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Research Application Summary

Assessment of current and potential geographic distribution of the papaya mealybug, Paracoccus marginatus (*Hemiptera:Pseudococcidae*) in Mozambique

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Abstract

Papaya mealybug, *Paracoccus marginatus* is a polyphagous pest that can damage several genera of host plants. Since its first detection in Pemba (northern of Mozambique) in 2013, there has been no information on its current geographical distribution and spread patterns to other areas in the country. Thus, this study aimed at assessing the distribution and predicting the potential geographic distribution of *P. marginatus* in Mozambique. A field survey was conducted from September 2015 to February 2016 in Cabo Delgado, Nampula and Sofala provinces. Field data on *P. marginatus* occurrence and infestation levels were collected in 3 to 6 districts from each province. An ecological niche model was used based on presence and absence data to predict the potential geographical distribution of the pest. Results showed that papaya mealybug occurred at high densities and was well established and widely spread in most of the sampled sites in the northern provinces of Cabo Delgado and Nampula. There was no occurrence of *P. marginatus* in the sampling sites of Sofala province, in the central region of the country. The present results confirm the occurrence of *P. marginatus* only in the northern provinces of Nampula and Cabo Delgado. This is an indication that the distribution of *P.marginatus* was restricted to the northern region of the country. The ecological niche model (ENM) indicated that much of the coastal area of Mozambique had favourable environmental conditions for *P. marginatu*s occurrence. The ecological niche model predicted for the next 50 years showed that the probability of occurrence of *P. marginatus* in Tete, Sofala and Zambezia would increase. Since *P. marginatus* was not detected in the central and southern of Mozambique it is imperative that its spread is monitored continuously to define pest free areas and establish management strategies in order to reduce the impact of the pest in the country, including the establishment of domestic quarantine measures and reinforcement of boarder control inspection services.

Key words: Ecological niche model, Mozambique, *Paracoccus marginatus*, species distribution

Résumé

La cochenille de la papaye, Paracoccus marginatus, est un parasite polyphage qui peut endommager plusieurs genres de plantes hôtes. Depuis sa première détection à Pemba (nord du Mozambique) en 2013, aucune information n'a été fournie sur sa répartition géographique actuelle ni sur les tendances

de sa propagation dans d'autres regions du pays. La presente étude visait donc à évaluer et prévoir la répartition géographique potentielle de P. marginatus au Mozambique. Une enquête de terrain a été menée de Septembre 2015 à Février 2016 dans les provinces de Cabo Delgado, Nampula et Sofala. Des données de terrain sur l'occurrence de P. marginatus et les niveaux d'infestation ont été collectées dans 3 à 6 districts de chaque province. Un modèle de niche écologique basé sur des données de présence et d'absence a été utilisé, pour prédire la répartition géographique potentielle du parasite. Les résultats ont montré que la cochenille de la papaye était présente à haute densité et largement répandue dans la plupart des sites échantillonnés dans les provinces de Cabo Delgado et de Nampula. P. marginatus n'a pas été détecté dans la province de Sofala, au centre du pays. Les résultats actuels ne confirment la présence du parasite que dans les provinces du nord, indiquant que sa distribution était limitée à la région nord du pays. Le modèle de niche écologique indiquait qu'une grande partie de la zone côtière du Mozambique présentait des conditions environnementales favorables pour l'occurrence de P. marginatus. Le modèle de niche écologique prévu pour les 50 prochaines années a montré que la probabilité d'occurrence de P. marginatus à Tete, Sofala et Zambezia augmenterait. Comme P. marginatus n'a pas été détecté au centre et au sud du pays, il est impératif de suivre sa propagation, afin de définir les zones exemptes d'organismes nuisibles et d'établir des stratégies de gestion visant à réduire leur impact sur le pays, y compris par la mise en place de systèmes de protection interne et mesures de quarantaine, et le renforcement des services d'inspection du contrôle des frontières.

Mots clés: Modèle de niche écologique, Mozambique, Paracoccus marginatus, distribution des espèces

Introduction

Papaya mealybug, *Paracoccus marginatus* Williams and Granara de Willink (Hemiptera: Pseudococcidae) is native from Mexico and Central America and was first described in 1992 (Williams and Granara de Willink, 1992) and re-described in 2002 (Miller and Miller, 2002). Thereafter it has spread to more than 15 countries worldwide (Tanwar *et al.,* 2010). The papaya mealybug has never gained the status of a serious pest in its native place probably due to the presence of an endemic natural enemy complex. However, in places where it was introduced without their native natural enemies, it is a serious threat to numerous agricultural products (Tanwar *et al.*, 2010).

In Africa *P. marginatus* was first recorded in Ghana in 2009, where it caused economic losses in 85% of all papaya farms in papaya growing regions (Cham *et al.,* 2011). Since then the occurrence of the pest was reported in other countries such as Benin, Nigeria, Togo, Gabon, Mauritius, Réunion, Seychelles and Tanzania (Muniappan *et al.,* 2009; IITA, 2015). In Mozambique, the papaya mealybug was reported for the first time in Pemba, Cabo Delgado province in September 2013 by Cugala *et al.* (2013). Results of this preliminary evaluation showed that this pest represents a serious threat to the productivity of several host crops but mainly papaya. Due to the fact that *P. marginatus* is a new invasive pest, there is no information on its distribution in Mozambique. Therefore, the understanding of its geographical distribution is crucial for planning and establishment of management strategies.

On the other hand, species distribution models also known as bioclimatic models or ecological niche models (ENM´s) have been widely used in prediction studies of the potential distribution of invasive pests (Pereira and Petterson, 2001). Such tools proved to be effective on predicting the potential geographical distribution of the invasive fruit fly, *Bactrocera dorsalis* (De Meyer *et al.,* 2009; Magagula *et al.,* 2015) and the coconut whitefly, *Aleurotrachelus atratu*s (Checo, 2014) providing expected status about the future distribution of the pest and helping establish long term management strategies. However, there are no studies involving the use of this tool for the prediction of potential areas of occurrence of *P. marginatus* in Mozambique. Therefore, this study is aimed at assessing current and predicting future distribution of the *P. marginatus* in Mozambique.

Materials and Methods

Field surveys were conducted during September 2015 to February 2016 in the northern provinces of Cabo Delgado and Nampula and in the central province of Sofala. A total of six districts were selected in the provinces of Cabo Delgado (Pemba, Metuge, Macomia, Ancuabe, Quissanga, Chiúre) and Nampula (Nampula city, Nacala-porto, Nacala-velha, Murrupula, Meconta, Monapo), and three districts were selected in Sofala province (Nhamatanda, Dondo, Beira). Evaluation of the occurrence and distribution of *P. marginatus* were based on direct evidences regarding field data (infestation levels and pest density) for the surveyed districts, and indirect evidences from information provided by phytosanitary inspectors in the provinces of Manica, Inhambane, Gaza and Maputo (presence or absence of the pest).

In each surveyed district, three areas were selected for data collection. Sampling sites were selected based on their susceptibility with regard to the high risk of introduction of *P. marginatus* such as main entry points (sea ports), main tracking road corridors, coastal proximity, market places, residential areas, papaya production areas, main transportation routes, and towns close to points of entry (Magagula *et al.,* 2015). Presence of any individual of *P. marginatus* in the study areas confirmed the occurrence of the pest. In each study site 20 papaya plants were randomly selected and evaluated whether they were infested (1) or not (0) by papaya mealybug. Of these, five infested plants were randomly selected for sampling and three infested leaves from each plant for estimation of the population density.

The maximum entropy method (MaxEnt) (Phillips *et al.,* 2006) was used as ecological niche modelling technique to predict the potential distribution of papaya mealybug in Mozambique in the present and future (20 to 50 years). Data on the presence and absence of the pest in sampling sites was georeferenced (geographical coordinates) to perform the model. Seven environmental variables (BIOCLIM) were extracted from the Worldclim database and interpolated at 14 km of spatial resolution (Table 1). They were all continuous and selected for their common use in ENM´s and its importance in the occurrence and distribution of species such as *P. marginatus* (De Meyer *et al.,* 2009). This would provide information about areas that are conducive for the development of the pest based on similarities of the environmental conditions with the areas where occurrence had been confirmed. Before running the model, its accuracy was tested by running 75% training data and 25% subsample data for testing the predictive power of the model (Magagula *et al.,* 2015).

Table 1. Environmental variables used in MaxEnt model for the prediction of potential distribution of *P. marginatus* in Mozambique

Variable	Code	Type	Source
Annual mean temperature	BIO1	Continuous	Worldclim
Mean diurnal range (mean of monthly (max temp-min temp))	BIO2	Continuous	Worldclim
Maximum temperature of the warmest month	BIO5	Continuous	Worldclim
Minimum temperature of the coldest month	BIO6	Continuous	Worldclim
Annual precipitation	BIO12	Continuous	Worldclim
Precipitation of wettest month	BIO13	Continuous	Worldclim
Precipitation of driest month	BIO14	Continuous	Worldclim

Adapted from Magagula *et al.,* 2015

Results and Discussion

The pest status and distribution of *P. marginatus* in Mozambique is shown in Figure 1. It is observed that papaya mealybug occurs at high densities and it is well established and widely distributed in the north of the country, specifically in the provinces of Cabo Delgado (Pemba, Metuge, Macomia, Ancuabe) and Nampula (Nampula city, Nacala-porto, Nacala-velha). Nampula had the highest pest density and infestation levels (1289 mealybug/leaf and 59.3% of infested plants) followed by Cabo Delgado (720 mealybug/leaf and 58.7% of infested plants). Higher values of density and infestation levels were recorded in Nacala-velha district (3668 mealybugs/plant and 100% of infested plants) and the lowest in the district of Ancuabe (104 mealybugs/plant and 25% of infested plants). Higher values of density and infestation levels were also recorded in Nacala-velha district (3668 mealybugs/plant and 100% of infested plants) and the lowest in the district of Ancuabe (104 mealybugs/plant and 25% of infested plants).

Despite the pest occurrence at high densities in these provinces, symptoms of infestation of the pest were not observed in the districts of Quissanga and Chiúre (Cabo Delgado) and in the districts of Murrupula, Meconta and Monapo (Nampula). On the other hand, field surveys in the central province of Sofala confirmed the non-occurrence of the pest in all assessed districts (Nhamatanda, Dondo, Beira).Thus, the northern region is considered infested and the central region a pest free area.

Cugala *et al. (*2013) reported the occurrence of *P. marginatus* in Pemba, Cabo Delgado province and they stated that the pest was restricted in the northern part of Mozambique. The detection of *P. marginatus* in new areas of the province of Cabo Delgado and Nampula is an indication that this pest is spreading to new areas. The rapid spread of the pest is supported by its polyphagous nature, enormous reproductive capacity, rapid development and high survival rate, which contributes to rapid population growth and spread to new areas (Tanwar *et al.,* 2010). Ahmed *et al.* (2015) reported the presence of the pest in papaya samples from Niassa province and was intercepted in China. The occurrence of *P. marginatus* in the north of the country and the non-occurrence as we move to the south is an indication that this species was probably introduced in the northern region of Mozambique through the ports of Pemba and Nacala Porto and/or Nacala Velha.

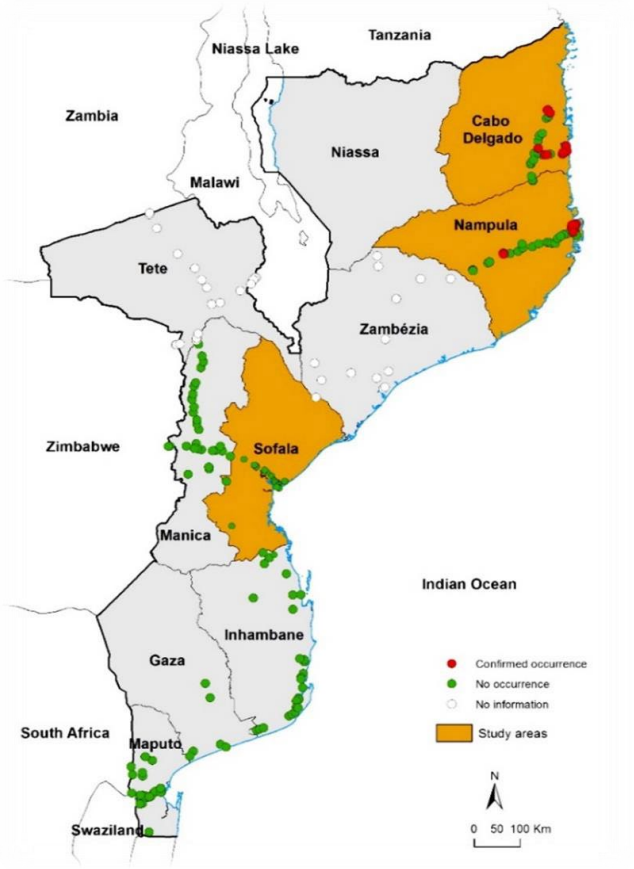

Figure 1. Sampling sites and places of confirmed occurrence and non occurrence of *P. marginatus* in Mozambique

The prediction of the current and future occurrence of *P. marginatus* is shown in Fig. 2 (red shades represent higher probability of occurrence and blue shades null probability of occurrence). The ecological niche model (MaxEnt) indicated that much of the coastal area of Mozambique has favourable environmental conditions for development of *P. marginatus,* constituting a region with high probability of occurrence of this species. In general, the probability of occurrence of this species is high in the north (higher fitness), moderate in the central area (except the province of Manica where the probability of occurrence is null) and restricted or reduced in the south. Isolated occurrence is predicted in the Tete province up to the border with Manica province and within the provinces of Gaza and Inhambane. According to De Meyer *et al.* (2009), regions with high suitability for the occurrence of species (as shown in Fig. 2) are more susceptible to invasions relatively to low fitness areas.

Despite the fact that the survey´s results showed Sofala province as a pest free region, the ENM predicts this region as potential niche for *P. marginatus*. Additionally, possible climate changes predicted for the next 50 years show that from 2036 to 2066 (next 20-50 years) the probability of occurrence of *P. marginatus* in Zambezia, Sofala and Tete provinces would increase, making

the central region of Mozambique a suitable habitat for *P. Marginatus* (Figures 2b and. 2c). A reduction in the outbreaks of occurrence of this pest in the southern region of Mozambique (from Save River to Maputo province) from 2016 to 2066 is estimated and this region is expected to become less suitable habitat for this kind of invasions over the time (Figures 2a), 2b) and 2c).

Since the presence of *P. marginatus* is not confirmed in the center and south of Mozambique it is imperative that surveillance programmes and sustainable management strategies are put in place to reduce the impact of the pest, mainly in the northern and central regions where the ecological niche modelling predicted these zones as having greater habitat suitability and higher probability for development and survival of *P. marginatus.*

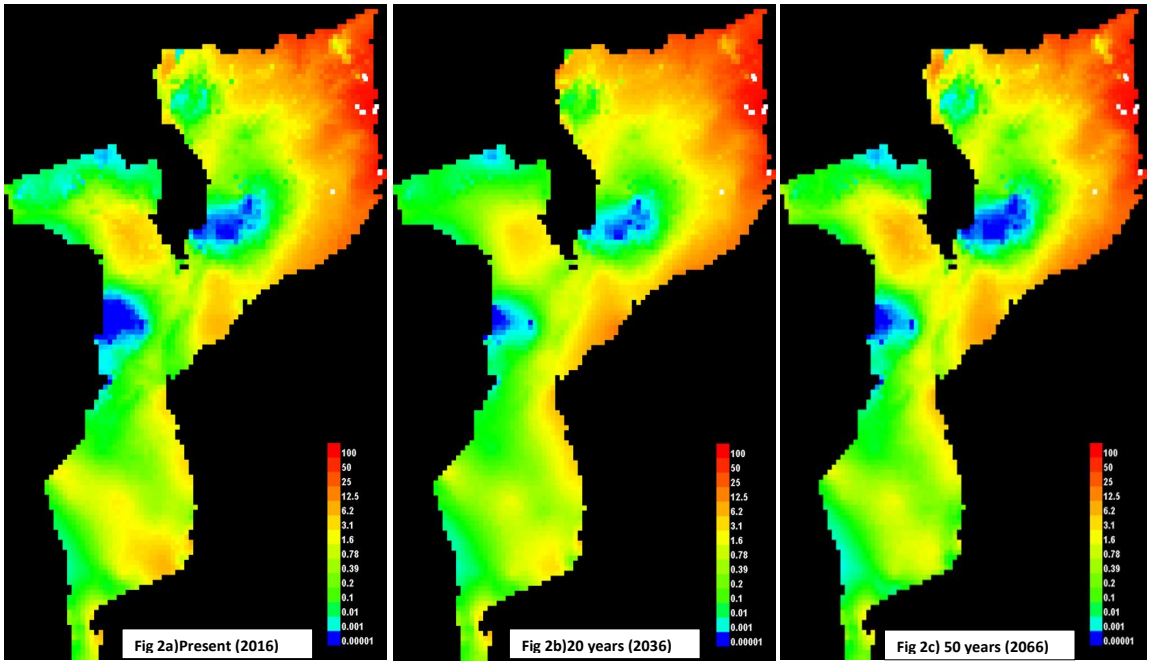

Figure 2: Predicted spread of *P. marginatus i*n Mozambique, 2016-2066

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References

Ahmed, M.Z., He, R.R., Wu, M.T., Gu, Y.J., Ren, J.M., Liang, F., Li, H.L., Hu, X.N., Qiu, B.L., Mannion, C.M. and Ma, J. 2015. First report of the papaya mealybug, *Paracoccus marginatus* (Hemiptera: Pseudococcidae), in China and genetic record for its recent invasion in Asia and Africa. *Florida Entomologist* 98 (4): 1158-1162.

Cham, D., Davis, H., Obeng-Ofori, D. and Owusu, E. 2011. Host range of the newly invasive mealybug species *Paracocccus Marginatus* Williams and Granara De Willink (Hemiptera: Pseudococcidae) in two ecological zones of Ghana. *Research in Zoology* 1 (1): 1-7.

Checo, T. A. 2014. Avaliação da distribuição e potenciais zonas em risco de invasão da mosca branca invasiva do coqueiro (*Aleurotrachelus atratus*) usando o modelo de nicho ecológico em Moçambique e África. Tese de Licenciatuta. FAEF-UEM.

Cugala, D., Cumbe, R., Wanyonyi, M., Ambasse, D. and Omar, R. 2013. An out break of a new devastating invasive species, papaya mealybug, *Paracoccus marginatus* in the northern region of Mozambique - a serious threat to papaya production. A report submitted to Agrifuturo/USAID, Maputo, Mozambique. 7 pp.

De Meyer, M., Robertson, M.P., Mansell, M.W., Ekesi, S., Tsuruta, K., Mwaiko, W., Vayssières, J-F. and Peterson, A.T. 2010. Ecological niche and potential geographic distribution of the invasive fruit fly *Bactrocera invadens* (Diptera, Tephritidae). *Bulletin of Entomological Research* 100: 35–48.

Magagula, C. N., Cugala, D. C., Monadjem, A. and Dlamini, W. M. 2015. Predicted regional and nation distribution of *Bactrocera dorsalis* (syn. B. invadens) (Diptera:Tephritidae) in southern Africa and implications for its management. *African Entomology* 23 (2): 428-437.

Miller, D.R. and Miller, G.L. 2002. Redescription of *Paracoccus marginatus* Williams and Granara de Willink (Hemiptera: Coccoidea: Pseudococcidae), including descriptions of the immature stages and adult male. *Proceedings of the Entomological Society of Washington* 104: 1-23.

Pereira, R. S. and Peterson, A. T. 2001. O uso da modelagem na definição das estratégias para a conservação da biodiversidade. Available in: http://www.comciencia.br/reportagens/biodiversidade/bio18.htm>. Accessed on 10 December 2015.

Tanwar, R. K., Jeyakumar, P. and Vennila, S. 2010. Papaya mealybug and its management strategies. Technical Bulletin 22, NCIPM, New Delhi, India. 22 pp.

Williams, D. J. and Granara de Willink, M. C. 1992. Mealybugs of Central and South America. CAB International, Wallingford, England. 635 pp.

Muniappan, R., Shepard, B. M., Watson, G. W., Carner, G. R., Rauf, A., Sartiami, D., Hidayat, P., Afun, J. V. K., Goergen, G. and Ziaur Rahman, A. K. M. 2009. New records of invasive insects (Hemiptera: Sternorrhyncha) in Southeast Asia and West Africa. *Journal of Agricultural and Urban Entomology* 26 (4):167-174.

International Institute of Tropical Agriculture (IITA). 2015. Food security and livelihoods at risk as destructive pest invades Tanzania. The fast spreading and highly destructive papaya mealybug reaches Tanzania. IITA Press Release, 20 April 2015. http://www.iita.org/2015-press-releases/-/asset_publisher/CxA7/content/food-security-andlivelihoods-at-risk-as-destructive-pest-invades-tanzania?redirect=%2F2015-press-releases#.VUn-OEbwuHs