.

On ornamental palms, the risk analysis approach has led to distinguished between the infested and not infested parts of the infested palms. Only for the first ones, specific protocols of intervention have to be respected. Further, the different types of protocols depend on the equipment available and the local conditions. Such approach based on risk analysis and taking into consideration the local conditions remains to be developed for date palms. Very simple protocol that can be managed at the farm level with very simple equipment can and has to be proposed.

2.6. Data Management/ GIS / Validation

- **Current status:**

In general data management system on RPW-IPM (collection, transmission, management, analysis and outputs) is limited and not coherent. Currently there is a lack of user friendly application for data collection and transmission for use by farmers and other personnel involved in the control operations in the field.

- **Challenges/weaknesses:**
  1. Lack of involvement of the farmers/stakeholders in data collection and monitoring.
  2. Stakeholders are not familiar with GIS assisted data management and its advantages.
  3. Lack of a GIS assisted data management in most of the RPW infested countries.
  4. The current system is entirely manual and is prone to errors.
  5. Lack of a standardized data collecting form for the countries.
  6. No geo-reference maps of palm trees in most countries.

- **Proposed improvements/recommendations:**
  1. Develop a user friendly mobile application for reporting, data collection and transmission.
  2. Develop a GIS and spatial database to be used operationally by countries.
  3. Use a remote sensing imagery to geo-reference palm trees in countries to be used as primary base map in the GIS.
  4. Establish a training programme for different categories of the users of the tools (mobile apps, GIS, software).
  5. FAO may take the lead to ensure global harmonization of RPW related GIS that would have associated nodes at country level that could facilitate extension to all host palms.

The system could be supplemented eventually with the use of drones to assist with inspections and data collection and transmission. It is proposed that FAO Headquarters takes the lead in this topic, learning lessons and adopting the experience from the Canary Islands system.

2.7. Farmer Participation in the IPM Programme

- **Current status:**
  1. At present farmer/other stakeholder participation is very weak in the management program in most of the countries.
  2. In many countries, there is a lack of policy and means for involvement to encourage the participation and sharing among farmers/stakeholders.
  3. In some countries there is good and active participation of the farmers which is helping in the control of the pest.
  4. Some meetings, farmers' meets, etc. are organized by public agencies.

- **Challenges/ weaknesses:**
  1. Lack of interest in farmers/stakeholders resulting in the closing of several gardens. This makes it difficult to transfer the technology and establish a communication link.
  2. Weak extension programs makes the participation of farmers/stakeholders in the IPM programs very weak and this restricts the feedback mechanism to improve the available programs.
  3. Enough has not been done to make the farmers aware of the risks and economic impact of RPW and its management on the production and productivity of date palms.
  4. In some countries the owners employ workers or lease out their farms. In such cases the communication between extension agencies and farmer owners does not directly reach the workers who do the farm operations.
  5. Insufficient knowledge of the socio-economic situation of the farmers.

- **Proposed improvements/recommendations:**

1. There is an immediate need to evolve a clear cut policy on farmers/stakeholders' participation and engagement in RPW –IPM programs.
2. Pilot project to demonstrate the involvement and engagement of farmers/stakeholders where there is no such program in vogue.
3. Strengthening extension programs, activities, knowledge sharing mechanisms, communications, farmers' organizations, etc. for farmers/stakeholders.
4. Improving the policies towards incentives to have a positive impact on a better marketing and incomes to farmers.

2.8. Role of Cooperatives, NGOs and Private Sector

- **Current Status:**
  1. There are very few cooperatives, NGOs, Private sector companies supporting programs of IPM of RPW.
  2. The agencies involvement in the programs is not strong and there is no assessment of their participation.

- **Challenges/ weaknesses:**
  1. Number of agencies involved are few and far distributed
  2. Lack of coordination between government/public agencies working in this field with the NGOs/Private sector and cooperatives.

Proposed improvements/recommendations:

1. Government agencies working with RPW-IPM programs should establish defined linkages and coordination mechanism with NGO. Private, Cooperatives to make the program more meaningful and effective.
2. Involvement of Oasis program in the RPW program in concerned countries.

2.9. Capacity Building

- **Current Status:**
  1. There are several capacity building programs on RPW-IPM that are being implemented. However, these programs are not sufficient and often do not reach the workers, farmers etc.

- **Challenges/ weaknesses:**
  1. The frequency of the programs is inadequate due to lack of funds and other resources.
  2. Continuous updates are not made available to the stake holders at regular intervals.
  3. There are no structured capacity building programs for different categories of personnel like workers, farmers, technicians etc.

- **Proposed improvement/recommendations:**
  1. There is an urgent need for developing the capacity building programs, tailor made for different categories of personnel (farmers/workers and others) involved in the implementation of IPM of RPW.
  2. Introduction of participatory approach (Farmers Field School) for farmers and farm workers to empower them updated knowledge and field practices.
  3. Use of social media and mobile applications for knowledge and experience sharing.

4. National RPW-IPM programs should develop training materials with authentic, updated information in different languages to serve the needs of different categories of personnel.

2.10. Communication and Extension Service

- **Current Status:**
  1. Communication and extension services are currently weak in most of the countries with respect RPW-IPM.
  2. RPW dedicated telephone lines exist in some countries that are used to transmit RPW alerts.

- **Challenges/ weaknesses:**
  1. Communication linkages are weak between the concerned stakeholders.
  2. Lack of tailor made extension programmes for the concerned stakeholders.

- **Proposed improvements/recommendations:**
  1. Use of social media to expedite transmission of information is essential.
  2. Involve specialists on communication and also the extension agencies to facilitate dissemination of information among all the stakeholders.
  3. Active involvement of extension agencies during the entire programme.

2.11. National, Regional and International Cooperation / Networking

- **Current Status:**
  1. The component of cooperation and networking at the National level does exist in some countries.

- **Challenges/ weaknesses:**
  1. Lack of Regional and International cooperation and networking on RPW-IPM.

- **Proposed improvements/recommendations:**
  1. There is an urgent need to strengthen cooperation among institutions at the National level and initiate programmes of cooperation at the Regional and International level.
  2. Periodic exchange of personnel to study and be exposed to an on-going RPW-IPM programme.