Conference Paper

Selection of Adaptive Agricultural Technologies in Digital Agriculture

Andrey V Gostev[1], Aleksey I Pykhtin[2], and Roman V Popadinets[2]

[1]Head Scientist Researcher, All-Russian Research Institute of Agriculture and Soil Protection from Erosion, Kursk Federal Agricultural Research Centre, Kursk, Russia
[2]Information Technologies and New Enrolment Department, Southwest State University, Kursk, Russia

Abstract

As follows from the analysis of the collected experimental material of long-term field trials of the Kursk Federal Agricultural Research Centre and generalization of the activities results of leading domestic research and educational institutions, as well as the practical results of many agricultural enterprises of the eastern part of Europe, we have identified the most effective conditions for the use of basic agricultural methods in wheat cultivation technologies as well as spring and winter barley, seed peas, buckwheat, grain maize, oats, millet and winter rye cultivation technologies of different levels of intensity which contribute to the rational use of available resources of agricultural producers based on the prevailing soil and climatic conditions. The technologies made it possible to prepare scientific-methodological approaches and a mathematical model to solve the problems of selecting an adaptive technology of crops cultivation. A normative-reference database for different types of crops cultivation technologies has also been made, including a list of zoned recognized varieties and hybrids of crops under study, necessary technology methods taking into account conditions of their effective use. Currently, an algorithm and the corresponding software are being developed to choose the most expedient technology of crop cultivation for specific soil and climatic conditions depending on a set of defining factors. There has been created software (in the form of a complex of programs for stationary computers and mobile electronic devices with the Android operating system. A specialized website has been developed. It provides a scientifically well-grounded selection of crops varieties and hybrids for the eastern part of Europa on the basis of user-specified conditions.

Keywords: agricultural technology, rational choice, software, crops

Corresponding Author:
Aleksey I Pykhtin
aipykhtin@swsu.ru

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1. Introduction

The transition of the domestic economy to the level of the sixth technology revolution of the world scientific and technological progress is connected, among other things, with the development of digital information technologies in agriculture. In accordance with the program ``Digital economy of the Russian Federation'', approved by the Government of the Russian Federation (order No. 1632-p of July 28, 2017), the development of digital technologies is being planned in various sectors of the economy. On February 28, 2019, Council on priority direction of scientific and technical development of the Russian Federation ``Transition to highly productive and environmentally friendly agro- and aqua economy, developing and implementing the systems of rational use of chemical and biological defense equipment of agricultural plants and animals, storage and effective processing of agricultural products, creation of safe and high-quality, as well as functional food stuffs'' approved the scientific part of the integrated development project ``Digital and intelligent systems of land use, land management and agriculture of the new generation''. Thus, the digitalization of domestic agriculture is becoming one of the key areas that contribute to improving the efficiency, productivity, quantitative and qualitative increase of grown products, which will undoubtedly have a positive effect on improving their competitiveness, quality of citizens' life, economic growth and national food security.

In its turn, one of the main tasks of adaptive landscape specific agriculture is to improve the interaction of natural and economic systems through the creation of highly efficient, environmentally balanced farming ecosystems, taking into account the maintenance of the most important functions of the soil, the most efficient and rational use of natural and climatic resources and obtaining sustainable crops of agricultural products [1].

In recent decades, in the Russian Federation and abroad, a great attention has been paid to highly productive resource-saving technologies for the cultivation of agricultural crops. Due to the diversity of natural and material conditions in the vast territory of the Russian Federation, a set of possible variants of cultivation technologies even for one agricultural crop is very large, as well as the possibility of incorrect selection of the used variant of agricultural technology because of applying a conventional routine practice without taking into account the specifics of relief or soil and climatic conditions of each agricultural field. The formation of an adaptive version of agricultural technology on the basis of a comprehensive analysis of the specifics of each site is quite a difficult task, which requires extensive practical experience and multi-level conformity assessment to obtain an adequate end result, as it is necessary to take into consideration the influence of many conditions, such as: the level of soil fertility, the degree of weed infestation, the availability of labor force, combustive and lubricating materials, fertilizers, chemical crop protection agents, growth regulating chemicals, farm machinery and so on. On the other hand, the level of planned crop yields, as well as the quality of the grown products plays an important role in the development of highly productive resource-saving agricultural technologies. In addition, the calculation of the maximum crop capacity is not always justified due to the lack of any determining factor, and excessive application of pesticides alone carries the risk of contamination of soil, groundwater, and, consequently, the environment as a whole.

As a result of carrying out long-term agricultural technology tests on crops cultivation in various regions of the country, a huge amount of data has been accumulated. Scientists have revealed a lot of basic regularities that contribute to both the conservation of soil resources and quantitative and qualitative increase in crop yields. Therefore, the vector of research focus and development should be gradually moved to the field of synthesis and analysis of the information obtained. It should result in the preparation of scientific recommendations, guidance papers, as well as Registers of agricultural technologies, but there is still no convenient, fast and adequate way to transfer such developments to the end users -- agricultural producers. Under the circumstances, the process of making agricultural products is inseparable from the acquisition of new agricultural knowledge and skills, and therefore it should be considered as a single, interconnected system that allows us as soon as possible introducing significant results of domestic science in agricultural production. In this regard, one needs the transition from expert-descriptive (qualitative) systems to quantitatively filled ones, involving the use of system relationships and scientifically sound regulatory framework, as well as specialized software to automate the selection of both individual agricultural methods and agricultural technologies in general, based on advanced and breakthrough results of domestic agricultural science.

Meanwhile, in recent years there has been an active growth of developments in agriculture which use the latest achievements in the field of information science and engineering both at the level of implementation of automatic solutions (onboard sensors, positioning systems, navigation systems, etc.) and at the level of automated decision support systems. Software content, creation and improvement of specialized knowledge databases, generation, optimization and implementation of agricultural solutions, taking into consideration the variability of natural and climatic conditions of cultivated fields represent a vast potential for further development. Therefore, a crucial role in the process of learning the basics of effective land use will be played by research aimed at improving the information support of decision-making methods (models, algorithms, databases and expert systems) [2]. At present, research in this field is being carried out both by the Russian scholars: Vyacheslav Yakushev (Agrophysical Research Institute) [3], Nikolai Stepnykh (Ural Federal Agricultural Research Center) [4], employees of the Siberian Federal Center of agrobiotechnologies under the leadership of Victor Alt: Vladimir

Kalichkin [5] and Svetlana Isakova [6], Deepak Keshwani (North Carolina State University, USA) [7], Jantonio Lopez-Riquelme (Universidad Politécnica de Cartagena, Spain) [8], Brett M. Whelan (University of Sydney, Australia) [9] and many others. Moreover, every year the number of such studies is growing. It means that competition is increasing, which in the end should lead to an increase in their quality.

2. Materials and Methods

On the other hand, Russian agricultural scientists have collected a huge amount of scientific data that must be systematized, generalized and based on a deep analysis of the information received to form the principal conditions of agricultural technologies adaptability of resource-saving orientation in relation to different soil and climatic conditions of our country. Therefore, scientists should develop and implement modern information technology systems more actively to transfer new knowledge and improve existing approaches to the design of science-based agricultural technologies. These technologies should be in the form of expert support systems to address the most important agricultural issues, and agricultural producers need to use more actively the most significant results of research in this area to improve the efficiency of agricultural production, as the irrational choice of crops cultivation technologies leads to excessive consumption of resources, increase in cost of production, decrease in production profit and profitability. Due to the fact that the process of automation of agricultural technologies adaptive selection is quite complicated and depends on many factors and conditions, it is advisable to do it in stages and consistently.

Furthermore, the relevance of scientific research on the creation of systems of automated rational selection of adaptive agricultural technologies is due to the need to prepare comprehensive domestic competitive tools and packaged developments that contribute to the reduction of anthropogenic environmental degradation in the short term and improve the quality of grown products through the use of science-based approaches and standards in relation to resource saving in agriculture. They are aimed at solving specific tasks within the framework of priority scientific directions defined in the strategy of scientific and technological development of the Russian Federation (Approved by the order of the Russian Federation President of December 1, 2016 No. 642) - sub-item ``d'' of item 20 -- ``transition to highly productive and environmentally friendly agro- and aqua economy, developing and implementing the systems of rational use of chemical and biological defense equipment of agricultural plants and animals, storage and effective processing of agricultural products, creation of safe and high-quality, as well as functional food stuffs".

The development of a scientifically well-grounded system of supporting agricultural producers to provide rational selection of highly profitable adaptive technologies of crops cultivation is the final stage in the process of improving the zonal technologies of crop products cultivation. This stage involves the generalization of recommendations for the rational use of technological methods, scientific basis for the formation of resource-saving technologies, as well as the development of expert systems that carry out scientifically sound selection of optimal agricultural technologies for the given soil and climatic conditions.

Purpose of the conducted research is to develop a science-based system of support of agricultural producers to provide rational choice of highly profitable adaptive technologies of crops cultivation for different conditions of the eastern part of Europe on the basis of generalization, analysis and systematization of experimental data. Taking into consideration the prevailing soil and climatic conditions of a particular territory, this system should make it possible to choose a scientifically based technology of the selected crop cultivation, and thus contribute to increasing the profitability of crops production. It also should ensure the environmental orientation of technologies through the effective use of mineral fertilizers, fuel and chemical crop protection products, selection of the optimal variety or hybrid of crops, agricultural machinery used, taking into account the requirements of import substitution and the preliminary calculation of the economic efficiency of the selected technology.

3. Results and Discussion

The development of a system to support agricultural producers in relation to the rational choice of adaptive technologies of crops cultivation has been carried out for the 8 most common crops of the eastern part of Europe. These crops include peas, buckwheat, grain maize, oats, millet, wheat and barley (winter and spring varieties), winter rye.

Furthermore, since the studies were conducted for the conditions of the eastern part of Europa, the analysis and generalization of long-term and short-term field experimental data on the development and optimization of crops cultivation technologies or individual methods of crops cultivation was performed for 8 regions of this part of the Russian Federation: North, North-West, Central, Volga-Vyatka, Central Black Earth, North Caucasus, Middle Volga and Lower Volga Regions. Naturally, within each of the above listed region there was a significant diversity of both soil-climatic and landscape conditions, which was also taken into account in the formation of the initial information unit.

For the purposes of optimization, the process of developing a normative-reference database of agricultural producers' support system in order to make a rational selection of highly profitable adaptive technologies of crops cultivation for the conditions of the eastern part of Europa was divided into several stages, involving the development of databases of the second order [10]:

1. Regulatory and reference database of agricultural producers' support system for rational choice of crops varieties and hybrids;

2. Regulatory and reference database of agricultural producers' support system for rational choice of fertilizers system in crops cultivation;

3. Reference database system of agricultural support for rational choice of processing soil in crops cultivation;

4. Regulatory and reference database of agricultural producers' support system for rational choice of protection system in crops cultivation;

5. Regulatory and reference database of agricultural producers' support system for rational choice of seeding and harvesting methods in crops cultivation.

Currently, the selection of the most appropriate variety or hybrid of an agricultural crop is quite a complex multifactorial task that requires the presence and application of specific and narrowly focused knowledge, as well as practical experience of its application. In addition, periodic analysis of reference information on new crops varieties and hybrids allowed cultivation in the planned region in Russia and the results of their state variety testing is necessary. If the set of the above factors is too common, there is a high risk of wrong selection, which leads to decreasing possible profits.

The conducted analysis of the selective inventions of main crops varieties and hybrids that were included into the State register [11] for the period from 2014 till 2018 made it possible to obtain the following achievements: over the past five years, originators have introduced 607 varieties and hybrids of the main crops allowed cultivation in the eastern part of Europe, including more than half (314 units) - hybrids of grain maize (including universal orientation), 93 varieties of soft winter wheat, 52 varieties of spring barley, 33 varieties of peas, 32 hybrids of winter rye, 23 varieties of soft spring wheat, 16 varieties of spring oats, 15 varieties of winter barley, 10 varieties of hard winter wheat, 9 varieties of millet, and only 5 varieties of buckwheat and hard spring wheat (less than

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1% of the total number of varieties of these crops introduced in the State register of selective inventions of the Russian Federation for the last 5 years).

Therefore, in the framework of implementing the first stage of the study, the researchers of All-Russian Research Institute of Agriculture and Soil Protection from Erosion -- structural division of ``Kursk Federal Agricultural Research Centre'' have developed an application software ``Program for science-based selection of varieties and hybrids of crops'' [16] in the form of a computer program, Web application and apps for smartphones in order to provide agricultural producers with correct and relevant information about the existing varieties and hybrids included in the Register of selective inventions and approved crops for cultivation in the eastern part of Europa. This application software is available for free use on the website http://alimlios.beget.tech/ and in the android app store Google play market (Crops: selection of varieties and hybrids). Moreover, if we talk about the mobile application, this is the first domestic development of the state budgetary institution in the field of agriculture and crop production for mobile electronic devices with the Android operating system (Figure 1).

In the standard operating mode, an authorized user of a stationary personal computer or mobile device with the Internet access goes to the website http://alimlios.beget.tech/ and or downloads the application (Crops: selection of varieties and hybrids) and can choose from 8 items (peas, buckwheat, grain maize, spring oats, millet, wheat, winter rye, barley). Then, a user specifies the necessary values of features for the varieties or hybrids of the selected culture and gets a list of recommended varieties/hybrids of crop culture for the selected region of the European part of the Russian Federation (with the opportunity to find out more about them).

The further stage of the research was to develop a problem-oriented database of agricultural producers' support system for the rational choice of highly profitable adaptive technologies of crops cultivation. The structure of this database included the following units: unit of initial (input) information, unit of normative information, unit of calculation algorithms.

One should note that in the process of adaptation of agricultural technologies to the existing natural and climatic features of the landscape, it is necessary to clearly differentiate each agricultural method, according to the appropriateness of its application under the current conditions [12]. Therefore, it is necessary to reliably fill in the unit of initial information, since the basis of adaptive agricultural technology is formed with the help of these indicators when using the unit of normative information. Moreover, if the unit of agro-climatic indicators is primarily used to assess the compliance of the existing natural conditions to the comfortable growth of crops, then, for example, the natural

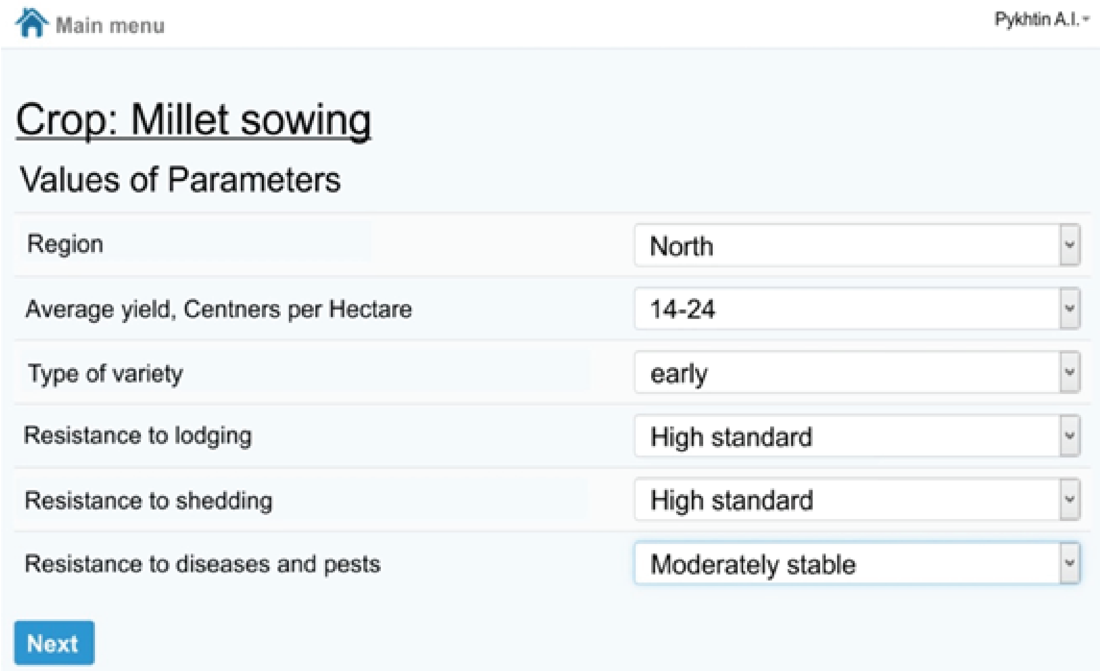

Figure 1: Software for a scientifically based selection of varieties and hybrids of crops for the climatic conditions of the eastern part of Europa.

and climatic zone, slope exposure and humus content are used to determine the level of the basic yield of an agricultural technology.

In its turn, the unit of normative information consists of 6 main criteria which determine efficiency and resource-saving orientation of agricultural technologies: costs of live labor (per man-hour), costs of fuel and lubricant materials (kg), need for fertilizers (kg of active material) and pesticides (liters or kg), machine capacity (hectares per hour or tons per hour) and power demand (kW per hour). When filling the block of normative information and determining the values of the needed crops criteria, there were used regional registers of agricultural crops cultivation technologies (for example, the Register of cultivation technologies of grain, leguminous, cereal and oilseeds crops in the Volgograd Region [13] or the Register of cultivation technologies of crops for the conditions of the Vladimir Region [14]) were used.

Traditionally, any technology of agricultural crops cultivation includes several groups of agricultural methods: methods for basic tillage, methods for secondary tillage and sowing, methods for crop tending, methods for protecting plants from weeds, diseases and pests, techniques for harvesting and primary processing of output products. If we assume that each unit can have three solutions, then within one agricultural technology there may be 35 or 243 options possible. In fact, there may be much more due to different variations of auxiliary agricultural methods. The use of adaptability principle contributes to the quantitative reduction of possible variations, and the identification of the most profitable of them allows agricultural producers obtaining the greatest profit in terms of spent resources. The database assumes the presence of regulatory information for each unfavorable item to calculate the resource requirements for this or that agricultural technology, as well as to identify the most profitable option. Such regulatory information implies the availability of extensive background information (Data Bank), the formation of which was also carried out within the current tasks of our study [15].

The unit of calculation algorithms is represented by three algorithms: rational choice of adaptive technology of crop cultivation (for selected conditions), approximate calculations of economic and energy efficiency of agricultural technologies.

We have also made a mathematical operation model of this support system. We are finishing works on the development of a computer program algorithm and on filling the data bank of agricultural machines, tools and units.

4. Conclusion

Thus, the practical application of the ongoing studies' results will allow the expert organizations being involved in scientific and technological support of agricultural producers to use advanced methodological approaches for solving problems in the selection of an adaptive technology or a specific agricultural method in the cultivation of basic crops, or any variety/hybrid of cultivated crops. Research organizations that are interested in the development of similar expert systems will be able to use a well-established database, as well as a mathematical model of the algorithm for the rational choice of an agricultural technology for other groups of cultivated plants, or for other soil and climatic conditions.

The use of the developed support system for the rational choice of highly profitable adaptive crop cultivation technologies by agricultural producers will allow us applying scientifically-based agrotechnological solutions both in the design and in the implementation of resource-saving agricultural methods during the entire cycle of wheat and barley(spring and winter varieties), peas, buckwheat, grain maize, oats, millet and winter rye cultivation in agricultural technologies of different levels of intensity.

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Conflict of Interest

The authors have no conflict of interest to declare.

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