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Article

The Manifold Aspects of the Fight Against the Red Palm Weevil in an Urban Area: Study Case, San Benedetto del Tronto (Central Italy)

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Simple Summary: The red palm weevil (Rhynchophorus ferrugineus) is a weevil beetle native to Asia which has assumed highly invasive behavior in the Mediterranean Sea basin, causing great damage to both crops (dates) and ornamental plants (cities). The absence of natural antagonists here implies that for its control chemical substances must be used, administered both to cure the infested palm and to prevent its attack. Through a multidisciplinary approach we analyzed the evolution of the distribution of this beetle in a coastal city (central Italy) rich in Canary Island date palms, considering both the control strategies used and their potential effects. We observed that the palm stock was drastically reduced by this beetle in about 15 years; the preventive fight put in place by the local administration is very effective against new palm tree attacks but has a potential negative impact on the environment, costs a lot but is currently the only effective tool to preserve the cultural landscape of this area. The challenge is to find the right balance between all these aspects.

Abstract: The implications related to the fight against alien organisms often affect different sectors, from the economic to the landscape one or from the public health to the ecological one. This paper is an upgrade of our previous study focused on the evolution of the red palm weevil in a coastal urban area (central Italy); we investigate the evolution of this parasite in the following period (2013-2020), considering both the effectiveness of the chemicals used and their potential effects. With a multidisciplinary approach, on the one hand we carried out a spatio-temporal analysis to analyze the extent and mode of pest spread over time using historical aerial photos, freely available remote sensing images and field surveys, integrated in a GIS environment, and on the other hand we performed an assessment of the chemical risk associated with the substances used to protect the palms from the red weevil. The fight against weevil is now concentrated in specific areas (parks, relevant roads, villas, hotels, farmhouses, nurseries); the applied preventive chemical treatments are very effective in preserving the palms, but they show a toxic potential for all organisms. We discuss current local management of this pest focusing on the several aspects involve into the fight against this beetle in an urban area.

Keywords: red palm weevil; fight; pesticides; potential chemical risk; urban environment; GIS; spatial distribution analysis

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1. Introduction

The red palm weevil (RPW), *Rhynchophorus ferrugineus* Olivier, 1790 (*Coleoptera Curculionidae*), is one of the most harmful palm pests and its damages to date palms was recorded since the mid-1980s in Saudi Arabia and then in Egypt in the 1990s (Cox 1993). The RPW then spread since 2000 in the Mediterranean basin (EPPO Reporting Service 1996, 1999a, b, 2004, 2006a, b, c, 2007a, b, c, d, e, 2008a, b, 2009, 2010a, b; EPPO/OEPP 2013), infesting palms essentially belonging to the genus Phoenix, used here for ornamental purposes.

The fight against the red palm weevil is unfortunately still an open question; early detection of the RPW is challenging because larvae (the most damaging stage) are endophytic (Soroker et al. 2017). Several control methods have been used and tested so far, including biological control by means of entomopathogenic nematodes (e.g., *Steinernematidae* and *Heterorhabditidae*), fungi (e.g., *Beauveria bassiana*, *Metarhizium anisopliae*), virus (*Baculovirus oryctes*, *Cytoplasmic Polyhedrosis Virus*) (Wraight et al., 2001), bacteria (*Bacillus* sp., *Pseudomonas aeruginosa*) and mass trapping (Rochat et al. 2006; Faleiro et al. 2012; Masilamany et al. 2012; Mazza et al. 2014; Giblin-Davis et al. 2013; Lin et al. 2017). Nevertheless, insecticide applications are, at present, the most effective method for protecting palms from attack by palm weevils (Milosavljević et al. 2019). Insecticides can be applied outside the apical part of the plant (cover high pressure sprays or low-pressure solutions) (Rochat et al. 2006; Masilamany & Tang 2013; Al-Shawaf et al. 2013; Peri et al. 2013; Al-Dosary et al. 2016; Llopis et al. 2018; DOA 2016) or inside it (trunk injection method) (Kielbaso et al. 1979; Dembilio et al. 2014). In the first case, treatment should be repeated periodically, depending on the persistence of the sprayed insecticide (Ferry and Gomez 2012) and local climate; in the second one, treatment may be more scattered over time (Chihaoui-Meridja et al. 2020). For these reasons, endotherapy is regarded as a safer method rather than spray diffusion, with low adverse effects on non-targeted species, humans and environment (Chihaoui-Meridja et al. 2020).

In the Marche Region, chemical control of *Rhynchophorus ferrugineus* started in 2008 and it was carried out using 15–20 litres per palm of an insecticide spray solution, containing as main chemical active substances chlorpyrifos (CPF) or acetamiprid (ACE)/imidacloprid (IMI). At least one treatment application per year was conducted during the last years (Nardi et al. 2011). Thus, considering the widespread use of these synthetic pesticides, concerns arise regarding the environmental fate and potential toxic effects of these compounds within our study area. ACE and IMI are two neonicotinoid insecticides that act as selective agonists of type-2 nicotinic acetylcholine receptors in insects (Gervais et al. 2010). However, distribution of these compounds into the plant's pollen and nectar (Stoner and Eitzer 2012) contributes to expose other non-target invertebrates such as pollinating honeybees (*Apis mellifera*) (Johnson and Pettis 2014; Chagnon et al. 2015). In addition, both soil drench and seed treatment may contribute to spreading the contamination, also exposing vertebrate species including humans (Rogers et al. 2019). CPF is one of the most widely used chlorinated organophosphate (OP) pesticides and it is well known as a highly persistent chemical, especially in aquatic ecosystems (EPA 2000; Watts 2012). CPF toxicity has been shown to vary, ranging from neurological dysfunctions to endocrine disruption, in both human and animal studies (Rahman et al. 2021).

Urban areas look like specific challenges for the management of pest infestations such as RPW, as infested palms are placed often on private land which may complicate control programs (Milosavljević et al. 2019) and because pesticide use is highly regulated to preserve public health. In this regard, a sequential photo-surveillance approach may be very useful to monitoring the evolution of pest because allows the quantification of mortality rates and spread patterns (Cohen et al. 2012; Hogan et al. 2017); usually photos refer to satellite (Cinnirella et al. 2020) or drones (Milosavljević et al. 2019). Many of these territories link their image precisely to the presence of palms and therefore have to face this great problem. For instance, the municipal area of San Benedetto del Tronto is known as the Palm Tree Coast; hence the importance of preserving its palm tree heritage at all costs for tourism purposes.

In this paper, we present the evolution of the RPW spread in the San Benedetto del Tronto Municipality (at 2020) with respect to the previous status (2007 - 2012) (Cinnirella et al. 2020) using available remote sensing images, field surveys and GIS. Moreover, we predict the potential adverse health effects that may result from exposure to chemicals used for RPW control by carrying out a systems toxicology method. The specific objectives of this work were: a) to evaluate the effectiveness of the chemical treatments carried out by the municipality of San Benedetto del Tronto; b) to analyse the new RPW spatial distribution in this urban area; c) to predict signalling pathways targeted by insecticides that are potentially associated to adverse consequences; d) to suggest specific management urban measures. As far as we know, this was the first study that considers the multiple aspects of the fight against the RPW in an urban area.

2. Materials and Methods

2.1-. The study area and collected data

The Municipality of San Benedetto del Tronto is our study area and it's located along the Adriatic coast of Central Italy (Fig. 1). The bioclimate is Mediterranean (Upper meso-mediterranean thermotype) (Pesaresi et al. 2017) with: i) annual rainfall and temperature averages of 551 mm and 15.8 °C, respectively , ii) dry summer (average temperature of 24°C), iii) rainy and moderately cold winters (average temperature of 7°C) (Fazzini et al. 2013).

Figure 1. Location of the study area in the Marche Region, central Italy (Municipality of San Benedetto del Tronto)

Starting from the map generate in previous study in which we analysed the RPW distribution during the period July 2007- July 2013 (Cinnirella et al. 2020), through aerial photos of Google Earth time series, Google Street view time series and subsequent field surveys, all the Phoenix canariensis palm trees in San Benedetto del Tronto municipality were recollected at the end of 2020 year and reclassified in terms of contagious (health, dead-infested).

Based on the interviews with municipal employees and analysis of the municipal administration's acts (www.comunesbt.it), what was done in this area against the RPW in the period 2013-2020 was reconstructed. It was therefore possible on the one hand, to classify the palms in terms of treatment (treated, untreated) and on the other hand, to estimate the quantities and type of pesticides used.

2.2-. Geo-statistical analysis

To analyze the recent distribution of the RPW (palms dead or infested) with respect to the chemical treatments carried out (palms treated or untreated), the new collected data were entered into a previous GIS (ESRI® ArcGIS© 10.1 (ESRI 2012)).

The Hot spot analysis (Getis-Ord Gi*) was performed to highlight statistically significant areas of clustering (infestation; chemical treatment), based on a new output shape file that reports a z-score, a p-value and a confidence level of aggregation or dispersion bin field (Gi_Bin) for each feature (high z-score and small p-value: spatial cluster with high values; low negative z-score and small p-value: spatial clustering with low values; z-score near zero: no apparent spatial clustering).

In our case, we performed two Hot spot analyses, one for the infested palms (dead or attached) and another one for the treated palms.

For this reason, the input shape file was modified by adding short numerical attribute fields, based on the classification of all the palms in terms of the contagious event (1, infested or dead palm; 0, healthy palm) and chemical treatment (1, treated palm; 0, no treated palm).

Through overlapping of the resulting maps (the two generated shapefiles displayed by the Gi_Bin values), it was possible to verify if a possible data cluster of health palms is superimposed on a possible data cluster of treated palms.

For this purpose, we generate a map in which polygons of a net (20 mt x 20 mt) report by different colour, the information about "healthy and treated" and "healthy and not treated" palms; in this context we also generated an index based on the overlapping percentage.

Finally, to support this evaluation, statistical analysis was performed for PRW infections on the considered palm trees. The risk factor affecting RPW occurrence was determined using the Chi-square test of independence between the status of each palm (infested or dead; health) and a different treatment (chemical treatment yes or not). The Chi-square testing was securely performed as his assumptions were respected: no more than 20% of the cells can have an expected frequency less than five (in mean 1845.75), no cell can have an expected frequency less than one and the sample size was big enough (Whitlock & Schluter 2015; Roscoe & Byars 1971). In our study the null hypothesis for this test stated that the infection's occurrence does not depend on the chemicals treatment (treated vs untreated).

2.3-. In Silico Prediction of insecticide Toxicity

IMI and CPF were investigated using an integrative systems toxicological model to predict biological effects at the human, bird, amphibian, fish and insect system level. We used existing data from the Search Tool for Interactions of Chemicals (STITCH v5.0) database containing the interactions between chemicals and proteins to develop a network-based predictive model of the selected pesticides with targets. This approach has also been widely accepted to study chemical-gene interactions (Iskar et al. 2010; Chakraborty 2014). STITCH acts as a probabilistic network, by collecting interactions from multiple sources, including experimental evidence, databases, and published data. The overall confidence score ranges from 0 to 1, where a value of 0.15 is considered as low confidence, 0.4 as medium confidence, and a score equal to or higher than 0.7 is regarded as high confidence. To obtain a reliable set of interactions, we removed all interactions with a confidence score lower than 0.7 and pesticides connections with uncharacterized protein. IMI and CPF were annotated with a canonical SMILES code retrieved from PubChem (C1CN(C(=N1)N[N+](=O)[O-])CC2=CN=C(C=C2)Cl; CCOP(=S)(OCC)OC1=NC(=C (C=C1Cl)Cl)Cl, respectively). In order to clarify the relationship between the selected pesticides and protein and their involvement in signaling pathways, we represented data using InterPro database, GO enrichment and KEGG pathway enrichment analyses provided by STITCH.

3. Results and discussions

3.1-. RPW occurrence

Table 1 shows the classification of the palms according to the state (healthy / dead-infested) and the type of treatment (chemical treatment yes or no). Since at the beginning of the infestation (2007) more than half of the palms have died and of these, just over 60% after 2013.

From the second half of 2013, the Municipality has systematically treated (4 treatments per palm per year) by chemicals (Tab. 2), palms placed on the Sea-road, "Dei Mille" road, city centre and urban parks (1627 palms).

At the end of 2020, about 90% (89.73) of treated palms and about 35% (34.42) of untreated palms were not infested by the RPW. It should be noted that the latter percentage drops to 16.5% if untreated palms placed in nurseries, gardens of villas or hotels (places where there is interest and economic availability) are not included in the calculation.

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Table 1. Classification of palms by status and type of treatment

Category	Number
Total palms	7385
Healthy	3442
Dead-infested	3943 (on which 2456 from 2013)
Treated (from 2013)	1627
Healthy and treated	1460
Dead-infested and treated	167
No treated	5758
Healthy and no treated	1982 (on which 1032 in Nursery or Villas/Hotels)
Dead-infested and no treated	3776 (on which 272 in Nursery or Villas/Hotels)

Figure 2 shows how the evolutionary effects of the RPW distribution affected the entire study area.

Figure 2. Evolution of the red weevil distribution in the study area (period 2013 – 2020); all palms in yellows, healthy palms in green and dead-infested palms in red color.

Considering the dead-infested palms among the treated ones (Fig. 3) it is possible to notice a central area in which the concentration of the infested is higher compared to the remaining areas.

Here the direct management of the Municipality (application of the treatments by municipal employees) is interrupted and that entrusted to an external company begins; the interviews revealed that in this area there were often misunderstandings between the two parties which led to the skipping of treatments and therefore, the possibility of the RPW to attack.

Figure 3. Palms treated on the left (green dots) and palm trees dead-infested between those treated on the right (red dots). The central area with the greatest concentration of palm trees dead-infested between the treated ones (red arrow), corresponds with the contact area between the direct management of the municipality (municipal employees) to the north, and that entrusted to an external company, to the south.

The chemicals employed in this period are pesticides usually used in open field agriculture, whose ministerial authorizations for use in urban environments changed over the years (Tab. 2).

Table 2. Chemicals used in the study area against the RPW, in compliance with ministerial authorizations.

Chemicals	**Year**
Afidina quick (clorpirifos, deltamethrin)	2013 - 2014
Khoinor plus (imidacloprid, ciflutrin)	2015
Reldan (clorpirifos-metile)	2016 - 2019
Asset five (pyrethrins)	2020
Intercept granular (imidacloprid)	2013 - 2020

3.2-. Geo-statistical analysis

Comparing the hot spot map for treated palms with that of infested palms, it has been observed a very strong overlap (Fig. 4). This means that where the palms were treated, the healthy palms concentration is high. Only little red areas (little hot spot clusters) are placed outside the areas interested by Municipality's treatments (Fig. 4 dx).

By interpretation of aerial and terranean photos (Google Earth, Google Maps, Google Street) and field surveys we verified the nature of this little hot spot; they correspond to palm nurseries or villas/ farmhouses/hotels' gardens.

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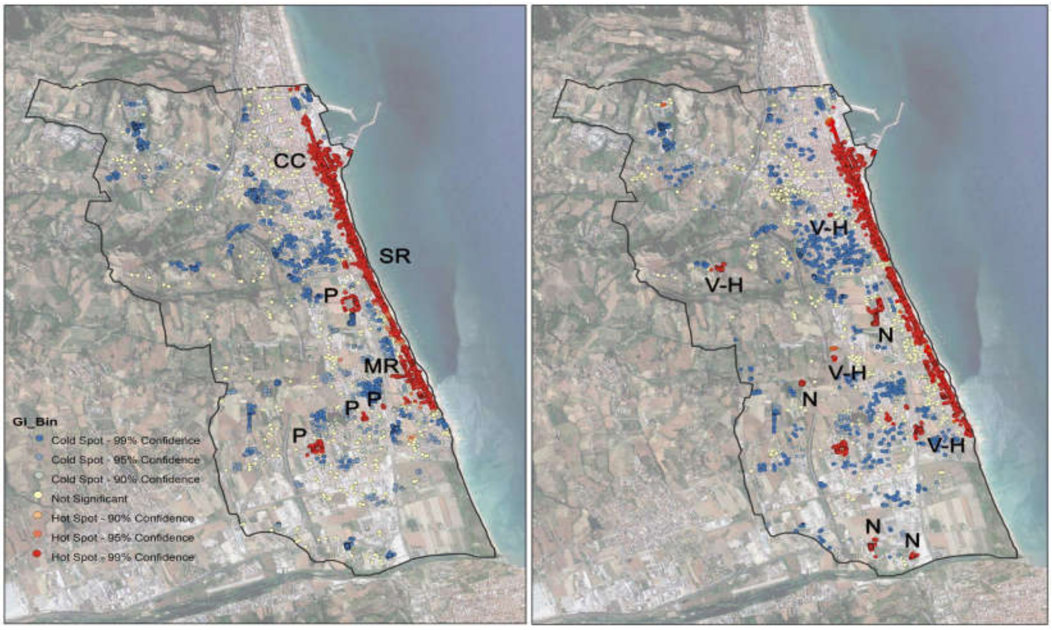

Figure 4. Hot spot analysis maps where in red colour cluster groups of palms; sx for chemically treated palms, dx for health palms. SR: sea-rod; CC: city centre; MR: "Dei Mille" road, P: urban parks N: nursery; V-H: Villas, Hotels or Farmhouses.

This fact is best appreciated in the overlap map between treated healthy palms and untreated healthy palms (Fig. 5). The overlapping degree index, generated based on the percentage of number of squares superimposed between the two derived hot spot maps (fishnet 20 x 20 mt), is equal to 84.92%. This percentage grows up to 95% not considering the squares relating to the nurseries and villas/hotels gardens.

Figure 5. Assessment of the degree of overlapping between "HSA health" vs "HSA treated" maps and analysis of anomalies. Green square: area with treated and healthy palm; Red square: area with healthy palm not treated by the Municipality. Square sampling 20 x 20 mt

Finally, to support these spatial results by a statistical test, the Chi square test was calculated based on the RPW occurrence on "Treated" and "No treated" category palms (starting values in Tab. 1). We perform two X2 tests, one considering all "No treated" palms and another one subtracting those placed in nurseries or hotels/villas/farmhouses' gardens. With 1 as the degree of freedom (contingency table 2 x 2), the resulting values were X2= 358.82 (p-value= 2.2-16) and X2= 441.84 (p-value= 2.2-16), respectively. Therefore, the null hypothesis of independence was rejected mining that the RPW occurrence depends on whether a given palm has been treated or not.

3.3-. Computational approach to predict Imidacloprid- and Chlorpyrifos -protein interaction networks

We built a chemical and biological interaction network to investigate the molecular pathways associated to the effects of IMI and CPF on five model organisms (i.e. Apis mellifera, Gallus gallus, Danio rerio, Xenopus silurana, Homo sapiens). Using a confidence score > 0.7 (high confidence score according to STITCH), we identified four main metabolic processes associated with proteins interacting with both chemicals (Table 3).

Table 3. List of the main representative interactive pathways with Imidacloprid and Chlorpyrifos after enrichment analysis using STITCH v5.0.

Pathway ID	Pathway description	#Protein	Matching proteins in the network
Apis mellifera			
IPR006201 IPR006202 IPR018000 IPR006029 AME04040	Neurotransmitter-gated ion-channel family	8	nAChRa2,nAChRa3,nAChRa4,nAChRa5, nAChRa6, nAChRa7,nAChRa8,nAChRb1
GO:0042135 GO:0001507	Neurotransmitter catabolic process	3	AChE-1, AChE-2, LOC410721
AME00001	Metabolism	2	GB18660-PA, LOC552229
Xenopus silurana			
PF02931 PF02932	Neurotransmitter-gated ion-channel family	8	Chrna3,chrnb4,ENSXETG00000018003, chrna2,chrna6,chrna7,chrnb2,ebn
GO:0006581	Neurotransmitter catabolic process	1	AChE
XTR00199 XTR00001	Metabolism	2	CYP1A1,chat
XTR04052	Signaling and cellular processes	2	fgf2,fgf13
Danio rerio			
PF02931 PF02932	Neurotransmitter-gated ion-channel family	11	Chrnab4,ENSDARG00000037427, ENSDARG00000058393, LOC568467, chrna2a,chrna2b,chrna4,chrna6,chrna7, chrnb2a,chrnb2b
GO:0042135	Neurotransmitter catabolic process	3	AChE,ENSDARG00000053709, ENSDARG00000058492
DRE00199 DRE00001	Metabolism	2	CYP1A1,chat
DRE04052 DRE03037	Signaling and cellular processes	3	fgf2,fgf13a,fgf13b,lyz
Gallus gallus			
PF02931 PF02932 GGA04040	Neurotransmitter-gated ion-channel family	8	Chrna6,chrna7,chrnb3,LOC396120, chrna3,chrna4,chrnb4,chrna2
GGA04147	Signaling and cellular processes	3	LYZ,fgf2,fgf13
GGA01000 GGA00199	Metabolism	3	BCHE, CYP1A4,chat
Homo sapiens			
GO:0005230	Neurotransmitter-gated ion-channel family	3	Chrna4,Chrna7,Chrfam7A
GO:0042136	Neurotransmitter catabolic process	1	AChE
GO.0017144 GO:0006805 GO:0006629 GO:0002682 GO:0044255 GO:1901575	Metabolism	11	BCHE,CYP1A1,CYP1A2,CYP2B6, CYP2C19,CYP2E1,CYP3A4,NR1I2,chat, CAT,PON1
GO:0032870 GO:0008286 GO:0009967 GO:0060397	Signaling and cellular processes	16	AKT2,CASP9,CASP3,ESR1,FGF2,FGF20, IL10,FGF13,TNF,MAPK1,MAPK3,NR1I2, PARP1,LYZ,ANXA5,IL1B

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GO:0060396
HSA04010
IPR008996

Data indicated that most of the identified proteins belong to the neurotransmitter-gated ion-channel family. The neurotransmitter-gated ion-channels constitute a very important group of transmembrane receptor-ion channel complexes in vertebrates and invertebrates. These receptors open transiently upon binding of specific ligands and govern synaptic neurotransmissions in the nervous system and neuromuscular transmissions (Smart and Paoletti 2012). Overall, our findings are not surprising since they exactly match the insecticidal mode of action of the neonicotinoids (Shimada et al., 2020). Indeed, nicotinic acetylcholine receptors (nAChRs) are the main targets of neonicotinoid insecticides, including IMI. Structural analyses of nAChR have recently increased revealing that the nitro group of IMI plays a pivotal role in the selective action of neonicotinoids with insect nAChR (Ihara et al., 2022). However, recent studies suggest possible adverse impacts of neonicotinoids on non-target organisms including mammals (Burke et al. 2018; Berheim et al. 2019). IMI was found to activate the nAChR signalling in neonatal rats (Kimura-Kuroda et al. 2012) and cultured human neurons at concentrations that can be potentially reached by dietary or accidental exposure (Loser et al. 2021a).

Along with the neurotransmitter-gated ion-channels, high confidence scores were found also for genes involved in neurotransmitter catabolic processes, particularly acetylcholinesterase (AChE). The inhibition of AChE is a well-known mechanism triggered by CPF and it is responsible for neurotoxic effects in insects. However, several studies suggest the potential of CPF in generating harmful effects also in non-target species. For example, exposure to CPF has been associated with neurodevelopmental disorders in rodents and humans (Berg et al. 2022; Slotkin and Seidler 2005). In amphibians, CPF was found to induce subletal toxicity and indirect effects by impacting their ecosystem (Beasley 2020). CPF is also known to have noncholinergic effects such as inhibition of the oxidative metabolism of sex steroids (Hodgson 2012). This is in line with our analysis that identified the cytochrome P450 (CYP) pathway as one of the key targets for CPF in each analyzed vertebrate model. Previous reports have shown that CPF induces reproductive disorders in mammals by affecting gametes (Nardi et al. 2011; Tanvir et al. 2016) probably through oxidative stress mechanisms (Abolaji et al. 2017). In the human model, we found that the cluster associated to metabolic pathways accounts for the largest number of CYPs and also includes genes encoding antioxidant enzymes such as CAT, enzymes involved in the choline pathway such as choline O-acetyltransferase (chat) and butyrylcholinesterase (BCHE), and esterase (PON1). Similarly, two esterase proteins were found involved in biological processes associated with IMI/CPF exposure in Apis millifera. In conclusion, this computational approach was conducted to gain insight into the consequences of prolonged exposure to both IMI and CPF widely used in the chemical control of Rhynchophorus ferrugineus. Our analysis demonstrates that both pesticides have a high toxic potential to all organisms for inducing neurotoxic effects and likely endocrine interference, especially in mammals (Figure 6).

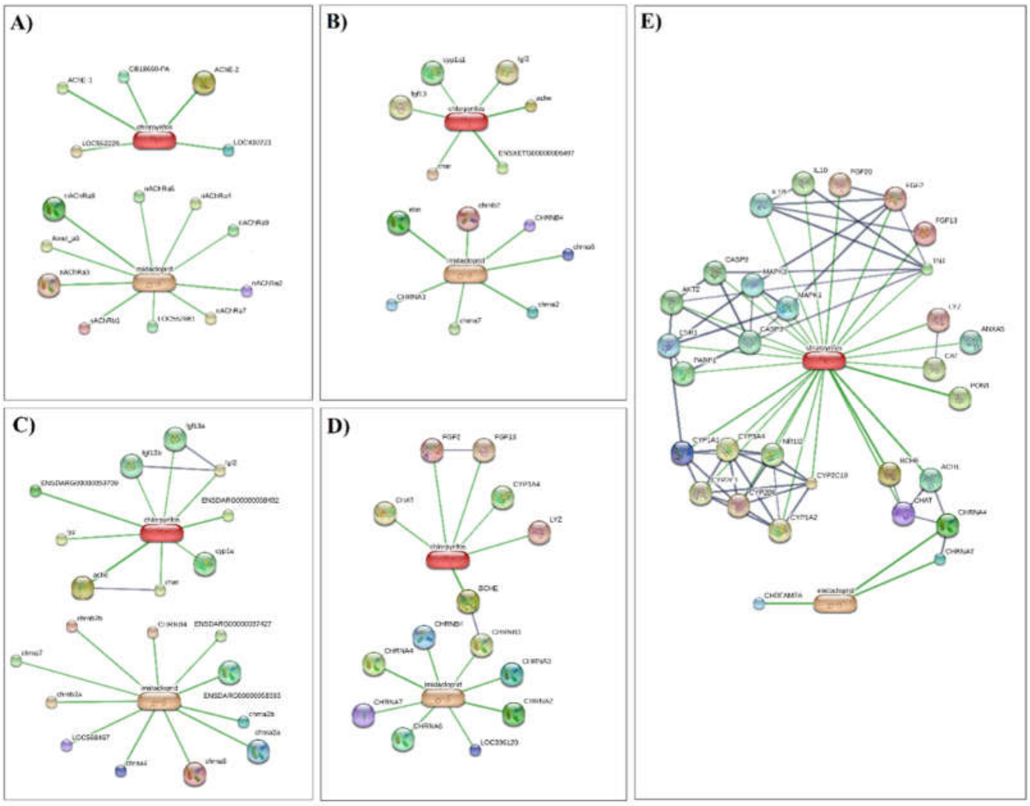

Figure 6. Interactions of Imidacloprid and Chlorpyrifos in A) Apis mellifera, B) Xenopus silurana, C) Danio rerio, D) Gallus gallus, E) Homo sapiens. Chemicals are represented as pill-shaped nodes, while proteins are shown as spheres. Nodes that are associated with each other are linked by an edge with a confidence score higher than 0.7. All connections with uncharacterized protein were removed to enhance visualization.

These effects are closely related to their bioaccumulation capacity that is evident for organochlorines, but it may also concern neonicotinoids. Indeed, IMI can persist for months in some soil conditions and may pose a risk to other organisms in the area. Thus, more research is needed for tracking these pesticides and their metabolites in the study area and for monitoring their long-term effects on non-target species, including humans.

4 - Conclusions

Our monitoring, carried out about 7 years from the previous one and about 13 years from the appearance of the RPW in this area, showed how this beetle has heavily influenced the palm tree heritage in the study area, reducing it by more than half.

In recent years, the Municipality, in concert with the Phytosanitary Service of the Marche Region, has actively worked to cope with the advance of this plague, initially implementing large-scale Integrated Pest Management and localised preventive treatments, later on.

Our data show that the fight against the weevil is now concentrated in the areas of municipal relevance (front sea road, parks) and at villas, hotels, farmhouses and nurseries; in the rest of the territory, the large number of died-infested palm trees observed in recent years, clearly highlights the failure of the large-scale Integrated Pest Management with respect to a punctual approach (street, park).

In this perspective, Milosavljević et al. (2019) proposed the inappropriate management planning, poor coordination between stakeholders, and public resistance to implementation of controls, as potential causes of this failure and we substantially agree on this.

The geospatial analysis approach used in this work demonstrates that preventive treatments, if well implemented, are very effective in preserving the palms from the RPW attack. This success,

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however, must deal with the problems related to the use of chemicals, as well as with the economic impact related to their massive usage. Indeed, the systems toxicology approach used herein, highlights potential hazards to non-target species due to repeated applications and long-term insecticide exposure.

We conclude that the multidisciplinary approach adopted in the present study has proved to be very useful to evaluate the many aspects related to the fight against RPW in an urban environment.

In accordance with Sawyer & Casagrande (1983), we believe that the long-term objective should be to elaborate new designs for urban environments that will minimize the negative interactions between people and pests, limiting the use of pesticides in urban areas. In this regard, it would be advisable to promote a diversified and therefore more resilient urban vegetal landscape, with quite many different plant species, as this composition would more successfully weather new possible alien pest invasions.

Author Contributions: Luca Bracchetti: Investigation, Methodology, Data curation, Writing- Original draft, Writing- Reviewing and Editing; Conceptualization. Paolo Cocci: Methodology, investigation, Writing- Original draft. Francesco Alessandro Palermo: Conceptualization, Supervision, Writing - original draft, Writing-Reviewing and Editing.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due they are partly owned by local governments.

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Conflicts of Interest: The authors declare no conflict of interest.

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