Computer program for forecasting and calculating the number of winter wheat phytophages

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Abstract. Modern GIS technologies used in agriculture are able to analyze a variety of indicators, and allow you to integrate the data, as they are all geo-referenced and specialized in working with spatial information. For a long period of time, we have been conducting studies on phytophages on various crops, the main of which is winter wheat. In the process of research, an analysis of the general structure of winter wheat agrocenosis was carried out. A large variety of relationships has been established that affect the number of pests that are exposed to various exogenous factors. All the identified factors were divided into categories, allowing to determine the characteristics of changes in the number of phytophages in crops at different stages of its development and to assess their degree of influence on the triotrophic system "winter wheat - phytophage - entomophage" in space and time. This analysis allowed to establish the main factors influencing the number of insects in the process of winter wheat development and create a computer program. When creating a program, a certain phase of winter wheat ontogenesis with factors (abiotic, biotic and anthropogenic) acting on it was taken as a basis. Filling the database of agricultural land, the issuance of data on the morphological and biological features of pests and their entomophages are given in the form of reference books. As a result, the created program allows to predict the number of dominant species of phytophages and the optimal timing of protective measures, depending on the stage of winter wheat ontogenesis and changing environmental conditions.

1. Introduction
The analysis of the general structure of winter wheat agrocenosis was carried out, which showed that there is a wide variety of causal relationships affecting the number of pests exposed to various exogenous factors [1, 2, 3]. The factors were divided into categories that allowed us to identify vectors of change in the number of phytophages in winter wheat crops in various phases of its development and to assess their degree of influence on the triotrophic system "winter wheat-phytophage-entomophage" in space and time. This analysis allowed to isolate the main factors influencing the number of insects in the process of winter wheat development and create a computer program [4, 5].

The core of the system is a certain phase of winter wheat ontogenesis with factors acting on it (abiotic, biotic and anthropogenic). Logging into the system is done by entering the input data for calculations, and its output by calculating the average temperature in this phase and the total amount of precipitation [6]. Filling the database of agricultural land, the issuance of data on the morphological and biological features of the pests species and their entomophages are given in the form of a reference book.
Calculation of the density of phytophagous populations and their entomophages on one square meter or on one plant in different phases of ontogenesis; the effectiveness of entomophages and the need for protective measures; the output of the calculation results is carried out in the windows of the program interface. As a result, a report is being formed [7].

Agrocenosis of winter wheat is an artificial ecosystem, and it differs from natural ecosystems by a smaller variety of species and does not possess self-regulating mechanisms of the species number in the system. When analyzing the general structure and dynamics of the winter wheat agrocenosis, we obtained an extremely large variety of causal relationships between the elements of its system, which are affected by many factors. We divided the factors into categories: abiotic, biotic and anthropogenic, studying their influence on the plant-phytophage-entomophage troph allows us to see tendencies in the number of insects in agrocenoses during different phases of the culture ontogenesis, and to evaluate their influence on it in space and time. Such an analysis allowed us to build a logical model and create a computer program for calculating the number of phytophages and their entomophages under the influence of factors on the number of winter wheat entomocenoses with the calculation of the efficiency level of natural entomophages and the threshold of phytophages harmfulness [8].

2. Materials and methods
The program is based on the analysis of the biological characteristics of the winter wheat development, phytophagous populations and their entomophages. The number of insects, the efficiency level of natural entomophages and the threshold of phytophages harmfulness (corn- bug, cereal aphids, wheat thrips and corn sawflies) are calculated for the spring-summer period of the winter wheat development in the Central Ciscaucasia.

The file structure of the program “Calculation of the main pests number of winter wheat and their entomophages in various phases of ontogenesis depending on abiotic, biotic and anthropogenic factors” includes the following components:

- Local SQLite database file. The file contains the main user and program settings, reference books, as well as analytical research data presented in the form of tables, on which the computational algorithms of the program are based during its work;
- Executable program file (Pests.exe);
- Dynamic build library (.dll) files used by the program to interact with the SQLite file database and export reports to MS Excel;
- Image files (in .jpg and .png formats) used when displaying reference information in addition to the main functionality of the program.

The logical organization of the program’s source code is represented by three main components:

- Data access layer. Includes classes that describe the correspondence of tabular database representations to domain classes, as well as algorithms through which work with the local data store is performed using the object-oriented technology ORM Entity Framework 6 for the embedded relational SQLite database;
- A layer of domain logic. The layer is represented by classes that describe the essence of the subject area, as well as the service class, which allows to calculate the number and display recommendations based on them. Includes methods for exporting reports to Excel spreadsheet or a plain text file as selected by the user;
- The user interface of the program. Includes classes that describe the composition, appearance and behavior of all elements of the program graphical user interface.

3. Results and discussion
When you start the program, the necessary reference and analytical data from the pests.sqlite3 file are loaded first. Directories are a collection of tables, the main contents of which are the names and internal
service codes of the subject area entities. The analytical data tables contain lists of constant values of coefficients necessary to take into account various factors affecting the number of insects.

List of reference books:

- **Animals** - names, brief descriptions of the species composition, the biological characteristics of the insects development in the conditions of the Central Ciscaucasia and other background information about the pests and their entomophages presented in the study;
- **AnimalCategories** - categories of insects presented in the study (pest, ethnophage);
- **AnimalImages** - names of photo files, phenological calendars associated with the insects under study;
- **CultivarTypes** - types of varietal characteristics;
- **Cultivars** - winter wheat varieties;
- **GrowthPhases** - names of the phases of the winter wheat development;
- **FertilizerSystems** - types of fertilizer systems used in farms;
- **Fields** - directory of agricultural land, replenished by the user;
- **Predecessors** - types of precursors for the agrocenosis of winter wheat;
- **TillageSystems** - tillage systems used in farms;
- **WeedinessTypes** - the degree of contamination of winter wheat agrocenosis in farms;

List of tables with analytical research data:

- **CFormulaConstants** - coefficients for the dependence formulas of the insect number from the average temperature and the total amount of precipitation of the phase;
- **CCultivarType** - coefficients of the varietal characteristics effect;
- **CFertilizerSystem** - coefficients of the fertilizer system effect;
- **CPredecessor** - coefficients of the predecessor effect;
- **CTillageSystem** - coefficients of the tillage system effect;
- **CWeediness** - coefficients of the contamination level effect;

The menu item “Help-Species Biology” displays an information guide; photos of species, the species composition of the insects studied and the percentage by species in the years of research, phenological calendars and development cycles of dominant species in the Central Ciscaucasia.

After successful loading from the database, the main program window will be displayed on the screen. The left part of the window contains controls, through which the user enters the necessary initial data, as well as a list of agricultural land (objects) that the user changes at his own discretion during operation. In the right part of the window there are text fields, where the number of each pest and entomophage calculated based on the entered parameters is displayed. The displayed calculation results are automatically updated when the user changes any initial conditions. In the process, the program stores in user memory the settings entered by the user for each pair of “Agricultural object - Winter wheat development phase”. If necessary, these settings can be saved and / or loaded, thus avoiding re-entry during the next session with the program.

In order to get the correct result of calculating the insects number in the winter wheat agrocenosis in a certain phase of its ontogeny, the user needs to perform a number of actions:

In the corresponding list of the left part of the main program window, select the agrocenosis (field, agricultural object) for which you need to make a calculation or see the forecast of the population calculation. If necessary, you can add a new agrocenosis (field, agricultural object). The list of agrocenoses or agricultural objects is stored in the local database of the program and serves for the user convenience, taking into account a large number of land.

Select the phase of wheat development for which it is necessary to make a calculation from the proposed list.
From the drop-down lists of the Impact Factors group, the user selects the values for the varietal characteristics of the cultivated variety in the agrocenosis with respect to phytophages, the tillage system used in this agrocenosis, the applied fertilizer system, the predecessor and the degree of contamination in this agrocenosis, which most closely correspond to the state of the real agricultural object for which the number is calculated.

Enter the values of the average temperature of the winter wheat ontogeny phase and the total amount of precipitation in the text fields of the group “Average temperature (°C) and amount of precipitation (mm) of the phase”. The temperature value must be in the calculated range for the phase indicated next to the input fields in the same group; otherwise, the program will produce a zero result for all insects. If necessary, to calculate the average temperature of the ontogenesis phase, you can use the wizard, which opens by pressing the button with the image of the thermometer, or by selecting the "Actions-Average temperature / precipitation" item in the main menu of the program, calculating the average temperature of each day as follows and dividing it by the number days of the phase duration in this way we obtain the average temperature of the phase, all precipitations are driven in and summarized during this phase of ontogenesis.

In the case of the correct input of the initial data in the right part of the window, the results of calculations of the phytophages number and their entomophages for a certain agrocenosis will be displayed when exposed to abiotic, biotic and anthropogenic factors. To save the report in the form of an MS Excel book or a text document, use the menu items from the “File-Reports-...” list.

The calculation of the insects number is made according to the formula:

\[ N = F_{\text{temp.prec.}} \times C_{\text{cont.}} \times C_{\text{var.charact.}} \times C_{\text{till.syst.}} \times C_{\text{fert.syst.}} \]

where:
- \( F_{\text{temp.prec.}} \) - analytical dependencies of changes in the insects number from the combined effect of temperature and precipitations, obtained by applying statistical methods (regression and correlation analyzes).
- \( C_{\text{cont.}} \) - coefficient of the contamination level effect of the winter wheat agrocenosis on the insects number;
- \( C_{\text{var.charact.}} \) - coefficient of varietal characteristics effect on the insects number;
- \( C_{\text{till.syst.}} \) - coefficient of the tillage system effect on the insects number;
- \( C_{\text{fert.syst.}} \) - coefficient of the fertilizer system effect on the insects number.

The coefficients of the considered factors effect in the winter wheat agrocenosis obtained by calculating in comparison with a generalizing indicator of the statistical aggregate, which put out the individual differences in the values of statistic, allowing to compare different aggregations among themselves on a given basis for a given phase.

The economic thresholds of phytophagous pest damage are calculated taking into account the effectiveness of their natural entomophages: the quantitative ratio of phytophages to one individual of its predators and parasites at the time of calculating the number in the agrocenosis. Based on these calculations, the program recommends the need for zero tillage of winter wheat agrocenosis with insecticides during the studied ontogeny phase of winter wheat for each category of pest.

You can also see the number of phytophages and their entomophages in the spatial distribution of winter wheat agrocenosis, the calculation is made on the basis of empirical data for eight years using the formula:

\[ N = N_{\text{aver.}} \times C_{\text{distributed}} \]

where:
- \( N_{\text{aver.}} \) - average number of this species in this agrocenosis in this phase of ontogenesis;
- \( C_{\text{distributed}} \) - coefficient of effect of the distance from the field’s edge of winter wheat agrocenosis on the insects number.
Using the menu item "View" of the program main window, the user can set a convenient format for presenting numerical data of the calculation results and analyze whether there is an outbreak threat of any phytophagous (corn-bug, cereal aphids, wheat thrips and corn sawflies) and in what phase of ontogenesis number escaping from entomophage control can occur and on which agrocenoses of wheat.

4. Conclusions
Therefore, the core of the system is a certain phase of winter wheat ontogenesis with factors (abiotic, biotic and anthropogenic) acting on it, logging into the system is input of initial data for calculations, and its output is calculating the average temperature of the phase and total precipitation; filling the database of agricultural land; issuing data on the morphological and biological features of the pests species and their entomophages in the form of a reference book; the calculation of the density of the phytophages population and their entomophages on one square meter or on one plant in different phases of ontogenesis; the effectiveness of entomophages and the need for protective measures; displaying the calculation results in the program interface window and generating a report with its saving.

Technical characteristics of the created program. Computer program. Type of computer: IBM PC-compatible PC. Language: C#. OS: Windows 7, 8, 10, Vista. The volume of the program: 39.1 MB.

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