Invasive insect potato tuber moth *Phthorimaea operculella*: stages of distribution in Russia and prognosis

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Abstract. This work summarizes all known data on the distributive history of *Phthorimaea operculella* in Europe, Asia and Russia with special reference to the current process of invasion to different regions of Russia and prognosis on its future spread through Russian territories. The invasion of the pest started in Russia in 1980. During last ten years from 2010 to 2020, *Phthorimaea operculella* occupied 5 new Regions of Russia. The threat of naturalization of the pest is high because the potato tuber moth has a high reproductive potential and cases of multiple introductions to various territories of Russia as well as registrations of the pest in places of vegetable storage are known. The modern map of the distribution of *Phthorimaea operculella* in Russia and selected foreign countries is composed.

1. Introduction

*Phthorimaea operculella* (Zeller, 1873) or a potato tuber moth is a moth of the family Gelechiidae (Insecta, Lepidoptera) – serious pest, which infests potatoes, tobacco and other nightshade plants mainly in the southern regions of potato cultivation zone and in places of its storage (Fig. 1). The potato tuber moth is native to South America (the Andes).

In our days the moth has colonized all the continents except Antarctica. In South America, the moth occurs in Peru, Bolivia and Brazil [1]. In North America, the moth is found in Oregon and California (USA) [2]. In Europe, the potato tuber moth was introduced in Austria, Bulgaria, Great Britain, Germany, Netherlands, Mediterranean countries and Ukraine. In Africa, it occupies Algeria, Egypt, Kenya, Libya, Morocco, Sudan, Tunisia, Eritrea, Ethiopia, etc. In Asia, it is found in Azerbaijan, Georgia, Israel, India, Iran, Syria, Turkey, Uzbekistan and Japan. In Australia and New Zealand, the moth lives in habitats where the average annual temperature does not drop below 10°C. In Russia, the pest has spread in Adyghea, Bashkortostan, Crimea and Karachay-Cherkessia Republics, Volgograd, Astrakhan and Rostov Regions, Krasnodar, Stavropol and Primorsky Krai [3–6].

According to Maslyakov, Izhevsky [7] the northern border of the potential range of the potato tuber moth in Russia runs along the line: Astrakhan— the central part of the Tsimlyansk Reservoir — the city of Kamenetz —Shakhtinsky (Rostov Region). The authors predicted that the expansion of the current range is possible to the north towards Bataisk, Taganrog and Novocherkassk, to the east towards Stavropol along the Kuban River Basin, to the southeast towards Dagestan and the coast of the Caspian Sea.
This work summarizes all known data on the distribution of the pest in Europe, Asia and in Russia to demonstrate the current process of invasion to different regions of Russia and make prognosis on its future spread on Russian territories.

2. Materials and methods
Data on the distribution of *Phthorimaea operculella* in Europe were obtained by analyzing publications on the distribution of the insects and various aspects of its economic significance. The main sources of information were publications on damage and distribution of the pest. Although these data are present in CABI and EPPO databases [8, 9], they cannot be considered complete because the data on the detailed distribution of *Phthorimaea operculella* in Russia are absent in this source.

3. Pathways and history of the invasion
In South and Central America, the potato tuber moth damaged tobacco and potatoes from the times of ancient Indian civilizations. The moth started to spread around the world only at the beginning of the XIX century. It was introduced in California (USA) in 1856; the pest caused serious damage in Oregon in 2002. Soon after that, the moth conquered the countries of southern Europe, then it colonized the south of Russia and Africa. Today the potato tuber moth is recognized as the main pest in New Zealand and Australia. It is a cosmopolitan species which has already spread throughout all the continents [8].

The history of invasion of the pest is not quite clear (Fig. 2). The earliest data of penetration in Europe in mentioned as 1906 year in Italy. However the species is reported in Spain (1926) and some other countries significantly later: France (1933), Bulgaria (1950), Romania (1958), Sardinia (1961), Sicily (1961), Netherlands (1968), Albania (1968). Approximately at the same time the invader was registered in China (1937), Georgia (1938), Japan (1957), Jordan (1965) and Iraq (1970). In 1980-1990s the habitat of *Phtorimaea operculella* in Europe and Asia was expanded, the main stages of invasion are known as Ukraine (1980), Turkey (1987), Portugal (1978), Great Britain (1983), Greece (1992), Iran (1992), Cyprus (1993), Malta (1994), Serbia (1994), Denmark (1994), Israel (1995), Austria (1995), Island (1996), Croatia (1996), Azerbaijan (2003), Uzbekistan(2009), Turkmenistan (2009), Slovenia (2010), Macedonia (2015), Moldova (2017), Hungary (2017) [9, 10, 11].

However, by now, in Bulgaria, Denmark, Great Britain, Netherlands and some other countries the potato tubermoth has been localized, intercepted or exterminated [12].
The invasive species appeared in Crimea in 1980, in the Krasnodar Region in 1981, in Adyghea after 1996, in the Rostov Region in 2002, and in the Stavropol Region in 2006. Currently, it is recorded in the Astrakhan, Rostov, Stavropol and Volgograd Regions and the Republics of Crimea, Adyghea, Bashkortostan and Karachay-Cherkessia. Multiple introductions of the pest to the Primorye Territory were noted since 1999, but till 2008 it was mainly found in vegetable stores [6]. According to unconfirmed data the pest may be introduced in Saratov Region and Kalmykia Republic.

**Figure 2.** Distribution of *Phthorimaea operculella* in Eurasia in the XX-XXI centuries

4. **Biology**

The potato tuber moth has a high reproductive potential. One female lays to 290 eggs on leaves or exposed parts of tubers. Caterpillars hatch in 3-15 days depending on temperature. They penetrate inside leaf or young shoot forming a blotch. Grown caterpillar of the second age penetrates into a tuber making long curved gallery inside it. In vegetable stores it immediately begins to feed on tubers. Taking into account the duration of different stages of development the minimal duration of the life cycle (3 days of egg+13 days for caterpillar+ pupal period 6 days) is 23 days. Adult moths live about 10 days. The tuber moth breeds continuously in those regions where temperature and other conditions permit.

Up to 13 generations a year are known for India [8]. However the pest is sensitive to temperature and eggs fail to hatch if low temperature (1-4°C) durates for 4 months and more. This fact helps to save the stored tubers under strict observance of the temperature conditions in the vegetable store. The temperature range of 15-40 degrees is the most favorable for the development cycle of the species and at 28°C the reproductive potential is the highest. The flight ability is low. Adults fly chiefly by night and are attracted to light. Caterpillars and pupae are located in the surface layers [13] of the ground and often freeze to death. The potato tuber moth is successful as an invasive species due to continuous year-round development in storages and possibility to disperse with infested potato tubers. It easily naturalizes in new habitats in case of warming.
5. **Impact on other species, ecosystems and humans**

Besides potatoes, the moth infests tobacco, tomatoes, eggplants, peppers and wild nightshade plants including thorn apples, henbane, nightshade, tomatillo, apple-of-Peru and belladonna. The pest damages of potatoes planted in spring attain 40-50%; those planted in summer reach 60-75%. Damages of tubers located closer to the surface achieve 90%. One tuber can be infested by up to 10 caterpillars. As a result, the moth significantly reduces the potato harvest. Its populations can sustainably breed only in habitats where the average annual temperature does not fall below 10°C. In this case, the moth can become a real scourge of farmers. In the Krasnodar Region, it produces in 3-4 generations in the fields but in the vegetable storehouse it can breed permanently. In tropical countries, the number of generations can reach 11-13 a year. In vegetable storehouses, if temperature regime is disturbed, it can destroy up to 80% of potato tubers [7, 14].

6. **Control**

In Russia, about 20 insecticides (Arrivo, Shar-Pei, Decis Pro, Bi58 New, Rogor, Inta-Vir, etc.) are applied against the potato tuber moths. In addition, insecticides used against the Colorado potato beetle also reduce the number of the potato tuber moth. Potatoes, especially seed tubers, must be processed with lepidocide including bacterial spores and protein crystals (delta-endotoxin) of *Bacillus thuringiensis* var. *kurstaki* for further storage. The tubers are usually treated with 1% suspension of this insecticide until completely wetted, then they are dried in the shade and stored in storehouse. Regular sorting and culling of damaged tubers can considerably reduce the effects of the pest. Tubers must be kept at a temperature below 10°C but optimal temperature range for potato storage is 3-5°C. In the farms with a high level agriculture technology, the potato tuber moth does not cause any yield loss either in the fields or during storage. It is possible to apply disinfection of tubers with Methyl Bromide fumigant. For industrial disinfection of the potato tubers, phosphine agents could be used at a rate of 3.6 g/m³ if the insecticide is accepted for potato use [15]. The potato tuber moth can be caught with pheromone traps [3].

7. **Conclusion**

The potato tuber moth belongs to the heat-loving species, which limits its distribution in the northern direction. In the warm season, in new regions, the moth can develop in several generations in the fields under favorable conditions, but later it dies during the wintering stage. Multiple cases of introduction of the pest with products, the ability to maintain foci of continuous reproduction in storage facilities in case of violation of the temperature regime, high reproductive potential, do not allow to reduce the intensity of control of this invasive species. In the case of global warming, the pest's range may expand in a northerly direction.

**Acknowledgements**

This study was supported by the Russian Science Foundation (project no. 21-14-00123).

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