Application of digital agromonitoring for the assessment of feasibility of using pesticides in cultivation of agricultural crops in the Russian Federation

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Abstract

The article provides mathematical processing of data from reviews of the phytosanitary state of crops for 2010-2020 on the territory of the Russian Federation in accordance with the state assignment. In recent years, crop losses from diseases and plant pests have been increasing many times over the entire territory of Russia. The use of a significant amount of various pesticides in intensive technologies cannot withstand this. Pathogens become resistant to drugs and become more aggressive. Plants are under almost constant environmental stress. However, it is impossible to give up pesticides. The current level of development of science has led to the emergence of assessment methods using mathematical analysis to calculate the optimal doses of pesticides for plant protection. In 2020, the development and implementation of the "Digital Phytomonitoring" software began for georeferencing the phytomonitoring results, operational analysis of research data and visualization of the received phytosanitary information. One of the important tasks of digital monitoring is to predict the possible use of plant protection products and calculate their optimal values for the near future. The predicted volumes of protective measures are always preliminary and adjusted.

The doctrine of food security in Russia, approved by the President of the Russian Federation V.V. Putin, since 2010 provides for the provision of the country's population with high-quality plant-growing products of its own production and complete import substitution. The annual monitoring of the phytosanitary state of crops on the territory of Russia is one of the fundamental state services in the field of plant protection of the FSBI "Rosselkhoztsentr".

According to the state assignment, specialists carry out phytosanitary monitoring of agricultural land in the territory of the Russian Federation, which makes it possible to timely assess the spread of pests, diseases and weeds on agricultural crops and prevent crop losses.

The management bodies of the agro-industrial complex of the constituent entities of the Russian Federation and all persons carrying out activities in the field of crop production are regularly provided by the specialists of the FSBI "Rosselkhoztsentr" with operational information on the spread of harmful objects and the need for protective measures.

In 2020, the development and implementation of the "Digital Phytomonitoring" software began for georeferencing the phytomonitoring results, operational analysis of research data and visualization of the received phytosanitary information.

One of the important tasks of digital monitoring is to predict the possible use of plant protection products and calculate their optimal values for the near future. Agrochemicals intended to increase the productivity of agricultural crops perform certain functions in complex natural systems on the territory of the Russian Federation. Often, the introduction of these chemical components creates new problems in soil biocenoses, which in turn reduce the productivity of products. Careful selection and calculation of the required quantities of these drugs is required.

The predicted volumes of protective measures are always preliminary and are adjusted during the spring and summer phytosanitary surveys. The main agrochemicals - pesticides, used in agricultural technologies in significant quantities - are fungicides, herbicides and insecticides. The results of mathematical processing of forecast data for basic plant protection products for the last 10 years are shown in figure 1.
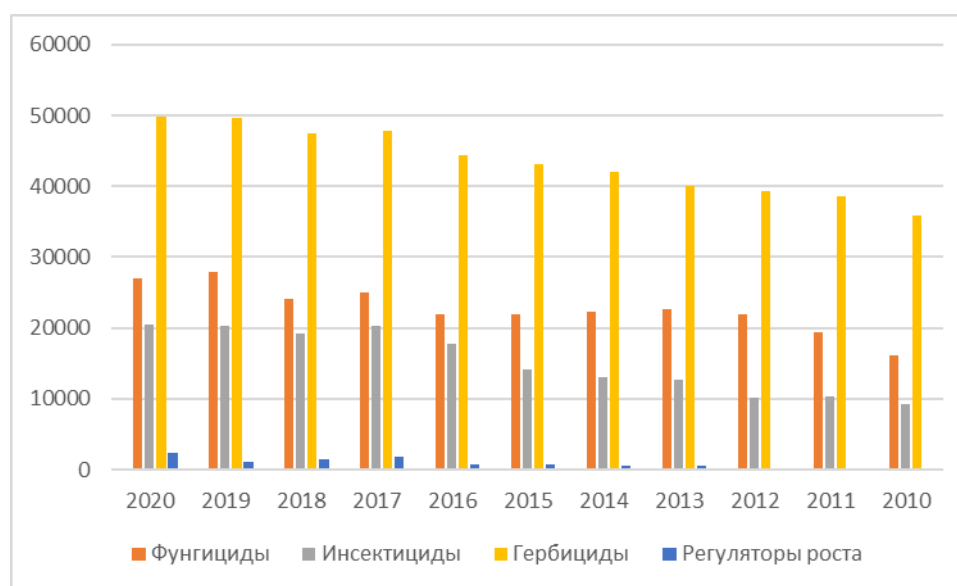

Figure 1 - The volume of work on plant protection in the RF in 2010-2020, thous. he.

Having studied the actual data on the total amount of use of various plant protection products over the past 11 years, a corresponding statistical mathematical model has been developed.

For definiteness and concreteness of presentation, we take the following relation as a mathematical model:

$$P_r = a_0 + a_1 x + a_2 y + a_3 z + b_1 x^2 + b_2 y^2 + b_3 z^2 + {} + c_1 xy + c_2 xz + c_3 yz$$

P_r – relative total volume of pesticides, x – relative volume of fungicides, y – relative volume of herbicides; z – relative amount of insecticides

a_0, a_1, a_2, ..., c_3 – constant coefficients determined from the actual data by the least squares method from the condition of the minimum sum of squares of deviations ΔP of the actual values of the objective function (P_F) from the corresponding calculated values of the objective function (P_r) according to relation (2), i.e. from the condition:

$$\Delta(x, y, z) = \sum_{i=1}^{n}\left(P_F - P_p\right)^2 \rightarrow min,$$

n – total number of experiments.

The main preparations for increasing the productivity of agricultural crops are fungicides, herbicides and insecticides. Growth regulators are used in small amounts, but their use has increased in recent years. Organic growth preparations are especially promising in this direction. The numerical values of the relative volumes are determined as the quotient of the actual volume to the corresponding area of application, in relation to the data for 2010 (table 1)

Table 1. Relative values of the volume of protective equipment in the Russian Federation for the period 2010–2020. (dimensionless units).

№	P_{iF}	x_i	y_i	z_i	Years	P_{ir}
1	1.000	1.000	1.000	1.000	2010	0.9999
2	0.794	0.850	0.786	0.757	2011	0.9740
3	0.848	0.972	0.786	0.783	2012	0.8483
4	0.940	1.058	1.027	0.835	2013	0.9399
5	0.955	1.032	1.046	0.869	2014	0.9539
6	1.031	1.065	1.180	0.938	2015	1.0320
7	1.031	1.001	1.401	0.907	2016	1.0310
8	1.110	1.097	1.541	0.943	2017	1.1103
9	1.130	1.105	1.518	0.976	2018	1.1298

| 10 | 1.165 | 1.234 | 1.549 | 0.981 | 2019 | 1.1649 |
| 11 | 1.183 | 1.208 | 1.583 | 0.999 | 2020 | 1.1828 |

P – relative total volume of pesticides; x – relative volume of fungicides;
y – relative volume of herbicides; z – relative amount of insecticides.

The values of **ten** unknown constants a_0, a_1, a_2, a_3, b_1, b_2, b_3, c_1, c_2, c_3 are determined [14] from a system of **ten** linear algebraic equations of the form:

$$\frac{\partial \Delta}{\partial a_0} = 2\sum \left[P_o(x_i, y_i, z_i) - P_p(x_i, y_i, z_i) \right] \quad (1) = 0,$$

To solve a system of **ten** linear algebraic equations, you can use any known method (Gauss method, Cramer's formulas, etc.)

$$a_0 n + a_1 \sum x_i + a_2 \sum y_i + a_3 \sum z_i + b_1 \sum x_i^2 + b_2 \sum y_i^2 + b_3 \sum z_i^2 + +c_1 \sum x_i y_i$$
$$+ c_2 \sum x_i z_i + c_3 \sum y_i z_i = \sum P_i,$$

After the values of the constant coefficients a_0, a_1, a_2, a_3, b_1, b_2, b_3, c_1, c_2, c_3, the function of three arguments $\Pi(x, y, z)$, have been determined, relation (1) allows us to find the "critical" (optimal) values of the parameters: x_{cr}, y_{cr}, z_{cr} from the system of **three** algebraic equations:

$$\frac{\partial P}{\partial x} = 0, \qquad \frac{\partial P}{\partial y} = 0, \qquad \frac{\partial P}{\partial z} = 0$$

or:

$$\begin{cases} a_1 + 2b_1 x_{cr} + c_1 y_{cr} + c_2 z_{cr} = 0, \\ a_2 + 2b_2 y_{cr} + c_1 x_{cr} + c_3 z_{cr} = 0 \\ a_3 + 2b_3 z_{cr} + c_3 y_{cr} + c_2 x_{cr} = 0 \end{cases}$$

Thus, after solving the system, the determination of the coefficients can be written down, you can write down the basic relationship in the form:

$$P_r = 2{,}964729 + 1{,}312080x - 3{,}421988y - 2{,}231998z +$$
$$+0{,}222143x^2 + 3{,}700855y^2 - 1{,}517340z^2 -$$
$$-6{,}420543xy + 3{,}051072xz + 3{,}340871yz.$$

we find the "optimal" (rational) values of dimensionless arguments:

$$x_{opt} \approx 0{,}959 \text{ (volume of fungicides)}, y_{opt} \approx 0{,}796 \text{ (volume of herbicides)}$$
$$z_{opt} \approx 1{,}105 \text{ (volume of insecticide)}$$

which determine the "optimal" (rational) value of the function:

Thus, based on the above, using the derived equations obtained during the mathematical processing of forecasts for the main plant protection products, it is possible to predict the

required minimum and sufficient amount of pesticides for use on the territory of the agro-industrial complex of the Russian Federation.

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