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WAYS TO DEVELOP MATHEMATICAL MODELS FOR PREDICTING THE DEVELOPMENT OF HARMFUL ORGANISMS OF FORESTRY CROPS

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ABSTRACT

The ways and principles of developing mathematical models for forecasting the development and spread of harmful organisms of forestry crops are described. At the same time, the features of the development of mathematical models, the possibility of predicting the dynamics of populations of forestry pests, the use of available data on the characteristics of the predicted object, the processing of these data by mathematical methods, obtaining a dependence linking these characteristics with time, and calculating with the help of the found dependence of the characteristics of the studied object at a given time. An example of the use of a mathematical model in determining the fertility of winter scoops in nurseries for the cultivation of seedlings of forest and ornamental plants is given.

Keywords: mathematical model, forecast, pests of forest and ornamental plants, method of group arguments, pest populations.

АННОТАЦИЯ

Описаны пути и принципы разработки математических моделей прогнозирования развития и распространения вредных организмов лесохозяйственных культур. При этом приведены особенности разработки математических моделей, возможности прогнозирования динамики популяций лесохозяйственных вредителей, использовании имеющихся данных о характеристиках прогнозируемого объекта, обработке этих данных математичес-кими методами, получении зависимости связывающей эти характеристики со временем, и вычислении с помощью найденной зависимости характеристик изучаемого объекта в заданный момент времени. Приведен пример использован-ия математической модели при определении плодовитости озимой совки в питомниках по возделыванию саженцев лесных и декоративных растений.

Ключевые слова: математическая модель, прогноз, вредители лесных и декоративных растений, метод группового аргументов, популяции вредителей.

INTRODUCTION

In recent years, a complex phytosanitary situation has developed in the Republic of Uzbekistan, associated with an increase in the acreage of forestry crops and changes in the system of their cultivation. The area of distribution of dangerous sucking and gnawing pests is expanding year after year.

Morphological and biological features of development, distribution area, harmfulness, scientifically - based forecasting and optimal timing of protective measures against the above-mentioned harmful organisms in Uzbekistan are insufficiently studied. A system of effective and environmentally safe measures to protect these crops has not been developed either.

Despite the successful fight against harmful organisms of forest and ornamental crops, many problems of the organization of monitoring of harmful organisms on the territory of the Republic, the development of scientifically–based forecasts of the appearance, development and spread of especially dangerous pests, diseases and weeds, the introduction of modern methods of monitoring of harmful organisms remain unresolved.

The formation and development of forestry crops are greatly influenced not only by cultivation techniques, but also by measures to combat diseases and pests. In the conditions of modern trends and technology of agriculture and concentration of production, phytosanitary problems are even more complicated. This requires strengthening research on the development of automated and remote methods for collecting, storing and evaluating data on the phytosanitary status of forestry crops in order to increase the reliability and efficiency of forecasts of the development of harmful organisms.

In practice, it is very important to establish the possible expansion or narrowing of the pest range, to anticipate in advance the degree of their development, the timing of individual infections and manifestations. The possibility of foresight is the essence of the forecast of the development of harmful organisms.

The task of forecasting for common pests is as follows:

- Determination of general trends towards the growth of pests or, conversely, to attenuation;
- Prediction of outbreaks of a particular pest, indicating for each area (zone) the intensity of the lesion and the amount of possible damage;
- Setting in advance the timing of individual infections and their manifestations in a given season in relation to the conditions of each district;
- Timely Informing forestry authorities and farms about the possible timing of the appearance of pests, the intensity of damage to crops and the extent of damage, as well as recommendations of necessary protection measures.

It follows from this that, based on forecasts, it is possible:

- Rational organization and timely implementation of preventive measures to protect plants from mass destruction by pests, i.e. planning of protective equipment and their distribution to the areas of cultivation of forestry crops, respectively, expected outbreaks and probable losses, as well as the distribution of protective control measures over time, respectively, the projected timing of plant infection;
- Recommendations to planning organizations for the production of necessary protective equipment and the implementation of appropriate measures;
- Recommendations to forestry authorities of appropriate organizational and economic, preventive, agrotechnical measures in cases of expected changes in the dynamics of pests.

Research Results

The development of mathematical models for predicting the dynamics of populations of forestry pests consists in using the available data on the characteristics of the predicted object, processing these data by mathematical methods, obtaining a dependence linking these characteristics with time, and calculating with the help of the found dependence of the characteristics of the studied object at a given time.

Thus, the pest population, like (Yakhyaev, 1994), can be considered as a certain process represented by the scheme shown in the figure, from which it can be seen that the set of parameters (V1, V2, ..., Vn) and (Z1, Z2, ..., Zm) form the input of the object of research and the set (Y1, Y2, ..., Yk) - output. Obviously, the inputs and outputs of an object can be considered as some multidimensional vectors in the parameter space. So, for vector V, the space has n dimensions, for vector Z - m dimensions, and for vector Y - k dimensions.

The output of an object is connected to its inputs in a certain way, for example, using the operator F,

$$Y = F(V, Z) \qquad (1)$$

characterizing the structure of this object.

Finding the quantitative relationship of the parameters (1), i.e. the full disclosure of the operator F, is the essence of the problem of the object we are considering. As a result of modeling, a mathematical model of this object is obtained.

In expression (1), the set V forms (in terms of ecology) a set of biotic factors, Z is a set of abiotic factors, and Y is a set of factors characterizing the pest population. They can be indicators such as the number (density) of pests, the size of the infected areas of forestry crops by pests, the dates of the appearance of pests, etc.

Let's assume that in expression (1) the vectors Y, V, Z are observable and their components can be measured. Then, if the structure of the operator is known, then the task of mathematical modeling of the dynamics of the population of forestry pests, which consists in determining the influence of biotic and abiotic environment factors on the dynamics of the pest population, is reduced to finding an unknown vector of parameters A = (a1, a2, as), the components of which are values depending on factors V and Z.

The solution of this problem allows us to move on to a range of problems related to solving the problems of forecasting the dynamics of the population of forestry pests and developing optimal control plans for them.

Let's assume that an analytical form of expression (1) has been found for some ecological process, i.e. the values of the parameters of vector A.

Let's assume that the resulting model described by expression (1) is adequate to the process under study. Then determining the value of Yt at the output of the model of some future moment t+1 is the essence of the forecasting problem for the vector Y.

Various methods are used to find the analytical form of expression (1). Since the factors of the biotic and abiotic environment can be considered as a subset of input factors, i.e.

$$X = V \cup Z$$

then the expression (1) will take the form:

$$Y = F(X) \qquad (2)$$

We write expression (2) as

$$Y_m = F_m(X_{m1}, X_{m2}, ..., X_{mn}) \qquad (3)$$

where the index m shows the type of pest.

Thus, expression (3) generally shows the relationship of the dynamics of the population of forestry pests with the factors affecting it.

As mentioned above, the predicted parameters of the pest population (ym) can be its characteristics such as the number (density), the size of infected areas, the dates of appearance of pests, etc., and their meters (factors of biotic and abiotic environment) are set by a specialist who knows the object of forecasting well.

To identify the analytical type of expression (3), various identification methods are used. We will focus on regression analysis and the method of group accounting of arguments (MGUA).

The least squares method can be applied to objects for which, based on a priori information (observation during experiments, meteorological data, data on plant cultivation methods), the structure of equations describing their behavior and nominal parameter values is known. In the simplest case of identification, the least squares method is based on the study of deterministic input and output signals (without taking into account random measured disturbances). Regression analysis algorithms are described in detail in (Ziyakhodzhaev et al., 1971).

The purpose of the MGUA is to obtain the result of a complete search according to the selection criterion. MGUA belongs to a group of methods based on mathematical processing of prehistory data and is designed to solve the so-called interpolation problems of technical cybernetics. Examples of such tasks are the tasks of pattern recognition, prediction of random processes, identification of the structure and parameters of complex objects based on the results of observing their work, optimal control with prediction optimization. In principle, these listed tasks can be solved by a complete search of all options according to a criterion called the selection criterion. The choice of such a criterion is heuristic, i.e. belongs to the programmer and is determined by the goal of solving the problem.

A complete search occurs in the process of gradual complication of the mathematical description or model. In this case, the complication goes discretely, i.e. new terms are added in each row, or the degree of the polynomial increases, or both occur simultaneously. Gradually increasing the complexity of the mathematical model, and setting a number of discrete values of its coefficients, with some small step, it is possible to organize a complete search of all possible variants of the model according to the specified selection criterion and thus find the best model (of all viewed). The presence of a minimum selection criterion makes it possible to find a single model of optimal complexity. The search method is alternate testing of models (brute force).

There are various GMDH algorithms (Ivakhnenko, 1971; Ivakhnenko et al., 1976), which differ from each other in the form of the approximating function. One of the algorithms is polynomial GMDH algorithms. These algorithms are used to implement multi-row selection when solving problems of finding the optimal model, given in the form of a power polynomial.

According to the polynomial GMDH algorithms, the complete description of the object (3) is replaced by a certain set of so-called partial descriptions, which are functions of two arguments. In the first row of the selection, particular descriptions look like:

$$Y_k = F_k\,(X_{kj}, X_{kl}),$$

in the second and subsequent rows:

$$Y_{ik} = F_k\,(Y_{i-1,}\,k, Y_{i}\text{-}_{1}, k+1)$$

As approximating functions of fk, polynomials of no higher than the second degree are used with respect to two arguments, on the first row of selection:

$$Y_{1k} = a_{1k}{}^{(0)} + a_{1k}{}^{(1)}X_{jk} + a_{1k}{}^{(2)}X_{lk} + a_{1k}{}^{(3)}X_{jk}X_{lk} + a_{1k}{}^{(4)}X_{jk}{}^{2} + a_{1k}X_{lk}{}^{2}$$

on the second and subsequent rows:

$$Y_{ik} = a_{ik}^{(0)} + a_{ik}^{(1)}Y_{i-1,k} + a_{ik}^{(2)}Y_{i-1,l} + a_{ik}^{(3)}Y_{i-1,k}Y_{i-1,l} + a_{ik}^{(4)}Y_{i-1,k}^2 + a_{ik}^{(5)}Y_{i-1,l}^2$$

Here i is the number of selection series, i = 2,3, ..., N; k is the number of particular descriptions, k = 1, 2, C_n^2 ;

j = 1, 2, …, N-1 ; l = j+1, j+2, …, N where N is the number of arguments.

The coefficients of particular descriptions are determined according to the data of the training sequence (OP), for which the least squares method is used. It should be noted that in order to obtain stable solutions, the existing data set is divided into training and verification sequences (PP).

The degree of regularity is estimated by the magnitude of the root-mean-square error on a separate test sequence (the minimum of this error is searched for).

To obtain the most regular mathematical description, either the correlation coefficient or the value of the standard error of measurements on a separate test sequence can be used as a selection criterion.

From row to row of selection, with the help of threshold selections, the most regular variables, called intermediate variables, are skipped from all particular descriptions. As the complexity of the intermediate variables increases, the complexity of the model increases and at some point it will become equal to the complexity of the object, while the value of the self-selection criterion reaches its extreme value. One of the intermediate variables of the last row is chosen as the final solution. A complete description of the object is obtained in the form of a set of intermediate variables.

As an example, let's consider the development of a mathematical model for determining the fertility of winter scoops (Agrotis segetum). It was found that the size of the head capsules and the weight of the pupae can be judged on the viability and fertility of this pest. Consequently, the fecundity of the winter scoop P is a function of such indicators as the size of the pupae (Xp), the weight of the pupae (Xm), the food that the host ate (Xk), i.e.

$$P = f\,(X_m, X_p, X_k) \qquad (4)$$

To identify the type of this function, data obtained in the conditions of forestry nurseries of the Tashkent region were used (table). To identify the type of expression (4), the method of group accounting of arguments based on the principle of heuristic self-organization and a standard program from the fund of algorithms and programs (Yakhyaev, 1978; Yakhyaev et al., 1986) was used.

Drawing

Interactions of the object of research and factors influencing it As a result, a description of expression (4) is obtained to determine the fertility of winter owl butterflies in the form of the following set of intermediate variables:

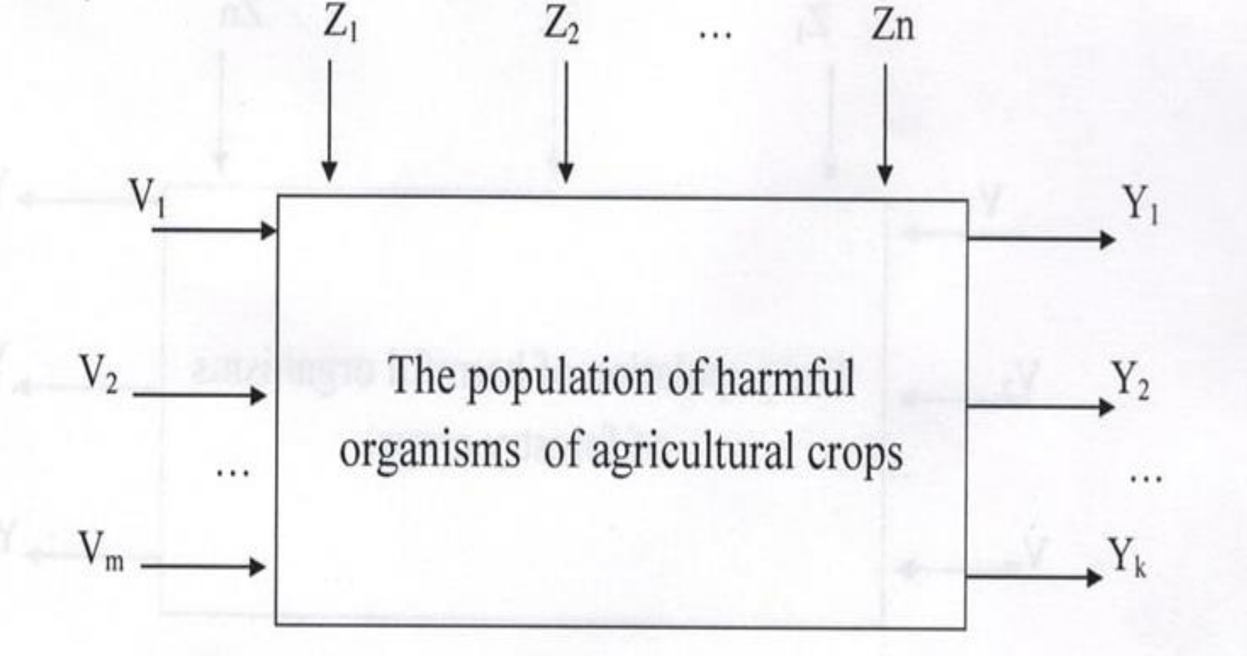
$$P = -587{,}77 + 1{,}345\ Y_{11} + 1{,}14\ Y_{12} – 0{,}0009\ Y_{11}Y_{12},$$

where $Y_{11} = -23287{,}67 + 1194{,}68\ X_p + 81{,}98\ X_m – 4{,}047\ X_mX_p$;

$$Y_{12} = 2155{,}81 – 356{,}21\ X_k - 109{,}25\ X_p + 27{,}578\ X_kX_p;$$

Here Xm is the mass of the pupae; Xp is the size of the pupae; Xk is the culture (feed) that the pest ate.

At the same time, the correlation coefficient is very high R = 0.94; and the approximation error was 14.5 eggs. The comparison of actual and calculated data is given in the table. The results obtained indicate the acceptability of this approach in determining the fecundity of host butterflies.



Picture. Interactions of the object of study and factors influencing it

Table Size, weight of winter owl pupae and fertility of butterflies when feeding caterpillars with different food

№	**Fertility of butterflies (number of eggs), in pcs. actual, calculated**		**Weight of pupae, mg**	**Pupal size, mm**	**Caterpillar nutrition (feed)**
1.	785	803	275	17,5	Cotton
2.	622	618	260	17,5	Loach
3.	300	317	260	16,0	alfalfa
4.	1011	998	310	19,5	Cotton
5.	940	916	296	19,0	Loach
6.	698	676	280	17,5	alfalfa
7.	786	741	285	18,0	Cotton
8.	638	613	280	17,5	Loach
9.	320	301	265	17,0	alfalfa
10	1040	983	310	20,0	Cotton
11.	993	975	295	19,0	Loach
12.	680	636	285	17,5	alfalfa
13.	789	796	295	18,5	Cotton
14.	815	841	255	18,0	Loach
15.	220	280	280	16,5	alfalfa
16.	1090	1043	310	19,5	Cotton
17.	1010	1001	310	19,5	Loach
18.	625	639	285	17,0	alfalfa

List of Literature

1. Ziyakhodzhaev M.Z., Kurbanaliev E. Approximation of functions of many variables//Dokl. Academy of Sciences of the Uzbek SSR, -No.6, -Tashkent, -1971, -pp. 16-18.
2. Ivakhnenko A.G. Systems of heuristic self-organization of technical cybernetics. – Kiev, "Technika", -1971, -372 p.
3. Ivakhnenko A.G., Zaichenko Yu.P., Dimitrov V.D. Decision–making based on self-organization. -M., "Soviet Radio", -1976, -280 p.
4. Yakhyaev H.K. Algorithms and the program of the group accounting method based on the principle of heuristic self-organization// "Algorithms", RISO AN UzSSR, -Tashkent, -1978, issue 34, -pp. 66-71.
5. Yakhyaev H.K., Turdieva N.M. Complex of applied programs for solving plant protection problems / State Fund of Algorithms and Programs of the USSR, -1986, - №50860000300.
6. Yakhyaev H.K. Development of scientific foundations for automation of forecasting and management of harmful objects of agricultural crops /Diss. at the sois. uch. of the doctor of agricultural sciences,-Tashkent,-1994, - 286 p.
7. Nafasov Z.N. Theoretical basis for the development of mathematical models for predicting the development of conifers. Journal of Agrochemical Protection and Plant Quarantine. - №5. - Tashkent, 2021. - P.44-46.