Establishment and Potential Risks of a New Invasive Pest, Red Palm Weevil *Rhynchophorus ferrugineus* in China

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Abstract

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The red palm weevil (RPW), *Rhynchophorus ferrugineus*, is a new important invasive pest to palm species in China. Potential distribution and risks posed by this pest in China were assessed using a developed pest risk analysis scheme in China. This paper dealt with the information concerning distribution, potential damage, economic value of hosts, possibility of transportation and spread and difficulties of risk management. Susceptible hosts grow across many areas of China. Through the use of the computer program CLIMEX and GIS, southern regions from Mt. Qinling, especially Guangxi, Guangdong, Jiangxi, Fujian, Hainan, Taiwan and Hongkong of China, were identified as the areas where climate and hosts are most suitable for the establishment of the pest. There is a high risk that RPW could enter, establish and cause damage to several important palm species. This risk analysis contributed to the decision to add RPW to the list of quarantined pests whose introduction and spread in China is banned.

Keywords: Pest risk analysis, Quarantine, Distribution, *Rhynchophorus ferrugineus*, China.

Introduction

The red palm weevil (RPW), *Rhynchophorus ferrugineus*, a concealed tissue borer, is a lethal pest of palms and is reported to attack palm species worldwide (43). Infested palms, if the infestation is not detected early and treated, often die. Although the weevil was first reported on coconut *Cocos nucifera* from South Asia, it has gained a foothold on the date palm *Phoenix dactylifera* in several Middle Eastern countries during the last two decades and has also moved to Africa and Europe (6, 7). Currently, the pest is reported in 15% of the coconut-growing countries and in nearly 50% of the date palm-growing countries. Only the American continent is apparently free of the pest (12). Recently RPW was accidentally introduced into south China, possibly due to the movement of infested planting material (25, 50). Because of appropriate climate and other natural conditions, the species infests many palms, especially those belonging to the genus *Phoenix* (25, 31, 47).

Because of serious damage to palm trees, RPW has been regarded as a new important invasive pest threatening palms in China (49). However, the potential distribution and risks of the pest are still not well understood. Zhang and Zhao (53) reported that the distribution of RPW was never over the Tropic of Cancer in China, while now the pest is established in some countries with latitudes from 40°C degrees north to 40°C degrees south (25). Thus, it is likely that RPW can spread to many other areas in China.

Pest risk analysis (PRA) is a process of evaluating biological or other scientific and economic evidence to decide whether a pest should be regulated and to determine the strength of any phytosanitary measures to be taken against it (22). Such analyses are now required by the World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures (ASPM) to justify phytosanitary guidelines applied to trade pathways, and are part of the processes of cultural and legislative control, which are used strategically to support plant health legislation protecting plants from pests at an international level (32).

In order to reduce further range expansion of RPW in China, this paper predicted the potential distribution of RPW and analyzed its risks using a developed pest risk analysis scheme in China (24). The information was used to support the addition of the pest to Chinese plant health legislation.

Materials and methods

Pest risk analysis

A semi-quantitative pest risk analysis scheme developed by the Chinese quarantine office (24) was used to determine the risks posed to Chinese palms by *RPW*. The text of the full scheme is not presented here, but a brief description is provided.

The risk analysis scheme has five phases. The first phase (P_1) consists of one index, which considers the pest current distribution in China. The analysis then progresses to the potential damage phase (P_2) that has three sequential indices regarding the potential economic damage (P_{21}), whether the pest is a vector for other quarantine pests (P_{22}) and the pest importance in other countries (P_{23}). The third phase (P_3) addresses the economic impact of hosts, including host plants species (P_{31}), area of host plants (P_{32}) and special economic value (P_{33}). Pest spreading ability is the fourth phase (P_4), which includes frequency of interception and capturing (P_{41}), survival rate of pest on transportation (P_{42}), distribution in other countries (P_{43}), potential establishment in China (P_{44}) and spread potential of the pest (P_{45}). The fifth phase (P_5) of the scheme assesses the difficulty of controlling the pest, which covers three vaiables, identification (P_{51}), treatment (P_{52}) and eradication difficulty (P_{53}). Each index is quantified a score of 0-3, and low scores are used for unlikely or low-risk events while high scores are used for very likely or high-risk events. Judgment has to be used in assigning each score and accounting for evidence from published sources, trade statistics, the internet or personal experiments. Each phase and the entire risk value can be calculated to get the risk degree (R) as follows:

P_1 is obtained directly from the first phase

$$P_2 = 0.6P_{21} + 0.2P_{22} + 0.2P_{23}$$

$$P_3 = Max(P_{31}, P_{32}, P_{33})$$

$$P_4 = \sqrt[5]{P_{41} \cdot P_{42} \cdot P_{43} \cdot P_{44} \cdot P_{45}}$$

$$P_5 = {(P_{51} + P_{52} + P_{53})}/{3}$$

$$R = \sqrt[5]{P_1 \cdot P_2 \cdot P_3 \cdot P_4 \cdot P_5}$$

For RPW, information from international spread and published reports was used to support the scores to the indices related to the risk in China.

Predicting potential establishment map

Based on phenology and climates similarity within a pest's native and spread distributions, the computer program CLIMEX can estimate an organism's potential geographic distribution and relative abundance in a given region (45, 46). In this paper, CLIMEX was used to estimate the key indices concerning potential distribution in invaded regions.

Some sources giving details of RPW's native distribution and invaded areas were summarized in Figure 1. The native regions of RPW chosen here were Cochin, Madras and Madurai, and information for invaded distribution, which have been listed in CLIMEX, were collected from the literature (12, 19, 25). After comparing the relationship of climatic factors between the native and invaded regions of RPW, we concluded that temperature was the most critical factor for RPW spread. A meteorological database within CLIMEX can match climates. Using this function, we can determine the regions with similar climates. In this study, the similar climatic coefficient estimated by CLIMEX was simply derived from the monthly means of daily maximum and minimum temperatures. To show the robustness of the model, the climatic similarities between the regions were simulated using a variety of weightings for the climatic variables. Both weightings of the monthly means of daily maximum and minimum temperatures were 1.0.

From Figure 1, the estimates of bio-climatic similarity coefficients for RPW from CLIMEX between native and invaded ranges of the pest were obtained and used to generate a climatic matching threshold showing the relationship between meteorological stations (Table 1). A spreadsheet was generated with the station name, latitude, longitude and similarity coefficients for China, saved as text file, and imported into ArcGIS 3.2 (ESRI, USA). The imported file was converted into a shape file using the ADD X-Y DATA function. The Arc-Gis Geostatistical Analyst function (ESRI) was used to generate predicted distribution grids of RPW. The inverse distance-weighted (IDW) deterministic method was used to generate weighted averages of nearby known values and to predict values for un-sampled regions. The climatic matching map of RPW distribution was generated. One of the advantages of the IDW method is that it assigns more weight to closer values to the predicted value than those that are further away. Meteorological station data, however, are rarely representative of the climatic conditions in the areas where host plants are grown. Increasingly, the climatic matching map was formed based on the overlapping analysis of host plants map and meteorological map, and then the predicted distribution of RPW in China was accurate.

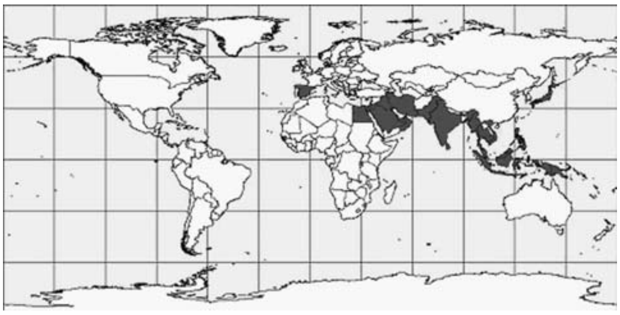

Figure 1. Global distribution of *R. ferrugineus* (red area). The map was a revised copy obtained from http://www.redpalmweevil.com

Risk management and completion of the PRA

Risk management is the final component of PRA (23). This stage considers the phytosanitary measures in uninfested regions and the measures to eliminate the pest in infested areas, including the likelihood of the pest to continue to be excluded from the PRA area, the likelihood of outbreaks to be eradicated, and the management options available for containment and control. The completed PRA, together with an information sheet on the general biology of RPW, will be submitted to the Chinese quarantine office to consider the risk posed by RPW and determine the plant health policy towards it.

Results

Global distribution of RPW

Being native to south India, RPW spread in the world extensively from the late 1970s and is now found in Australia, Bangladesh, Bahrain, China, Cyprus, Egypt, France, Greece, India, Indonesia, Iraq, Iran, Israel, Italy (including Sicily), Japan, Jordan, Kuwait, Malaysia, Oman, Pakistan, Palestine, Philippines, Portugal, Qatar, Saudi Arabia, Sri Lanka, Spain, Syria, Taiwan, Thailand, Vietnam, United Arab Emirates, Turkey, Morocco, Libya and other countries (25, 38). In China, it is found in Hainan, Guangxi, Guangdong, Hongkong, Taiwan, Yunnan, Tibet (isolated in Mutuo county), Fujian, Zhejiang, Jiangxi and Shanghai (25, 50). New invaded regions, however, are still been updating mainly due to the continuous spread of RPW in urban China.

Table 1. The monthly means of daily maximum and minimum temperatures matching coefficients among the native regions (Cochin, Madras and Madurai) and the invaded regions of *R. ferrugineus*

Native stations	**Cochin**		**Madras**		**Madurai**	
	Daily					
Invaded stations	**maximum temperature**	**minimum temperature**	**maximum temperature**	**minimum temperature**	**maximum temperature**	**minimum temperature**
Alexandria, Egypt	0.38	0.36	0.29	0.37	0.26	0.36
Cairo, Egypt	0.37	0.28	0.46	0.28	0.42	0.27
Bahrain	0.36	0.48	0.50	0.62	0.46	0.57
Amman, Jordan	0.26	0.15	0.23	0.16	0.21	0.15
Jeddah, Saudi Arabia	0.53	0.65	0.73	0.77	0.73	0.72
Riyadh. Saudi Arabia	0.30	0.33	0.49	0.37	0.45	0.35
Eilat. Israel	0.34	0.37	0.53	0.43	0.49	0.41
Jerusalem, Israel	0.28	0.16	0.22	0.17	0.20	0.16
Kuwait City, Kuwait	0.26	0.36	0.39	0.46	0.37	0.43
Sharjah, UAE	0.41	0.43	0.57	0.52	0.56	0.49
Karachi, Pakistan	0.61	0.50	0.62	0.65	0.59	0.60
Vientiane, Laos	0.81	0.59	0.68	0.63	0.63	0.61
Rangoon, Burma	0.87	0.77	0.59	0.83	0.64	0.82
Hanoi, Vietnam	0.43	0.50	0.42	0.60	0.38	0.57
Ho Chi Minh, Vietnam	0.83	0.87	0.67	0.78	0.70	0.87
Kuala Lumpur, Malaysia	0.80	0.82	0.67	0.70	0.68	0.77
Jakarta, Indonesia	0.75	0.87	0.61	0.69	0.57	0.77
Manila, Philippines	0.81	0.81	0.72	0.79	0.70	0.81
Bangkok, Thailand	0.78	0.85	0.71	0.83	0.74	0.88
Granada, Spain	0.18	0.11	0.15	0.11	0.14	0.11
Singapore	0.82	0.90	0.63	0.72	0.40	0.61
Almeria, Spain	0.26	0.24	0.19	0.25	0.17	0.24
Haikou, China	0.47	0.57	0.46	0.66	0.42	0.64
Kagoshima, Japan	0.21	0.18	0.16	0.19	0.19	0.14
Guangzhou, China	0.35	0.39	0.34	0.46	0.31	0.44
Nanning, China	0.36	0.41	0.31	0.49	0.29	0.47
Hualien, China	0.43	0.48	0.36	0.51	0.33	0.49
Taipei, China	0.35	0.41	0.33	0.44	0.30	0.42

The chosen stations synthesized the data between the distribution of *R. ferrugineus* and the data in CLIMEX

Potential economic damage

RPW attacks many species of palms and causes serious damage. Larvae feed on soft tissue in the crown of palms, often destroying the apical parts and causing death of the tree. It might be a serious pest in any EPPO country where palms are widely cultivated (38). On the basis of experiences in Spain, Esteban-Duran *et al.* (11) warned that RPW could potentially be introduced into other countries of the EPPO region with imported palms. The date-producing countries are particularly at risk; Israel and Jordan have already had outbreaks, and North African countries are clearly threatened. All Mediterranean countries, which grow palms as amenity trees in towns and on sea fronts, are facing a serious risk. Fitzgibbon *et al.* (15) identified the weevil as having potential for introduction and establishment in Northern Australia, as a pest of sugarcane. Menon and Pandalai (33) reported that RPW is a serious pest of coconut (*Cocos nucifera*) in India and Sri Lanka, where it killed 30-40% of coconuts in Sri Lanka (47). Ganapathy *et al.* (16) observed that 34% of coconut groves in Kerala (IN) were damaged by RPW, while Dhileepan (9) stated that the weevil was a major pest of oil palm (*Elaeis guineensis*) in the same state and reported on this host more generally in India (34). In its native areas, i.e. southern Asia and Melanesia, it feeds on a broad range of palms including coconut, sago, date, and oil palms. In some areas within this region, it has also been recorded as a serious pest of introduced palms, particularly coconuts (27). For example, in Tamil Nadu, India, 10-25% yield losses has been recorded in plantations of this palm (35). In Hainan Province of China, RPW is found in Wencheng, Qinglan, Tanniu, Dongjiao, Chongxin, Huiwen, Yandun, Qionghai, Wanning, Lingshui, Sanya, Ledong and others and causes death of 0.2-0.3 ha palms and/or coconuts (47). At present, the situation in Egypt is also severe. Although small numbers of date palms are infested, RPW has been recorded in each of the Delta administrative districts, as well as in some orchards along the road between Cairo and Alexandria and even in Cairo itself (7). In Israel, each newly infested palm is immediately eliminated (35). More than 4000 pheromone traps are located at a high density in 450 ha date plantations along the Jordan Valley (35). The incorporation of the systemic pesticide Confidor with irrigation water has been used. Despite all of these efforts, the newly infested palms are still being recorded, and after three years of the first detection, adult weevils are still caught in traps (35). Nevertheless, there is no evidence that RPW can serve as vector for any other pests (14, 35).

Economic impact of hosts

RPW feeds primarily on palms (Arecaeae) and has been recorded on the following plants: *Agave americana* (century plant) of Agavaceae; *Areca catechu* (betel nut palm), *Arenga saccharifera* (sugar palm), *A. pinnata* (sugar palm), *Borassus flabellifer* (toddy palm), *Borassus* sp. (palmyra palm), *Calamus merrillii* (rattan), *Caryota cumingii* (fishtail palm), *C. maxima* (giant mountain fishtail palm), *Cocos nucifera* (coconut), *Corypha utan* (= *C. gebanga*, *C. elata*) (gebang palm), *C. umbraculifer* (talipot palm), *Elaeis guineensis* (oil palm), *Livistona decipiens* (ribbon fan palm), *L. chinensis* (Chinese fan palm), *L. Saribus* (= *Livistona cochinchinensis)* (serdang palm), *L. subglobosa*, *Metroxylon sagu* (sago palm), *Oneosperma horrida*, *O. tigillarium* (nibong palm), *Phoenix canariensis* (Canary Island date palm), *P. dactylifera* (date palm), *P. sylvestris* (Indian date palm), *Oreodoxa regia* (royal palm), *Sabal umbraculifera* (pygmy date palm), *Trachycarpus fortunei* (Chusan palm) and *Washingtonia* sp. of Arecaceae; and *Saccharum officinarum* (sugar cane) of Poaceae (38). In China, palm trees, especially those belonging to the *Phoenix* genus, and some other species are the most important ornamental palms in the southern area in the Changjiang River basin (31). Coconut is a major plantation crop in tropical areas of China with more than half of a million farmers depending upon it for their livelihood. The crop is grown in Hainan Province on thirty thousand hectares with an annual production of nearly ten billion Chinese Yuan, making this region the largest coconut producer in China (26).

Spreading ability

RPW is a highly polyphagous species and might be found over a very wide geographical area with many different climates and farming systems. Several observations and studies have been made on the life cycle and feeding behavior of the weevil, which were mostly made in the second half of the last century in India and Southeast Asia, and were summarized by Wattanapongsiri (51).

Based on matching climates, the analogical climatic indices for the monthly means of daily maximum and minimum temperatures between the distribution of RPW in its native and invaded regions were made in Table 1. Table 1 indicated that the analogical indices of daily maximum temperatures were from 0.14 to 0.87 and of daily minimum temperatures from 0.11 to 0.87 between the native and invaded regions. Thus, at least one station whose daily maximum temperature index is above 0.14, and whose daily minimum temperature index is above 0.11 should be established for RPW in China. Acoording to this criterion, indices of 87 stations of China were calculated with the native stations and compared for their probality for RPW establishment. Increasingly, data of these stations were interpolated into GIS to generate an overlay map with climatic matching and host plants distribution. Then, the potential establishment areas were classified into three risk levels, high-risk with indices of 0.35-0.80, middle-risk with indices of 0.20-0.34, and low-risk with indices of 0.11-0.19, and the predicted risk analysis map was described (Figure 2). From the map, it can be seen that RPW can be widely distributed in the southern area from Mt. Qinling in China. The high-risk regions are Guangxi, Guangdong, Jiangxi, Fujian, Hainan, Taiwan and Hongkong. Thus, South China, East China and Southwest China are areas highly susceptible to RPW.

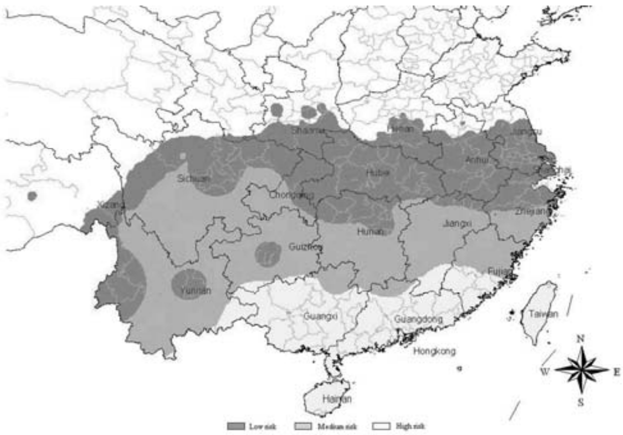

Figure 2. Potential distribution map of *R. ferrugineus* in China. The draft map was provided by the National Fundamental Geographic Information System of China. This map only extracted a part from the whole China map.

Difficulty of eradication

Usually damage caused by the RPW larvae is visible only after the host plants have been infested for a long time, but by the time symptoms appear, the damage becomes very serious and eventually result in palm death. With the cryptic life history and tendency of the pest to lay eggs on several palms, it would be difficult to detect early infestations, determine the extent of any outbreak area and discover new outbreaks, which greatly reduces the possibility of successful eradication. In most situations, the practicality of eradicating infested palms is unlikely to be a viable option. The late detection of the weevils constitutes a serious problem in fighting the pest and in any attempt to make the palms pest-free. Despite considerable research efforts spent so far, no safe technique for early detection of the weevil has been developed and applied.

Calculation of integrated risk value

Based on the semi-quantitative pest risk analysis scheme (24), the scores to the indices describing the risk of RPW were determined (Table 2). Each individual score and the total risk score were calculated as follows:

P_1=2, P_2=0.6×3＋0.2×0＋0.2×1=2, P_3=Max(3，3，3)=3,

$P_4=\sqrt[5]{3\times3\times1\times2\times2}=2.05$, $P_5=(2+1+3)/3=2$,

$R=\sqrt[5]{2\times2.0\times3\times2.05\times2}=2.18$

Table 2. Summary of the *R. ferrugineuss* risk analysis in China

No.	Index of evaluation	Score	Criterion of evaluation
1	Current distribution in China (P_1)	2	Native to south India, RPW spread within China widely in the late 1990s. It has been found in part of Hainan, Guangxi, Guangdong, Hongkong, Taiwan, Yunnan, Tibet, Fujian, Zhejiang, Jiangxi and Shanghai with the area less than 20% of all the provinces.
2.1	Potential economic damage (P_{21})	3	Estimate of economic loss is more than 20% of all the hosts.
2.2	Whether the pest is vector for other quarantine pests (P_{22})	0	There is no evidence that RPW can serve as vectors for any other pests.
2.3	Importance in other countries (P_{23})	1	More than 9 countries have list RPW on the quarantine list.
3.1	Host plants species (P_{31})	3	Proper hosts of RPW throughout China are more than 10 species
3.2	Area of host plants (P_{32})	3	Damaging of RPW is more than 350 ha
3.3	Special value of host plants (P_{33})	3	Host plants are some of the most important ornamental palms and a major plantation crop in tropical areas of China. The economical value of the palm is very important.
4.1	Frequency of interception and capturing (P_{41})	3	Intercepting and capturing accidents are increasing frequency on many ports of China.
4.2	Survival rate of pest in transportation (P_{42})	3	Survival of RPW is more than 40% in transportation.
4.3	Distribution in other countries (P_{43})	1	Distribution areas are less than 25% of the entire world.
4.4	Potential establishment in China (P_{44})	2	RPW can infest from 25-50% of areas in China.
4.5	Spread potential (P_{45})	2	The high rate of spread of this pest is human intervention, by transporting infested palm trees of various sizes and offshoots from contaminated to uninfected areas.
5.1	Difficulty of early identification (P_{51})	2	It is difficult to discover early infestation of RPW.
5.2	Difficulty of treatment (P_{52})	1	Currently killing rate of RPW using effective method is 50-100%.
5.3	Difficulty of eradication (P_{53})	3	Current method can not entirely eradicate RPW, and it is difficult and costly.

The integrated risk value of RPW was found to be 2.18, which has reached the criterion (> 1.5) of a quarantine pest (30). Thus, it is reasonable that RPW has already been listed on the quarantine sheets of China.

Risk management

Phytosanitary measures in uninfested areas

RPW is a dangerous pest in regions from Mt. Qinling in China. The high spread rate of this pest is the result of human activities by transporting infested palms of various sizes and offshoots from infested to uninfested areas. Outbreaks have already occurred in several provinces, but without rapid spread. It seems that, in the short term at least, domestic phytosanitary measures can contain these outbreaks if they are detected early enough. Therefore, it is quite reasonable that RPW has already been listed on the quarantine sheets in China. In areas where RPW is found, effective methods are difficult to be developed because of the concealed nature of the larvae. Once infested, palms must be cut in small pieces and should be burned (if possible) and/or buried deeply. However, burning may be a difficult option and some prefer to bury the infested palms. Clearly, the best strategy for uninfested areas in China is to exclude the pest by strict phytosanitary measures that all imported palms must be pest-free..

Measures to eliminate the pest in infested areas

Considering the environment health, biological control is the first recommended method in the infested areas. Some attempts have been made in the laboratory and field using the predacious *Chelisoches morio* in India (2). Gopinadhan *et al.* (17) reported that a cytoplasmic polyhedrosis virus infected all stages of the weevil in Kerala (IN), including late-larval stages, which resulted in malformed adults and drastic suppression of the host population. Although various mites have been reported in India as parasites for RPW (37, 40), their impact on the population needs to be further ascertained. Thus, no practical method of biological control is available at present. Currently recommended methods for management have focused on integrated pest management (IPM) (3, 10, 29, 44, 48). The IPM program included surveillance (1), pheromone lures (10, 13, 20), cultural control (18, 28, 38, 41) and chemical treatments (3). Reviews of control strategies and IPM for RPW have already been presented by various authors (35, 36, 42).

Discussion

The software program CLIMEX for Windows version 1.0 (45) was used to determine the key indices concerning the potential establishment of RPW and to define the invasible regions. It comprises three major functions, which are (i) to compare locations, which predicts the potential geographic distribution of a species based on its climatic requirements, (ii) to compare years using data from consecutive years, and (iii) to match climates by searching the meteorological database contained within CLIMEX for locations with climates similar to that of a specific location. This study focused on the third function to determine the potential range of RPW that has similar climates to a number of its native locations. Matching climates produced a 'match index' for all the locations via the software. Usually, the match index is the product of five climatic variables, which individually indicate the level of similarity for the average monthly maximum daily temperature, average monthly minimum daily temperature, average monthly rainfall, rainfall pattern and the relative humidity at 9 a.m. and 3 p.m. In this study, temperature was the most important climatic factor for RPW spread. CLIMEX uses a relatively simple procedure for the climate similarity model. The climatic similarities of RPW native and non-native ranges were calculated on two climatic parameters, maximum and minimum temperatures.

Climatic mapping systems, such as CLIMEX, which are used to predict the potential distribution of species in regions where the species does not exist currently (46, 52) or in the future under climate change scenarios (4), have been criticized (8) for its failure to take other key factors into account. Such criticism has been countered by Hodkinson (21) and Baker *et al.* (5), who stressed the importance of assessing other factors such as availability of hosts in addition to climatic suitability. This PRA does not only rely on CLIMEX, and CLIMEX results are not considered in isolation during the PRA process. CLIMEX has been used to show that parts of China do have climates that RPW would find suitable, although for successful establishment, other biotic factors such as host plants distribution and interaction with other species would also have to be appropriate. Thus, in this paper, the risk analysis was further enhanced by using GIS to integrate the host density distribution with climatic suitability in order to identify and rank the invasible areas. Such a map could allow for limited phytosanitary resources to be focused in the areas of greatest outbreaks found at a number of sites within the PRA area. We modified the method using the pivotal bio-climatic match value of RPW output from the CLIMEX model to interpolate into the GIS database covering host plants informations. Integrallty overlaying with the climatic map and the host plants map, the potential establishment of the pest was improved.

The present paper indicates that RPW is a quarantine pest of relevance to China. Preventing the establishment of a pest is more effective than managing the pest when it has established in a new geographical area (39). Currently, few measures to manage RPW in palm trees in China are applied and therefore, in all likelihood, if carried to China, RPW would be able to survive in palms in many cases, due to protection from host plants. Prohibiting the introduction of RPW from quarantine areas is the primary aim of ongoing risk management.

In this paper, the climate match was based on average monthly maximum and minimum temperatures, which might be inadequate, because it might neglect more other climatic factors. To overcome this problem, the CLIMEX model could be used, requiring more detailed climatic data, such as weekly averages, or a diversity of variables that indicate the amount of variation presented in the monthly averages based on the standard error of the monthly averages over a period of 10-50 year. Meanwhile, it is important to understand that at present, there are only 87 meteorological stations related to China in CLIMEX, and the number of locations is so limited in this country. This may introduce errors in prediction of RPW suitable areas and result in poor spatial coverage of areas with high climatic similarities to the areas of interest. In highly diverse areas, such as mountainous regions, a small geographical difference often results in a large climatic variability within a small area. Changes in the altitude and slope have large effects on temperature, so that the climate match in the valleys can be very different from that on a south-facing slope. Ideally, with improved versions of the program, the number of locations with meteorological data would be increased, and spatial extrapolation would be developed from the present meteorological data so that maps with isolines of percentage climatic match values can be produced.

Finally, written responses to the questions of the risk analysis scheme in China in addition to the use of CLIMEX and GIS were sufficient to convince China of its need to take an action; however, it is important to consider how the scores from this scheme can be used. A pest can be regarded as a quarantine pest if its total risk score is more than 1.5. The scheme was designed so that the relative risk of one pest or pathway could be compared with another. Scores given to each phase are attempts to reduce a wide range of information in a relatively simple way. Until more risk assessments are conducted, there are limitations for further analysis via using the scheme.

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الملخص

جو، روي تينغ وعزيز عجلان. 2011. الإستيطان التوطّن والخطر المحتمل للآفة الغازية الجديدة: سوسة النخيل الحمراء في الصين. مجلة وقاية النبات العربية، 29: 122-130.

سوسة النخيل الحمراء، *Rhynchophorus ferrugineus*، هي آفة جديدة غازية على أنواع النخيل في الصين. تم تقويم منطقة التوطّن والخطر الذي تمثله هذه الآفة في الصين باستخدام مخطط تحليل مخاطر الآفة المطوّر في الصين. هذا البحث تعامل مع المعلومات المتعلقة بالإنتشار، والأضرار المحتملة، والقيمة الاقتصادية للعوائل، وإمكانية نقلها ونشرها وصعوبة إدارء خطرها. تنمو العوائل القابلة للإصابة في عدة مناطق بالصين. ومن خلال استخدام برنامج حاسوبي CLIMEX ونظم المعلومات الجغرافية GIS في المناطق الجنوبية من جبال كينلينغ، وبخاصة منطقة قوانغشي، قوانغدونغ، جيانغشى، فوجيان، هاينان، وتايوان وإلى هونج كونج بالصين عُرفت بأنها المناطق الأكثر ملاءمة لتوطّن الآفة حيث المناخ والعوائل المناسبة. هناك خطر كبير من احتمال دخول سوسة النخيل الحمراء وتوطّنها وتسببها في الإضرار بأنواع النخيل المهمة في الصين. أسهم تحليل المخاطر لهذه الآفة في اتخاذ القرار بإضافة سوسة النخيل الحمراء إلى قائمة آفات الحجر الزراعي المحظور دخولها وانتشارها في الصين.

كلمات مفتاحية: تحليل مخاطر الآفة، الحجر الزراعي، الإنتشار، سوسة النخيل الحمراء*Rhynchophorus ferrugineus* ، الصين.

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