UDK 632.913.1

PRACTICAL METHODOLOGY OF ASSESSING PROBABILITY OF ESTABLISHMENT OF ADVENTIVE PLANT PESTS

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Received on December 08, 2015

Aim. To develop practical methodology of assessing the probability of establishment of adventive pests outside of their native range of distribution, using specialized software. **Methods**. International standards for pest risk analysis ISPM No. 2, ISPM No. 11, ISPM No. 21, PM 5/1(1), PM 5/2(2), PM 5/3(5), PM 5/5(1) and Agro Atlas (Afonin *et al.*, 2008), MapInfo v.11.0 (Pitney Bowes) and Idrisi Taiga (Clarklabs) software. **Results.** The presence of host-plant species range and the correspondence of ecoclimatic conditions of Ukraine (as a pest risk analysis area) to the climate indices of the current area of distribution of such pests as *Oemona hirta* (lemon tree borer) and *Thaumatotibia leucotreta* (false codling moth) were studied using specified software. The potential areas of establishment of these pests in Ukraine were defined. **Conclusions**. The efficiency and convenience of me-thods of assessing the risk of establishment of adventive plant pests using Agro Atlas, MapInfo v.11.0 and Idrisi Taiga software, were proven. It was determined that a potential area of establishment of *O. hirta* is the sou-thern part of Odessa region, an inconsiderable part of south-west of Mykolayiv region, south-western territory of Kherson region and almost the entire territory of the Crimean Peninsula. A potential area of establishment of *T. leucotreta* is an inconsiderable territory of the Black Sea coast − Tarkhankut Peninsula and Kerch Peninsula in the Crimea.

Keywords: practical methodology, pest risk analysis, establishment, *Oemona hirta*, *Thaumatotibia leucotreta*.
DOI: 10.15407/agrisp3.01.036

INTRODUCTION

It is commonly known that the main aim of plant quarantine is protection of state plant resources from introduction, spread and damage of quarantine pests, the list of which is formed on the basis of pest risk analysis (PRA). The aim of PRA is not just to define the status of the analyzed pests for a certain area (which allows characterizing them as regulated quarantine, regulated non-quarantine or non-regulated pests), but also to select proper phytosanitary measures to prevent the introductin of these pests into new territories or to localize and eradicate existing outbreaks.

It is rather time and effort consuming to conduct full-scale PRA, the algorithm and methodology of which is stipulated in full detail in international [1, 2] and regional standards [3] and national guidances [4]. PRA is conditionally divided into four stages: initiation, pest risk assessment, pest risk management and official registration of PRA process in a protocol format. Here the second stage is the most critical, as it is aimed at assessing the probability of introduction and establishment of adventives species in new territories, free from the latter, which is primarily conditioned by the presence of host plants and the suitability of ecoclimatic conditions [5–7].

There are different approaches to solve this task, in particular, there are suggestions of defining the area of potential establishmet of adventive pests using the statistical data of FAOSTAT, EUROSTAT, JRC or SEAMLESS regarding the availability of host plant, and their distribution in the PRA area [8–11]. Instead, it is recommended to assess the climatic suitability in the PRA area via the degree of its correspondence to ecoclimatic conditions in the area of current distribution of the pest analyzed – by the sum of effective temperatures, precipitation, hydrothermal coefficient, *etc*. Complex models [12, 13] and software were designed to solve the mentioned tasks, for instance, CAPRA program [8, 14] or CLIMEX program [15].

The application of the listed instruments envisages processing of a considerable amount of disaggregated data and obtaining the final assessment only at the end of a multi-stage algorithm. But it is also possible to assess the probability of establishment of adventive pests in a new territory via more convenient and accelerated procedure, using other software – Agro Atlas [16], MapInfo v.11.0 [17] and Idrisi Taiga [18] which combines geoinformational technologies and the biogeographical data and allows conducting ecological and geographical analysis and simulating potential spatial distribution of an organism using precise determination of a current area of the species and agroclimatic conditions of its establishment. This was set as the aim of our studies.

MATERIALS AND METHODS

The availability of economically relevant agricultural crops, grown in Ukraine, which are host plants for adventive plant pests, was determined using Agro Atlas software, which allows determining spatial location of over 500 cultivated plant species, their wild relatives and weeds [14].

Such software as MapInfo v.11.0, Agro Atlas and Idrisi Taiga [16–18] which allow designing compositions of scan-line and vector layers using computer-aided procedures, was applied to determine:

environmental factors in the area of current pest distribution, which limit the spread of the species;

quantitative ecological amplitude of the species regarding each limiting factor, comparing similar indices from the area of the adventive species and ecological maps by the methods of overlapping layers-maps and data extraction;

ecologically suitable territories on the map of Ukraine for the distribution of the species in terms of each limiting factor (reclassification);

potential area of establishment of the adventive species in the PRA area (Ukraine), favourable for its existence, via the combination of ecologically suitable territories into a unified map.

RESULTS AND DISCUSSION

The harmonization of phytosanitary legislation of Ukraine with EU requirements envisages the practical introduction of periodic reviews of the lists of regulated pests, including the ones due to the introduction of changes to the corresponding lists of the European and Mediterranean Plant Protection Organization (EPPO) – List A1 (the list of pests recommended for regulation, absent in the EPPO member countries) and List A2 (the list of pests recommended for regulation, present but not widely distributed in the EPPO–region, and which are officially controlled).

Although this norm was reflected in the Law of Ukraine "On Plant Quarantine", the latest review of the list of regulated pests of Ukraine was in 2010, whereas EU lists have been edited dozens of times during 2010–2016. In particular, such changes were noted for the status of fruit crop pests: lemon tree borer *Oemona hirta* (*Coleoptera:Cerambycida*) and false codling moth *Thaumatotibia leucotreta* (*Lepidoptera:Tortricidae*), which were transferred from the EPPO Alert list to A1 and A2 Lists, respectively, after the pest risk analysis conducted for EPPO countries.

As fruit production is one of the relevant branches of Ukrainian agriculture, there is a need for pest risk analysis and for the determination of the status of these pests in the territory of this country. The possibility of assessing the probability of establishment of adventive species in a new territory was elaborated in the framework of the analysis, using software – Agro Atlas, MapInfo v.11.0 and Idrisi Taiga.

O. hirta – lemon tree borer, is a pest of citrus fruit trees, wide-spread in New Zealand [19, 20]. In 1983 and 2010 it was intercepted in plants for planting of *Wisteria*, imported to Great Britain from New Zealand. In 2010, this species was included in the EPPO Alert list on the initiative of Great Britain, and in 2013 it was transferred to List A1 (the list of pests recommended for regulation, absent in the EPPO region) according to PRA results. Express-PRA, performed by the experts of the UK National Plant Protection Organization, and a subsequent full-scale PRA conducted by EPPO ex-

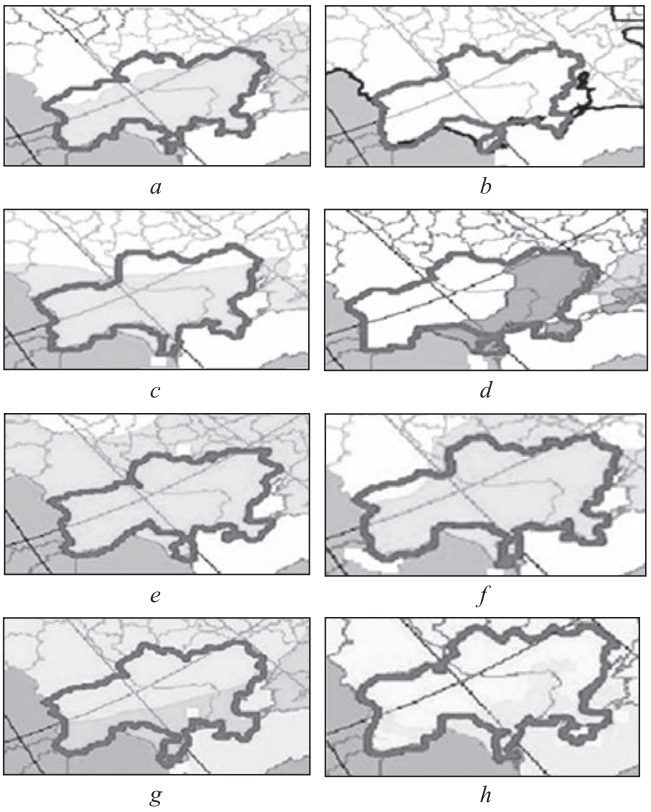

Fig. 1. The main economically important agricultural crops of Ukraine, susceptible to be infested by *Oemona hirta*: *a* – apricot; *b* – cherry; *c* – sweet cherry; *d* – peach; *e* – apple-tree; *f* – plum-tree; *g* − pear-tree; *h* − grapes

perts demonstrated that this pest poses a threat for the EPPO region.

The main host plants for this pest are citrus fruit trees (lemon, tangerine and grapefruit). In addition, it may infest about 200 species of plants from 81 families. Most infested plants are trees and shrubs, but the host list also includes vines and lianas as well as tall-growing perennial grasses with a tall stalk and a considerable number of ornamental plants. In New Zealand *O. hirta* is mainly viewed as a pest of citrus fruit trees. However, considerable damage to apple-tree gardens, vineyards and persimmon was registered in the 90s of the last century.

In general, this pest may infest over 40 species of fruit plants, including apple-tree, pear-tree, cherry-tree, plum-tree, peach-tree, grapes, walnut tree, persimmon, almond-tree, blueberry as well as many foresters and ornamental species of trees (poplar, birch, acacia, alder, elm, chestnut, pine, eucalyptus, wisteria, hibiscus, genista, hawthorn, spindle, lilac, rose). Many of these plants are grown in Ukraine (Table 1).

Spatial location of the majority of these plants in Ukraine may be determined using Agro Atlas software (Fig. 1).

Therefore, it was determined that the host-plant range on the whole territory of Ukraine may provide sufficient resources for the development of *O. hirta.*

While determining the possibility of establishment of this pest in Ukraine using MapInfo and Idrisi Taiga software, the following climatic factors, which may limit the pest development, were defined: the indices of average annual air temperature, average temperature of the warmest month (June) and the sum of active temperatures exceeding 10 °C. The results of determining Ukrainian territories, ecologically suitable for the development of *O. hirta* regarding each limiting factor are presented in Fig. 2.

It was determined that some climatic indices of the Ukrainian territory are partially satisfactory for the de-

Table 1. Plants, which are endangered by lemon tree borer invasion in Ukraine

Fruit trees	Shrubs	Species of ornamental and forest trees
Apple (*Malus*)	Grapes (*Vitis vinifera*)	Poplar (*Populus*)
Pear (*Pyrus*)	Hawthorn (*Crataegus*)	Acacia (*Acacia*)
Cherry (*Prunus cerasus*)	Spindle (*Euonymus*)	Alder (*Alnus*)
Plum (*Prunus domestica*)	Lilac (*Syringa vulgaris*)	Pine (*Pinus*)
Peach (*Prunus persica*)	Rose (*Rosa*)	Chestnut (*Castanea*)
Nectarine (*Prunus persica* var. *nucipersica*)	Wisteria (*Wisteria*)	Birch (*Betula*)
Walnut (*Juglans*)	Hibiscus (*Hibiscus*)	Elm (*Ulmus*)
Almond (*Prunus dulcis*)	Blueberry (*Vaccinium*)	Sycamore (*Platanus*)
Apricot (*Prunus armeniaca*)	Gooseberry (*Ribes uva crispa*)	Oak (*Quercus*)

velopment *of O. hirta* in different regions. However, judging by the combination of climatic factors the general area of establishment is considerably smaller and covers only the southern part of Odessa region, an inconsiderable part of south-western Mykolayiv region, the south-western territory of Kherson region and almost the entire territory of the Crimean Peninsula.

T. leucotreta (*Lepidoptera:Tortricidae*) – false codling moth, is a pest of fruit and field crops. The current area of its distribution covers a considerable part of the African continent [21]. In 1984, this pest was first found outside its area, in the planting of macadamia nuts in Israel, and in 2003 – on cotton and castor plant. In 2009, the pest was registered in a greenhouse in the Netherlands, and later – in Great Britain and Sweden. From 2001 to 2010 there were over 50 cases of interception of the pest in citrus fruits, imported from South Africa to EPPO countries [22]. As to EPPO region, this pest has been found at present on inconsiderable local territories, where cotton and castor plants are grown in Israel.

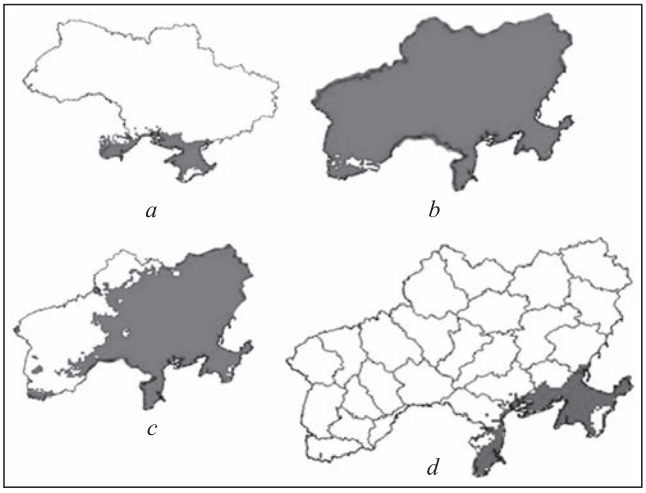

Fig. 2. Ecologically suitable territories for the development of *Oemona hirta* in Ukraine according to the indices of average annual air temperature (*a*); average temperature of the warmest month − June (*b*); the sum of active temperatures exceeding 10 °C (*c*); potential area of pest establishment in Ukraine (*d*)

Table 2. Agricultural crops in Ukraine endangered by false codling moth

Host plants of the pest	English name	Family	Crops grown in Ukraine
Capsicum spp.	Pepper	*Solanaceae*	Pepper
Citrus reticulata & hybrids	Mandarin orange	*Rutaceae*	
Citrus sinensis & hybrids	Orange	*Rutaceae*	
Citrus paradisi	Grapefruit	*Rutaceae*	
Gossypium spp.	Cotto	*Malvaceae*	Cotton
Litchi chinensis	Litchi, Litchee	*Sapindaceae*	
Macadamia spp.	Macadamia	*Proteaceae*	
Mangifera indica	Mango	*Anacardiaceae*	
Prunus persica	Peach	*Rosaceae*	Peach
Prunus persica var. *nucipersica*	Nectarine	*Rosaceae*	Nectarine
Persea americana	Avocado	*Lauraceae*	
Phaseolus vulgaris	Beans	*Fabaceae*	Kidney beans
Prunus armeniaca	Apricot	*Rosaceae*	Apricot
Prunus domestica	Plum	*Rosaceae*	Plum
Prunus cerasus	Cherry	*Rosaceae*	Cherry
Psidium guajava	Guava	*Myrtaceae*	
Punica granatum	Pomegranate	*Lythraceae*	
Quercus robur	Oak	*Fagaceae*	Oak
Ricinus communis	Castor oil plant	*Euphorbiaceae*	Castor plant
Rosa sp.	Rose	*Rosaceae*	Wild rose
Sorghum sp.	Sorghum	*Poaceae*	Sorghum
Solanum melongena	Eggplant	*Solanaceae*	Eggplant
Solanum lycopersicum	Tomato	*Solanaceae*	Tomato
Vitis vinifera	Grape	*Vitaceae*	Grape vine
Zea mays	Maize	*Poaceae*	Corn

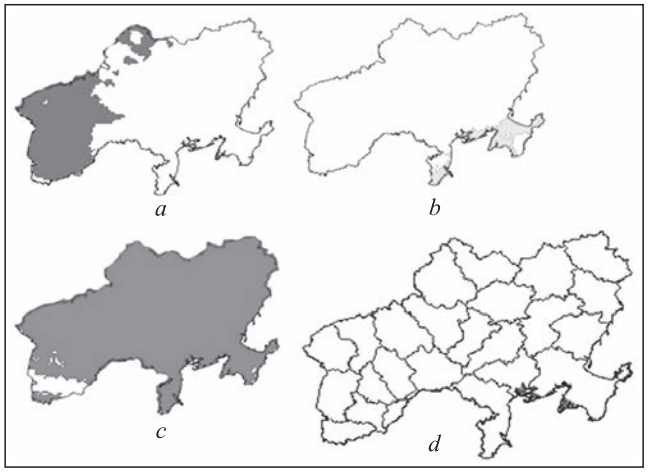

Fig. 3. Ecologically suitable territory of Ukraine considering different factors limiting the development of *Thaumatotibia leucotreta*: in terms of air humidity (*a*); the sum of active temperatures over 10 °C (*b*); the average multiannual minimal temperature in July (*c*); *d* − potential area of pest establishment in Ukraine

It is believed that the distribution of this pest outside of Africa is limited. However, the intensification of international trade and tourism increases the risk of the pest entry to other countries and the probability of its subsequent establishment in the new area, if conditions are favourable. Since 1984, false codling moth was found in 34 ports on 99 species of plants over 1,500 times in the USA. In July 2005, living caterpillars of this pest were found in the consignment of the citrus fruits from South Africa, which went through a preliminary cold treatment. According to the records of the National Phytosanitary Service of the Netherlands, *T. leucotreta* was detected four times on the cut flowers of roses, imported from Ethiopia, Tanzania and Uganda. Based on this statistics of interception, in 2011 EPPO experts took a decision to include this pest in the EPPO Alert list, and in 2013 it was moved to the A2 List after the PRA procedure.

False codling moth invades a wide range of agricultural and decorative crops many of which are grown in Ukraine (Table 2). Spatial distribution of the majority of these plants in Ukraine may be determined using Agro Atlas software (see Fig. 1).

The ecological correspondence of the territory for the development of this species according to a number of indices of climatic conditions in the area of the pest and the potential area of establishment were determined using MapInfo v.11,0, AgroAtlas and Idrisi Taiga software, and presented in Fig. 3.

The studies demonstrated that the potential area of T. leucotreta in Ukraine may include inconsiderable territories of the Black Sea coast, Tarkhankut Peninsula and Kerch Peninsula in the Crimea, the conditions of which are suitable for the development of false codling moth only during summer months.

CONCLUSIONS

The application of MapInfo v.11.0, AgroAtlas and Idrisi Taiga software is efficient to determine the probability of establishment of adventive plant pests in new, pest-free territories, and to define the borders of their potential area of distribution, which allows recommending this software for pest risk assessment, especially when the quick procedure is required.

It was determined that a potential area of establishment of *O. hirta* in Ukraine is the southern part of Odessa region, an inconsiderable part of south-western Mykolayiv region, south-western territory of Kherson region and almost the entire territory of the Crimean Peninsula. A potential area for *T. leucotreta* in Ukraine is an inconsiderable territory of the Black Sea coast, Tarkhankut Peninsula and Kerch Peninsula in the Crimea.

Практична методологія аналізу ймовірності акліматизації адвентивних фітофагів

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Мета. Розробити практичну методологію оцінки ймовірності акліматизації адвентивних шкідливих організмів в Україні (за межами їхніх існуючих ареалів) за використання спеціалізованих комп'ютерних програм. **Методи.** Міжнародні стандарти з аналізу фітосанітарного ризику ISPM № 2, ISPM № 11, ISPM № 21, PM 5/1(1), PM 5/2(2), PM 5/3(5), PM 5/5(1) і програмне комп'ютерне забезпечення Agro Atlas (Afonin et al., 2008), MapInfo v.11.0 (Pitney Bowes) та Idrisi Taiga (Clarklabs). **Результати.** Досліджено наявну кормову ба-

зу (рослини-господарі) і відповідність екокліматичних умов України (як регіону проведення аналізу фітосанітарного ризику) показникам сучасного ареалу шкідників *Oemona hirta* (лимонний вусач) і *Thaumatotibia leucotreta* (несправжня яблунева міль) та визначено потенційні зони їхньої акліматизації в Україні. **Висновки.** Доведено ефективність і зручність методів аналізу ризику акліматизації в Україні адвентивних шкідливих фітофагів із застосуванням комп'ютерних програм Agro Atlas, MapInfo v.11.0 та Idrisi Taiga. Встановлено, що потенційною зоною акліматизації *O. hirta* в Україні є південна частина Одеської області, незначна частина південного заходу Миколаївської області, південно-західна територія Херсонської області та майже вся територія Кримського півострова. Потенційним ареалом *T. leucotreta* в Україні є незначні території узбережжя Чорного моря − півостровів Тарханкут та Керченський в Криму.

Ключові слова: практична методологія, аналіз фітосанітарного ризику, акліматизація, *Oemona hirta*, *Thaumatotibia leucotreta*.

Практическая методология анализа вероятности акклиматизации адвентивных фитофагов

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Цель. Разработать практическую методологию оценки вероятности акклиматизации адвентивных вредных организмов в Украине (за пределами их существующих ареалов) при использовании специализированных компьютерных программ. **Методы.** Международные стандарты по проведению анализа фитосанитарного риска ISPM № 2, ISPM № 11 ISPM № 21 PM 5/1(1), PM 5/2(2), PM 5/3(5), PM 5/5(1) и программное компьютерное обеспечение Agro Atlas (Afonin et al., 2008), MapInfo v.11.0 (Pitney Bowes) и Idrisi Taiga (Clarklabs). **Результаты.** Исследована имеющаяся кормовая база (растения-хозяева) и соответствие экоклиматических условий Украины (как зоны анализа фитосанитарного риска) показателям современного ареала на примере вредителей *Oemona hirta* (лимонного усача) и *Thaumatotibia leucotreta* (ложной яблоневой моли) и определены потенциальные зоны их акклиматизации в Украине. **Выводы.** Доказаны эффективность и удобство методов оценки риска акклиматизации в Украине адвентивных вредных фитофагов с применением компьютерных программ Agro Atlas, MapInfo v.11.0 и Idrisi Taiga. Установлено, что потенциальной зоной акклиматизации *O. hirta* является южная часть Одесской области, незначительная часть юго-запада Николаевской области, юго-западная территория Херсонской области и почти вся территория Крымского полуострова. Потенциальным ареалом для *T. leucotreta* служат незначительные территории побережья Черного моря − полуостровов Тарханкут и Керченский в Крыму.

Ключевые слова: практическая методология, анализ фитосанитарного риска, акклиматизация, *Oemona hirta*, *Thaumatotibia leucotreta*.

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