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UTILIZAREA PREDICTORILOR BIOCLIMATICI PENTRU ESTIMAREA DISTRIBUȚIEI SPAȚIALE A SPECIILOR INVAZIVE PENTRU REPUBLICA MOLDOVA

Olga CRIVOVA, State University of Moldova, Institute of Ecology and Geography,
ORCID: 0000-0003-3061-7100, olga.crivova@sti.usm.md

Rezumat: *Buburuză asiatică (Harmonia axyridis Pallas, 1773) este o specie de origine asiatică, a fost utilizată ca agent de control biologic împotriva afidelor din întreaga lume. O serie de autori indică faptul că din 2008, buburuză asiatică a fost găsită în țările vecine Republicii Moldova - Ucraina și România. În republică însăși, a fost documentată în 2011-2012. Bazând pe datele multianuale a indicilor bioclimatici si baza de date online cabi.org a speciilor invazive, s-a analizat condițiile climatice favorabile si de limita pentru Harmonia axyridis. A fost efectuată analiza temporală a numărului de luni consecutive cu precipitații <40 mm, fiind factorul limitativ pentru distribuția Harmonia axyridis. A fost elaborat sistemul de notare pentru estimarea acestui factor limitativ și harta distribuției spațiale potențiale.*

Cuvinte-cheie: *Harmonia axyridis, speciile invazive, predicători bioclimatici, modele regresionale, factori limitative*

BIOCLIMATIC FACTORS FOR ESTIMATION OF SPATIAL DISTRIBUTION OF INVASIVE SPECIES ON REPUBLIC OF MOLDOVA-S TERRITORY

Abstract: *Asian ladybug (Harmonia axyridis Pallas, 1773) is a species of Asian origin, has been used as a biological control agent against aphids around the world. A number of authors indicate that since 2008, Asian ladybug has been found in the neighboring countries of the Republic of Moldova - Ukraine and Romania. In the republic itself, it was identified in 2011-2012. Based on the multiannual data of the bioclimatic indices and the online database cabi.org of the invasive species, the favorable and limiting climatic conditions for Harmonia axyridis were analyzed. The temporal analysis of the number of consecutive months with precipitation <40 mm was performed, being the limiting factor for the distribution of Harmonia axyridis. The scoring system was developed to estimate this limiting factor and map the potential distribution.*

Keywords: *Harmonia axyridis, invasive species, bioclimatic indexes, regression models, limiting factors*

INTRODUCERE

The Asian ladybug, or harlequin ladybug (Harmonia axyridis) is an invasive species that is considered an effective colonizer and a strong competitor for local species of ladybirds, since it occupies a wide trophic niche, has a high level of phenotypic plasticity in several of its vital characteristics, and to in addition, it is a voracious predator and has a significant dispersal ability, which allows it to migrate long distances to wintering grounds [1, p. 70, 71, 75]. It originally inhabited the continental temperate and subtropical regions of central and eastern Asia. [6]. While it was introduced to North America by accident [8, p 121], in Europe in the 90s of the last century it was actively advertised as a commercial product for aphid control in augmentative biological control programs indoors [15, p. 104].

The same author gives a map of the introduction of the Asian ladybug in Europe and North Africa, in which we see that there were two points in the immediate vicinity of the border of the territory of the Republic of Moldova - one in the southwestern, the other in the southeastern part of Ukraine. Perhaps this was the reason that already in 2009 the feral aggregation of the Asian ladybug was discovered in the neighboring countries of the Republic of Moldova - Ukraine [10, p. 24] and Romania [16, p. 155; 17, p.421]. In the Republic of Moldova itself, it was first discovered and documented in 2011-2012 [2, p. 40; 7, p. 136-137], including in peach orchards and vineyards.

Although laboratory experiments have shown that the Asiatic ladybug does not damage fruits, with the exception of raspberries, it nevertheless readily ate already damaged apples and grapes under laboratory conditions [9, p. 540-543].

Fig. 1 CABI/EPPO (2007) Harmonia axyridis. Distribution Maps of Plant Pests No. 689. CABI Head Office, Wallingford, UK

MATERIALS AND METHODS

We set the task to find out what favorable and limiting bioclimatic indices exist that contribute and, accordingly, prevent the spread of the invasive species of the Asian ladybug in the territory of the Republic of Moldova. We relied on the cabi.org online database of invasive species [3] to determine the type of climate preferred by a given species, lower and upper limits of mean annual temperature (ºC) (bioclimatic predictor BIO1), mean maximum temperature of hottest month (ºC) (bioclimatic predictor BIO5), mean minimum temperature of coldest month (ºC) (bioclimatic predictor BIO6), mean annual rainfall (bioclimatic predictor BIO12) [12, p. 4-7] and dry season duration (number of consecutive months with <40 mm rainfall) (table 1).

Regarding the preferred types of climate, we have already established that since 2000, the climate of the Republic of Moldova has been classified as having the Dw / Ds type [4, p. 86, 87], which is one of the preferred types of climate for this invasive species.

Tab. 1 Limiting bioclimatic indexes for Harmonia axyridis. CABI/EPPO (2007) Harmonia axyridis. Distribution Maps of Plant Pests No. 689. CABI Head Office, Wallingford, UK [3]

Bioclimatic index	Lower limit	Upper limit	Description
BIO1	-2	26	Mean annual temperature (ºC)
BIO5	22	33	Mean maximum temperature of hottest month (ºC)
BIO6	-32	17	Mean minimum temperature of coldest month (ºC)
Dry season duration	0	8	number of consecutive months with <40 mm rainfall
BIO12	120	1700	Mean annual rainfall (mm)

Taking into account the limited number of meteorological stations and high degree of relief's fragmentation, which essentially changes bioclimatic predictors BIO1, BIO5 and BIO6 spatial distribution, we had performed analysis and estimation of these fields' restitution methods [5, p. 47; 11, p. 1824-1830; 13, p. 95-97]. We used data of the 14 meteorological stations from State Hydrometeorological Services of Republic of Moldova and obtained regression models in Statgraphics Centurion VII software, the results are summarized in tables 2, 3.

*Tab. 2 Bioclimatic predictors regression equation T = Ah*H + Ay*Y + Ahrel*Hrel + Ahsquared * Ah*Ah + Aslope*Slope + C parameters*

Bioclimatic index	P values for independent values' regression equations'					
	Constant, C	**Absolute altitude, Ah**	**Relative altitude Ahrel**	**Absolute altitude squared, Ahsquared**	**Slope, Aslope**	**Latitude, Ay**
BIO1	0,0000	0,0047	-	-	-	0,0001
BIO5	0,0000	0,0003	-	-	-	0,0018
BIO6	0,0001	-	0,0032	-	-	0,0000
BIO12	0,0000	0,0012	-	0,0018	0,0162	-

Note: H –absolute altitude, m; Hrel – relative altitude, m; slope – slope's inclination angle, degrees, Y – latitude expressed in meters in WGS84 Transverse Mercator projection with 27º central meridian and false easting 500000 m.

Tab. 3 Statistical parameters that explain mean annual temperatures' regression model

Bioclimatic index	Model's P-value	R^2, %	Standard estimation error, °C	Mean absolute error, °C
BIO1	0,0000	87,7395	0,21936	0,150553
BIO5	0,0000	90,052	0,268364	0,190111
BIO6	0,0000	90,67	0,263652	0,174979
BIO12	0,0005	81,4777	21,3548	14,4058

Bioclimatic indexes modelling's results clearly demonstrate that mean annual air temperature and mean maximum temperature of hottest month decrease with the increase in altitude and geographical latitude. P value for constants in all of the equations does not exceed 0,0000, except for BIO6, and for independent variables and for all models it does not exceed 0,01, which corresponds to 99% confidence level. $R^2_{adjusted}$ values demonstrate that independent variables explain at least 81% from bioclimatic indexes' variance.

In order to calculate dry season duration which was deemed to be the limiting factor for Harmonia axyridis spatial distribution, we used monthly precipitations sums for 14 meteorological stations (data obtained from State Hydrometeorological Services) for the period of 1960-2016, thus obtaining the number of consecutive months with <40 mm rainfall for each station.

RESULTS AND DISCUSSIONS

Using Geographical Informational Systems (ArcGIS 9.2) and Spatial Analyst Tools, namely Single Output Map Algebra, we had obtained digital maps from the regression equations for the bioclimatic indexes BIO1, BIO5, BIO6 and BIO12 (fig. 2, 3, 4 and 5 respectively), on the basis of Digital Elevation Model (DEM) and its derived layers (slope, relative altitude, absolute altitude squared) and geographical latitude grid which were main variables for regression equations' spatial interpolation. However, if we consider the lower and upper limits for Harmonia axyridis in table 1, and analyse our obtained digital maps on fig. 2-5, we

conclude that climatic conditions of Republic of Moldova during the period in study are favorable for the development of the h. axyridis.

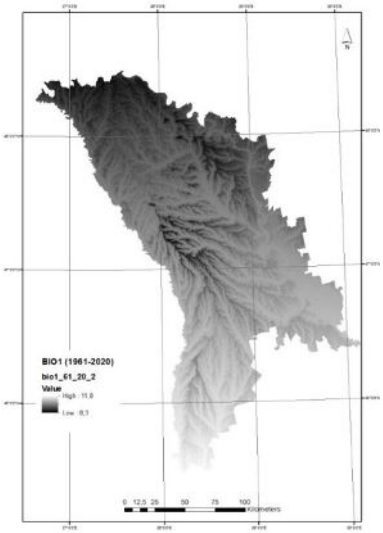

Fig. 2 Annual mean temperatures (BIO1)

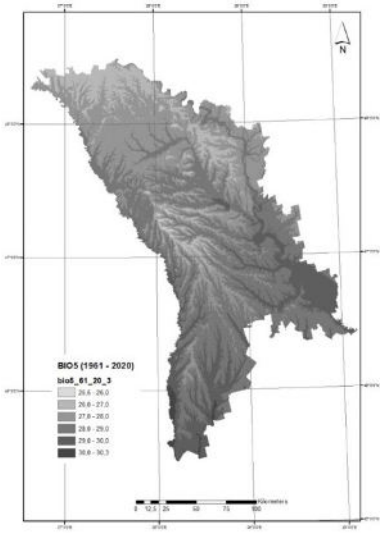

Fig. 3Mean maximum temperature of hottest month (BIO5)

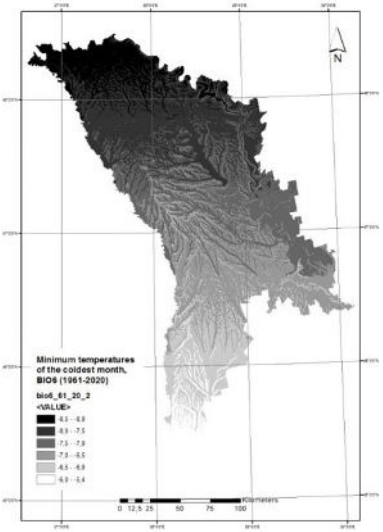

Fig. 4 Mean minimum temperature of coldest month (BIO6)

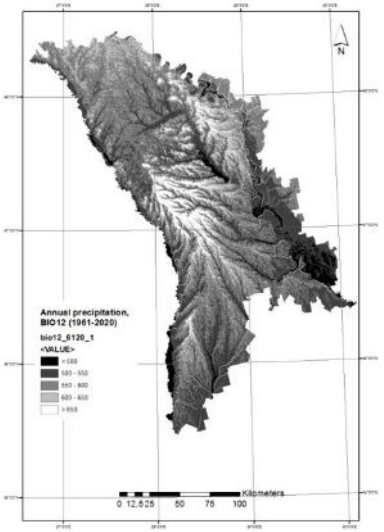

Fig. 5 Annual precipitations sum (BIO12)

Also, according to cabi.org, the limiting factor for the species in study will be 8 consecutive months or more with insufficient rainfall. In table 3 we had summarized the number of cases of the occurrence of insufficient (>40 mm) rainfall for 8 consecutive months or more, as it seems to be the only limiting climatological factor for the invasive species of harmonia axyridis. Considering that 8 months is a threshold value, we introduced a rating system in which

- If the number of consecutive months with precipitation below 40 mm is less than 8, then we assign 0 points
- If the number of consecutive months with precipitation below 40 mm is equal 8 then we assign 1 point
- If precipitation below 40 mm occur during more than 8 consecutive months - 2 points. (table 4).

This grading system allows us to obtain the severity of this limiting bioclimatic index, to assess its frequency of manifestation and eventually its spatial distribution.

Tab. 4 The frequency of the limiting bioclimatic indexes: more than 8 (or equal) consecutive months with the monthly precipitations sum less than 40 mm.

Meteorological station	Number of cases
Falesti, Tiraspol	9
Balti, Camenca	7
Baltata, Bravicea, Ribnita	6
Cahul, Cornesti, Stefan-Voda	4
Chisinau, Soroca	3
Briceni, Comrat, Leova	2
Dubasari	1

If we represent this in the form of a contour map using Spatial Analyst tools / Interpolation / Spline with barriers, we will get a spatial representation of the frequency with which the bioclimatic factor limiting the development of an invasive species occurred during the study period. Accordingly, the zones with the highest frequency (7-9 points) will be the most protected from the Asian ladybug, anf are thus

coloured in the shades of blue colour; the zones with the lowest frequency (0-2 points), on the contrary, will be most susceptible to its spread, and are coloured with brown. According to our model (Fig. 6), the southern part of the left bank of the Dniester River, as well as the regions of Criuleni, Causeni, Anenii Noi, Falesti, Glodeni and partly Balti were most often subjected to a long period of low precipitation, which, in theory, should limit the spread of this invasive species. At the same time, in the regions of Briceni, Leova and Dubosari, such conditions not only occurred less often, but moreover, in these areas, mainly long periods with insignificant amounts of monthly precipitation occurred before the beginning of 1990 in 75% of cases (Briceni - September 1982 - April 1983 and August 2000 - March 2001; Leova - June 1973 - April 1974 and Dubosari- June 1961 - January 1962).

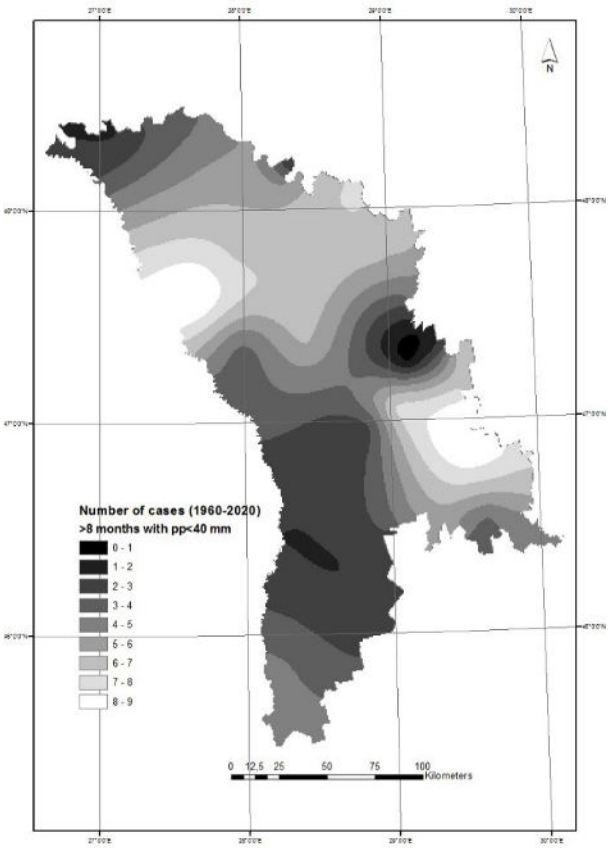

Fig. 6: Spatial distribution of the frequency of *the limiting bioclimatic factor (more than 8 consecutive months with the amount of monthly precipitation below 40 mm)*

CONCLUSIONS

Asian ladybug Harmonia axyridis is a new invasive species that has been recently recognized as a pest in fruit production and processing [8, p.543]. As insects become rare in autumn, adults of H. axyridis begin to harvest and feed on fruits such as apples (Malus domestica), pears (Pyrus communis), and grapes (Vitis vinifera). This is problematic for horticultural crops and especially for vineyards. H. axyridis are also difficult to remove from grapes, so they are crushed during harvest and processing. There are several bioclimatic indexes that influence distribution of this species and unfortunately most of them, e.g. mean annual temperature (ºC), mean maximum temperature of hottest month (ºC), mean minimum temperature of coldest month (ºC), and mean annual rainfall are favourable for harmonia axyridis within the limits of Republic of Moldova's territory. The consecutive months with the monthly precipitations sum less than 40 mm is the limiting bioclimatic index for the species. We had identified several regions that according to our model will be less affected by harmonia axyridis invasion.

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