# GEOGRAPHIC INFORMATION SYSTEM USED FOR ASSESSING THE ACTIVITY OF THE RED PALM WEEVIL *RHYNCHOPHORUS FERRUGINEUS* (OLIVIER) IN THE DATE PALM OASIS OF AL-HASSA, SAUDI ARABIA

*Massoud Abd-Elaty Massoud[1]*, Jose Romeno Faleiro[2], Mahmoud Abo El-Saad[3], Essa Sultan[4]*

[1] Water Studies Centre, King Faisal University, P.O. Box 420, Al- Hassa-31982, Saudi Arabia
[2] Arlem, Raia, Salcette , Goa -403 720, India
[3] Date Palm Research (Centre of Excellence), King Faisal University, P.O. Box 400, Al-Hassa-31982 Saudi Arabia
[4] Directorate of Agriculture, Al- Hassa-31982, Saudi Arabia

*Received: October 26, 2010*
*Accepted: May 12, 2011*

**Abstract:** In Al-Hassa, Saudi Arabia, the red palm weevil (RPW) *Rhynchophorus ferrugineus* (Olivier) is managed through the use of a pheromone trap based area-wide Integrated Pest Management (IPM) programme, covering nearly 3.0 million date palms.
In this study, Geographic Information System (GIS) based techniques were used to study the spatial spread of RPW in two RPW–IPM areas of Al-Hassa *viz*. Al-Khadoud (297 ha) and Sodah (168 ha) with high and low weevil activity, respectively. The position of RPW pheromone traps in both Al-Khadoud (140 traps) and Sodah (84 traps) were logged using the Trimble Geographic Positioning System (GPS), to determine the East Longitude and North Latitude of each pheromone trap. The Universal Transverse Mercator (UTM) co-ordinates for each trap were also recorded.
The weevil captures in pheromone traps, and the infestation reports for 2008 in the above operational areas were reported, Based on the reports, the territorial spread of the weevils and spatial distribution of infestations due to RPW on date palm, was depicted for both Al-Khadoud and Sodah at five levels. Further, regression analysis was carried out to ascertain the relationship between annual weevil captures (Y) in pheromone traps and infestation (X) reports for 2008, on a 10 ha scale, in Al-Khadoud and Sodah, through linear regression. Based on high $R^2$ values (> 0.70), we selected Y = 121.0+4.515X as the model that could quantify the above pest-infestation relationship in Al-Hassa. This study can serve as a basis for incorporating GIS technology for improving the on going RPW management strategy, in Al-Hassa, Saudi Arabia.

**Key words:** *Rhynchophorus ferrugineus*, Geographic Information System, Global Position System, date palm, spatial spread, Integrated Pest Management

## INTRODUCTION

The Kingdom of Saudi Arabia produces nearly a million tonnes of dates annually, accounting for 15 per cent of the global date production. With three million date palms, Al-Hassa (Hofuf) in the Eastern Province of the Kingdom is Saudi Arabia's most important date palm oasis.

Red palm weevil (RPW) [*Rhynchophorus ferrugineus* (Olivier)] (Coleoptera: Curculionidae /Rhynchophoridae /Dryopthotidae), a key pest of date palm, is reported to attack mainly young palms less than 20 years old (Abraham *et al*. 1998). RPW was first recorded in Al-Hassa, in 1992 (Anonymous 1998). Although infested palms in the early stage of attack recover with insecticide (trunk injection), palms in the late stage of attack have to be eradicated. El-Sabea *et al*. 2009, estimated that in Saudi Arabia, the annual loss due to eradication of severely infested palms, at a 1–5 per cent infestation rate, ranged from 1.74 to 8.69 million USD, respectively. This takes into account, a fixed eradication level of 20 per cent infested palms.

The Directorate of Agriculture, from the Ministry of Agriculture, is operating the RPW control programme in Al-Hassa. The programme uses a pheromone based Integrated Pest Management (IPM) strategy in over 60 operational areas, with varying degrees of success. Besides mass trapping of adult weevils in food baited pheromone traps, the detection of infested palms, use of chemical treatment (preventive and curative), eradication of severely infested palms, elimination of RPW breeding sites, implementation of quarantine regulations etc, are the other important components of the RPW–IPM strategy adopted against the pest in Al-Hassa.

The Geographic Information System (GIS) can serve as a valid tool in area-wide RPW–IPM programmes. GIS can log data pertaining to insect activity assessment, and also track infestation reports (Chefaoui *et al*. 2005; Pitt and

*Corresponding address:
maly@kfu.edu.sa

Worner 2007). GIS has been used to keep track of RPW infested palms in several countries, including Egypt and Spain (Barranco *et al*. 2006; Brun *et al*. 2006).

GIS is already being used to develop sustainable irrigation and drainage systems in Al-Hassa, Saudi Arabia (Massoud 2008). In this study, GIS based techniques (Arctur and Zeiler 2004; ESRI 2006) were used to study the territorial spread of RPW in two RPW–IPM areas of Al-Hassa *viz*. Al-Khadoud (297 ha) and Sodah (168 ha). In these areas, a pheromone based IPM programme has been implemented since 1994 by the Directorate of Agriculture. In Al-Khadoud, infestations were reported to be above the acceptable threshold of one per cent infested palms, while in Sodah it was less than one per cent (Faleiro 2008). We also determined the relationship between annual weevil captures (Y) in pheromone traps and infestation (X) reports for 2008, on a 10 ha scale through linear regression analysis

The main objectives of this study were:

1. Using GIS based techniques to study the territorial spread of RPW in two RPW–IPM areas of Al-Hassa *viz*. Al-Khadoud (297 ha) and Sodah (168 ha).
2. Building a geo-database for RPW traps and its related logging data pertaining to weevil captures in pheromone traps and also recording infestation levels.
3. Determining the relationship between annual weevil captures (Y) in pheromone traps and infestation (X) reports for 2008, on a 10 ha scale, in Al- Hassa through regression analysis.

## MATERIALS AND METHODS

In this study, GIS based techniques were used to study the spatial spread of RPW in two RPW–IPM areas of Al-Hassa *viz*. Al-Khadoud (297 ha) and Sodah (168 ha), with high and low weevil activities, respectively.

The GIS software used in this investigation was ArcGIS (version 9.3) and ERDAS Imagine (Version 8.6) as image processing software. Trimble Global Positioning System (GPS) was used; made up of a 8-channel GPS/MSK Beacon Pro XR receiver, TDC1 data logger, Integrated GPS/Beacon antenna, and camcorder batteries. The Trimble GPS software were: (1) TDC1 Asset Surveyor software (version 3.30) used to navigate and collect GPS field data and (2) Pathfinder Office software used to view, edit, and plot data, and export data to GIS.

RPW pheromone traps, in both Al-Khadoud (140 traps) and Sodah (84 traps), were set on date palm trees every 100 m along irrigation canals. The position of the traps were logged on the above GPS to determine the East Longitude and North Latitude of each pheromone trap (Fig. 1; Massoud 2008). The Universal Transverse Mercator (UTM) coordinates for each trap were also recorded. It is pertinent to mention, that although the distance between two consecutive irrigation canals in Al-Hassa is constant at 160 m, the length of the canals in the above study areas was found to vary from 300 to 1,000 m with the average canal length being 625 m. Hence, the average area between two consecutive canals, in the above study areas, is approximately 10 ha.

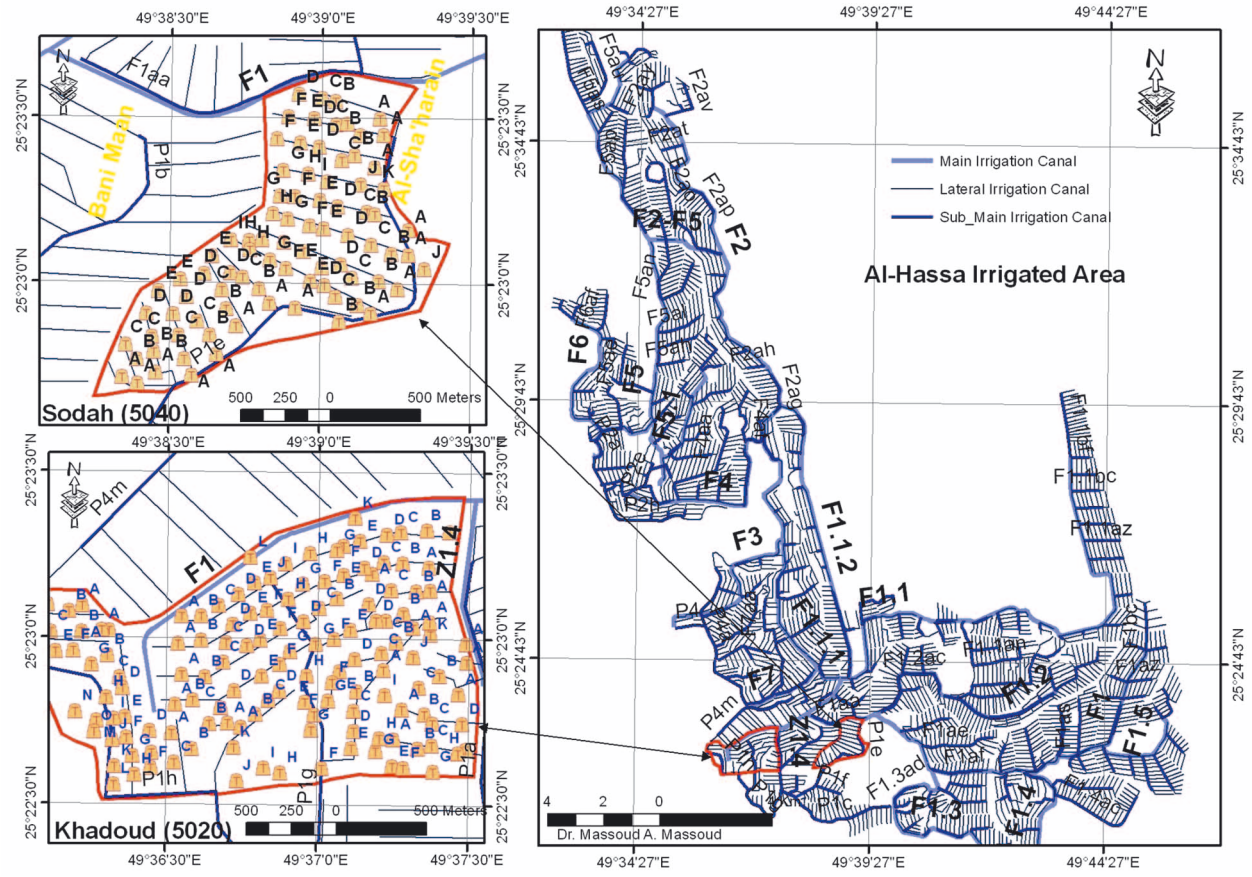



Fig. 1. Selected operational areas (Al-Khadoud and Sodah) indicating position of red palm weevil traps in Al-Hassa

Table 1. Designated categories of weevil activity and infestation due to red palm weevil in date plantations of Al-Hassa

| Categories | Weevil activity | Infestation level |
|---|---|---|
| Very low | 0–100 weevils/10 ha/year | 0–20/10 ha/year |
| Low | 101–200 weevils/10 ha/year | 21–40/10 ha/year |
| Medium | 201–300 weevils/10 ha/year | 41–60/10 ha/year |
| High | 301–400 weevils/10 ha/year | 61–80/10 ha/year |
| Very high | > 400 weevils/10 ha/year | > 80/10 ha/year |

The territorial spread of the weevils, and spatial distribution of infestations due to RPW were depicted for both Al-Khadoud and Sodah, at five levels (Table 1) of weevil activity and infestation level. Based on weevil captures in pheromone traps, palms are inspected to detect infestation due to RPW. Inspection is done by the Directorate of Agriculture responsible for implementing an area-wide RPW-IPM in the Al-Hassa oasis. It may be noted, that 70 per cent of the infestation cases reported during 2008, in the above operational areas, were in the proximity of traps recording weevil captures. Cases were, therefore, assigned pheromone traps for the plantations located between two consecutive canals, and utilized in this study. The remaining 30 per cent of the infestations recorded during the year, were generally allocated to the operational area. These infestations were not in the proximity of the pheromone traps recording weevil captures, and therefore could not be utilized in this study to assess the territorial spread of RPW in two RPW-IPM areas.

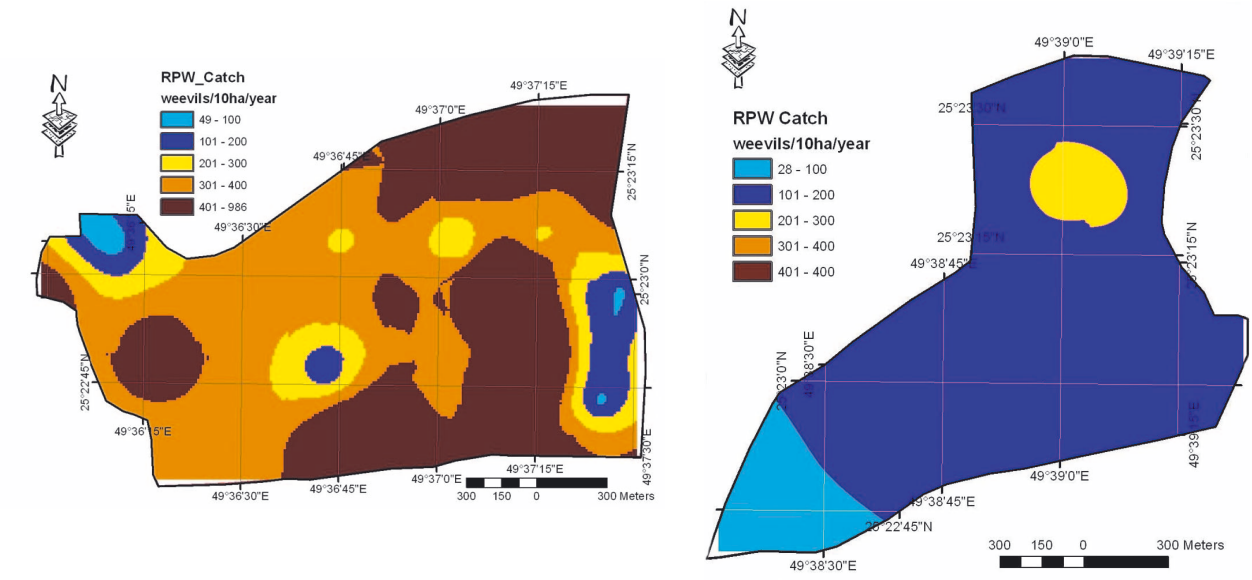
## RESULTS

Weevil captures (with the use of pheromone traps), and the infestation reports (in plantations between two consecutive canals) for 2008, were furnished by the Directorate of Agriculture in Al-Hassa. The territorial spread of the weevils (Fig. 2) and spatial distribution of infestations (Fig. 3) due to RPW on date palm, are depicted for both Al-Khadoud and Sodah at five levels as mentioned above, for both weevil activity (trap captures) and infestation.

Table 2 shows the geo-statistical analysis of the spatial distribution of RPW intensity during 2008. The spatial distribution refers to weevil captures in traps and infestations detected for both, Al-Khadoud and Sodah in Al-Hassa, using GIS system and spatial modeling. It is evident, that RPW was better managed in Sodah in 2008, compared to Al-Khadoud. In Sodah, 100.0% of the weevil captures in pheromone traps ranged from very low to medium (Table 2).

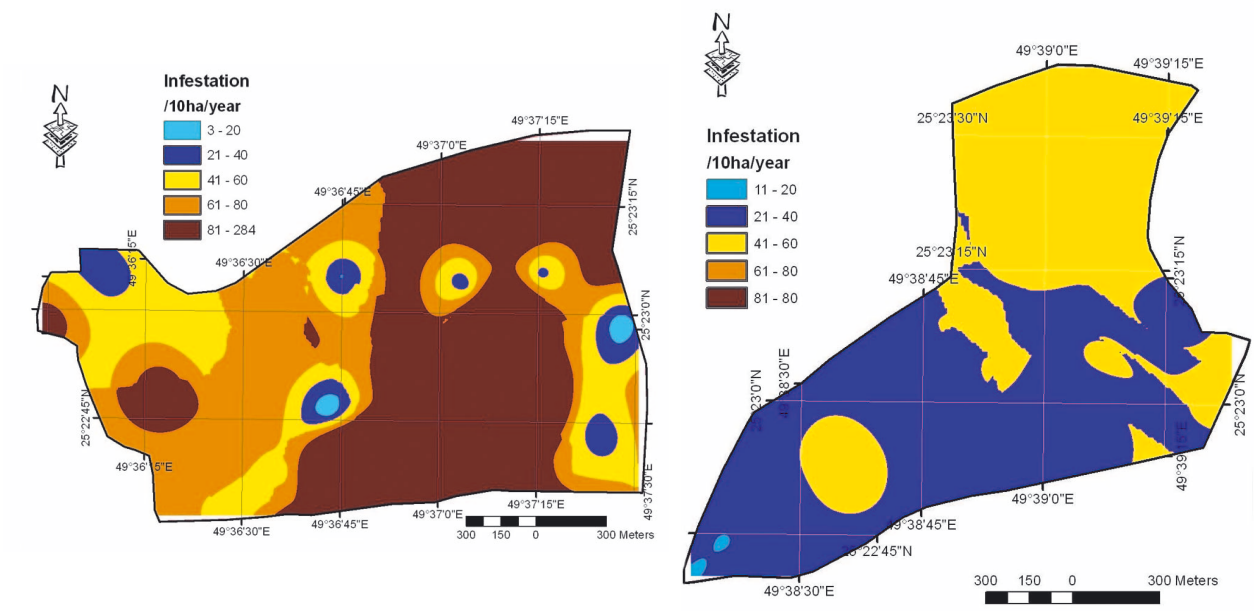
Table 2. Geostatistical analysis of red palm weevil (RPW) captures in pheromone traps and infestation in Al-Khadoud and Soda, Al-Hassa , Saudi Arabia in 2008

| Weevil captures in pheromone traps | | | | | | |
|---|---|---|---|---|---|---|
| Class | weevil captures | range | Al-Khodoud | | Sodah | |
| | | | No. pixels | [%] | No. pixels | [%] |
| 1 | very low | 0–100 | 352 | 0.9 | 2,795 | 8.5 |
| 2 | low | 101–200 | 2,143 | 5.3 | 29,272 | 88.9 |
| 3 | medium | 201–300 | 4,022 | 9.9 | 845 | 2.6 |
| 4 | high | 301–400 | 20,084 | 49.2 | 0 | 0.0 |
| 5 | very high | >400 | 14,189 | 34.8 | 0 | 0.0 |
| | | | 40,790 | 100.0 | 32,912 | 100.0 |
| Infestation due to RPW in date palm | | | | | | |
| Class | infestation levels | range | Al-Khodoud | | Sodah | |
| | | | No. pixels | [%] | No. pixels | [%] |
| 1 | very low | 0–20 | 186 | 0.5 | 47 | 0.1 |
| 2 | low | 21–40 | 1,380 | 3.4 | 16,223 | 49.3 |
| 3 | medium | 41–60 | 9,265 | 22.7 | 16,642 | 50.6 |
| 4 | high | 61–80 | 13,849 | 34.0 | 0 | 0.0 |
| 5 | very high | > 400 | 16,110 | 39.5 | 0 | 0.0 |
| | | | 40,790 | 100.0 | 32,912 | 100.0 |




Al-Khadoud Sodah

Fig. 2. Spatial models for the distribution of red palm week trap captures (weevil activity) in Al-Khadoud and Sodah (2008)




Al-Khadoud Sodah

Fig. 3. Spatial models for the distribution of infestation due to red palm week in Al-Khadoud and Sodah (2008)

In Al-Khadoud, however, nearly 94.0% of the weevil captures were registered in the medium to very high categories. A similar trend was observed with regards to the infestation levels in both the operational areas (Table 2).

Results presented in table 3 show the relationship between weevil captures in pheromone traps and infestation reports for 2008, on a 10 ha basis, in Al-Khadoud and Sodah. Linear regression equations reveal that in Al-Khadoud, where weevil activity and infestation were high, the linear equation gave a good fit as visualized from a high $R^2$ value ($R^2$ = 0.789). However, in Sodah where weevil activity and infestations during 2008 were low, the equation did not sufficiently explain the relationship due to comparatively low $R^2$ value ($R^2$ = 0.267). Further, when observations for both Al-Khadoud and Sodah were combined, to compute an equation and develop a general prediction model for Al-Hassa, high $R^2$ value (0.723) was obtained. High $R^2$ value was considered adequate to quantify the relationship between activity of RPW and consequent infestation in date plantations of Al-Hassa. This equation (Y = 121.0 + 4.515X) was used to quantify the pest – infestation relationship in Al-Hassa (Figure 4) where X is the estimated annual infestation and Y the annual weevil activity per 10 ha of date plantation.

Table 3. Regression equations to study the relationship between weevil activity and infestation due to red plam weevil in Al-Hassa

| Area | Linear equation | |
|---|---|---|
| Al-Khadoud | Y = 146.4 + 2.758X | $R^2$ = 0.789 |
| Sodah | Y = 75.56 + 1.832X | $R^2$ = 0.267 |
| Al-Hassa | Y = 121.0 + 4.515X | $R^2$ = 0.723 |

Y – yearly weevil capture/10 ha; X – yearly infestation/10 ha

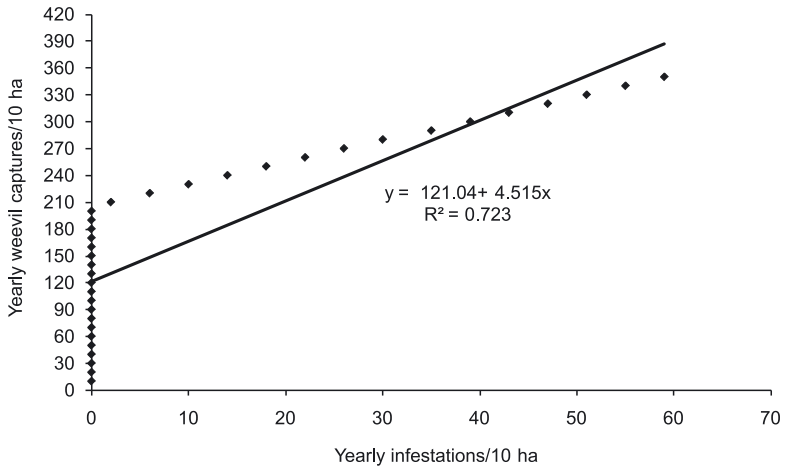



Fig. 4. Estimated infestation (X) at different levels of weevil activity (Y) in Al-Hassa, Saudi Arabia (2008)

## DISCUSSION

The results presented above, clearly depict the territorial spread of RPW in both Al-Khadoud and Sodah for 2008, with respect to weevil activity and infestation. From figures 2 and 3, it can be seen that high weevil activity in Al-Khadoud resulted in most of the area being severely infested. Such an infestation called for strengthening the RPW–IPM in Al-Khadoud. In Sodah, low weevil captures resulted in low infestation in most of the area. The low infestation indicated that in Sodah, the on-going IPM strategy is having the desired impact. Abraham *et al.* (2000) reported that the pheromone based strategy had successfully suppressed RPW in both Al-Khadoud and Sodah from 1994 to 1997. However, since 1997, the pest intensity in Al-Khadoud has worsened, and intensification of the IPM strategy as recommended by Abraham *et al*. (1998), is needed. The pictorial depiction of infestation levels in the two operational areas, also confirms the assessment that infestation levels were above and below the 1% threshold in Al-Khadoud and Sodah, respectively based on the concept of sequential sampling (Faleiro 2008). Such GIS aided pictorial depiction of the pest, if taken up at the smaller time interval of three months, would enable pest managers in Al-Hassa to determine those plantations that are most threatened by RPW. Al-Hassa pest managers could then divert valuable resources to those pockets where they are most required.

Brun (2006), used GIS to understand the progression of RPW population in a typical oasis eco-system in Egypt. Here, a monthly spatial distribution of RPW populations indicated dispersion of the pest through waves of infestations. The waves lasted about four months, corresponding to the RPW life cycle. In Spain, Barranco *et al*. (2006) studied the spread of the pest by recording eradicated palms infested by RPW, between 2001–2005, using GIS, in the Almunecar region.

The high coefficient of determination ($R^2$) of > 0.70, for the linear regression equation developed to explain the pest–infestation relationship, indicated that a large part of the variation in the annual infestation levels (X) as influenced by the weevil activity (Y) was explained by the developed regression equation (Y = 121.0 + 4.515X). From figure 4, it can be seen that annual weevil activity of up to 120 weevils per 10 ha would not result in any infestation. Also, these population levels (up to 12 weevils/ha/year) could be considered low with respect to the RPW–IPM strategy implemented in Al-Hassa. The linear equation developed to quantify the pest-infestation relationship for RPW in Al-Hassa, predicts that 130–350 weevil captures in pheromone traps/10 ha/year would result in 2–59 infestations/10 ha/year, respectively. Faleiro (2006) recommended initiation of area-wide RPW–IPM, at an action threshold of one per cent infestation.

Pest managers are increasingly using information technology to enhance and support their decision making capabilities. GIS can serve as a valuable tool in area-wide IPM programmes and is ideally suited for managing data on the nature, location and spread of pests. It allows storage of vast amounts of data on the spatial and temporal spread of a pest. (http://proceedings.esri.com/library/userconf/proc01/professional/papers/pap375/p375.htmUsing GPS and GIS).

GIS provides vast capabilities for tracking, and predictive analysis of a pest like RPW as presented in this study. GIS could substantially improve the area-wide RPW–IPM programme in Al-Hassa and other parts of the Kingdom.

## ACKNOWLEDGEMENTS

Institutional support provided for this study by Dr Salah Al-Eid, Director, Date Palm Research Centre (Centre of Excellence), King Faisal University (KFU), Al-Hassa; Dr. Khalid M. Al-Barak and Dr. Yusuf Y. Al-Dakheel, present and former Directors, respectively, Water Studies Centre, KFU, Al Hassa and Mr. Salah Nasser Al Homaidi, Director, Directorate of Agriculture, Ministry of Agriculture, Al Hassa, is gratefully acknowledged.

## REFERENCES

Abraham V.A., Al Shuaibi M., Faleiro J.R., Reda A. Abozuhairah, 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 Univ. J. Sci. Res. (Agri. Sci.). 3**:** 77–83.

Abraham V.A., Faleiro J.R., Al-Shuaibi M.A., Prem Kumar T. 2000. A strategy to manage red palm weevil *Rhynchophorus ferrugineus* Oliv. on date palm *Phoenix dactylifera* L. – its successful implementation in Al-Hassa, Kingdom of Saudi Arabia. Pestology 24 (12): 23–30.

Anonymous. 1998. Final report of the Indian technical team (Part A). Red Palm Weevil control project, Ministry of Agriculture and Water, Kingdom of Saudi Arabia: 1–65.

Arctur D., Zeiler M. 2004. Designing Geodatabases, Case Studies in GIS Data Modeling. ESRI Press, 380 New York Street, Redlands, CA 92373-8100, USA, 397 pp.

Barranco P., Lorente-Moreno F., Alcazar-Alba M.D., Pena-Mendez Y.J. 2006. Control of *Rhynchophorus ferrugineus* in Spain: field tests and treatments. Proc. 1st International Workshop on Red Palm Weevil. IVIA, Valencia, Spain, 28–29, November 2005, 180 pp.

Brun L. 2006. The date palm in Egypt: a traditional cash crop threatened by the Red Palm Weevil. Proc. 1st International Workshop on Red Palm Weevil. IVIA, Valencia, Spain, 28–29, November 2005, 180 pp.

Chefaoui R.M., Hortal J.N., Lobo J.M. 2005. Potential distribution modelling, niche characterization and conservation status assessment using GIS tools: a case study of Iberian Copris species. Biological Conservation 122: 327–338, www.elsevier.com/locate/biocon

El-Sabea M.R. Alaa, Faleiro J.R., Mahmoud M. Abo-El-Saad. 2009. The threat of red palm weevil *Rhynchophorus ferrugineus* to date plantations of the Gulf region of the Middle-East: An economic perspective. Outlooks Pest Manage. 20 (3): 131–134.

ESRI. 2006. Using ArcGIS Desktop, Environmental System Research Institute, 380 New York Street, Redlands, CA 92373-8100, USA, 442 pp.

Faleiro J.R. 2008. Consultancy Report "Establishment of National Date Palm Research Centre Al- Hassa, Kingdom of Saudi Arabia Phase – II (2007–2011)", submitted to the FAO of the United Nations on completion of the second 30 day IPM mission (UTF/SAU/015/SAU) on red palm weevil at the National Date Palm Research Centre, Al Hassa, Saudi Arabia, 35 pp.

Faleiro J.R. 2006. A review of the issues and management of red palm weevil *Rhyncophorus ferrugineus* (Coleoptera: Rhynchophoridae ) in coconut and date palm during the last one hundred years. Int. J. Tropical Insect Sci. 26 (3): 135–154.

http://proceedings.esri.com/library/userconf/proc01/professional/papers/pap375/p375.htm

Massoud A.M. 2008. Consultancy Report, submitted to the FAO of the United Nations on completion of a 60 day GIS mission (UTFN/SAU/012/SAU) on the establishment of the GIS unit at Hassa Irrigation and Drainage Authority(HIDA), Al Hassa, Saudi Arabia, 35 pp.

Pitt J., Worner S.P. 2007. Modelling invasive species spread using stochastic, high resolution, spatially explicit dispersal models integrated within a Geographic Information System. APHIS Science Panel on Pest Risk Mapping, Fort Collins, Colorado, June 5–7th, 2007.

## POLISH SUMMARY

### SYSTEM INFORMACJI GEOGRAFICZNEJ DO OCENY AKTYWNOŚCI *RHYNCHOPHORUS FERRUGINEUS* (OLIVIER) W OAZIE PALM DAKTYLOWYCH AL-HASSA, ARABIA SAUDYJSKA

W ramach programu Integrowanej Ochrony obejmującego blisko 3 miliony palm daktylowych, rejonach oazy Al-Hassa (Arabia Saudyjska) *Rhynchophorus ferrugineus* monitorowany jest przy użyciu pułapek feromonowych. W pracy wykorzystano techniki oparte na Systemie Geograficznej Informacji, w celu określenia terytorialnego rozprzestrzeniania się szkodnika *R. ferrugineus*, na obszarze oazy Al-Hassa, w dwóch rejonach objętych programem Integrowanej Ochrony: Al.--Khadoud (297 ha) i Sodah (168 ha), z uwzględnieniem odpowiednio silnej i słabej aktywności szkodnika. Lokalizacje feromonowych pułapek zarówno w Al-Khadoud (140 pułapek), jak też w Sodah (84 pułapki), zostały zalogowane przy pomocy Geograficznego Systemu Pozycjonowania – Trimble, w celu określenia współrzędnych: długości geograficznej wschodniej i szerokości północnej dla każdej pułapki. Dodatkowo określano współrzędne dla każdej pułapki z zastosowaniem systemu UTM.

Dane dotyczące odłowu szkodnika przy pomocy pułapek feromonowych oraz jego nasilenia występowania i terytorialnego rozprzestrzeniania na terenach objętych badaniami w 2008 roku, zestawiono w formie graficznej dla obu rejonów: Al-Khadoud i Sodah, z uwzględnieniem 5 poziomów. Dodatkowo przeprowadzono analizę regresji, w celu ustalenia zależności między rocznymi odłowami szkodnika (Y) przy pomocy feromonowych pułapek, a nasileniem jego występowania (X) w 2008 roku na obszarze 10 ha w Al.-Khadoud i w Sodah, dla obszaru 10 ha, przy pomocy liniowej regresji. W oparciu o wielkość współczynnika determinacji $R^2$ (> 0,70), opracowano wzorcowe równanie, gdzie Y = 121,0 + 4,515X, dla określenia powyższych zależności nasilenia występowania szkodnika w oazie Al-Hassa. Wyniki prezentowanych badań stanowią podstawę do wykorzystania w technologiach Systemu Informacji Geograficznej, w celu udoskonalenia strategii ochrony palm daktylowych w oazie Al-Hassa w Arabii Saudyjskiej.