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Monitoring and methods for seed quality assessment using modern technical means and digital technologies

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Abstract. The problems of the state and development of digitalization of agricultural technology management, problems in the development of digital innovations in agricultural enterprises and ways to solve them at the present stage are reviewed in the study, based on reviews of scientific publications by Russian scientists and information from Internet resources, examines. Development of geo-information technologies for crop production: electronic maps of fields, equipment monitoring systems, complexes for designing technologies for crops growing, databases of conditions and functions of agricultural landscapes (books on the fields history), methods for seed quality assessment using modern tools and technologies have been introduced.

1 Introduction

Currently, modern methods in agriculture are being actively developed. These methods can replace traditional technologies with advanced production. Through the use of various sensors and automated control devices (for example, weather monitoring, animal health sensors, position sensors), valuable data that will help determine patterns in the growth and development of plants and animals, as well as in the operation of agricultural machinery can be extracted. In its' turn it allows to control the basic processes in agriculture and strive to improve them.

According to experts, during the season farmers have to make more than 40 different decisions: what seeds shall be sow, when and how to treat them, how to fight sicks and other plants in a limited period of time. Many of these solutions are subjected to digitization. According to the Ministry of Agriculture, Russia takes 15th place in the world

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in terms of the level of digitalization of agriculture, and the market for information and computer technologies in the industry is estimated at 3600 billion rubles [1-3].

2 Problem statement

Despite the fact that national agricultural production indices have increased due to import substitution, the efficiency of domestic agriculture remains significantly lower than in the world's largest economies.

In Russia, the total cost of agricultural production per worker in 2015 was US $8000, in Germany – US $24000, and in the USA – US $195000.

Among the problems existing in the field of information technology (IT) in the agricultural sector there are an acute shortage of personnel (specialists) and dependence on imported technologies (about 95% of agricultural machinery is foreign).

In our country, only 10% of arable land has been transformed using digital technologies [4-6].

Ignoring new technologies can lead to a reduction in yield of up to 40%. The market share of digital technologies in agriculture is projected to grow every year as the desire to close the technological gap with developed countries becomes more urgent.

The industrial computing and information technology market is expected to grow by at least five times by 2026 [2, 4, 7-8].

"Project “Digital Agriculture” of the Russian Ministry of Agriculture [9] is intended to develop broadband access networks and telemetry infrastructure, which will become a key technological components of standards of Internet of Things and of logistics for the supply and delivery of agricultural products to consumers. This initiative was proposed by the department. According to the roadmap of the National Technology Initiative (NTI), the smart agriculture strategy, which includes automation , artificial intelligence and big data, will receive significant support from Russian companies [10, 26]. Domestic digital agricultural solutions such as “smart farm”, “smart field”, “spark herd ” and “a kind of greenhouse” will be scaled up. In addition, it is planned to create fifteen integrated digital solutions for agriculture. The limited experience of Russian technology suppliers in creation, implementation and operation of technological solutions, as well as a strong dependence on imports , are the main obstacles to the development of the Internet of Things. Associated limitations include low technology readiness, high cost, and little visible economic benefit from their use [2, 11-12, 21].

3 Research questions

The purpose of the study is to assess the quality of seeds using modern technical means and digital technologies to increase the yield of field crops.

Seed quality is a vital aspect of the early life cycle of plants, and its maintenance and reproduction over generations is critical since seed quality plays an important role at these stages. The best development of plant productivity and resistance can be achieved by obtaining the high quality seeds with good starting potential. The quality of seeds is determined by their formation on the mother plant by the sowing process. Seed quality is affected by post -harvest processes, including storage conditions. Currently, in the field of seed production, scientists are delving into the issues of determining quality (phenotype), determining its properties and accurately assessing it.

In agriculture, the practicality and relevance of this problem determine its relevance. In accordance with domestic terminology, seeds are classified as seed material according to their sowing characteristics and yield properties. For example, GOST 1203781 determines such sowing qualities as freedom from weeds, infestation with diseases and pests, germination and energy level. The ability of seeds to form plants that produce high yields is called yield capacity. Currently, the concept of seed quality is recognized in the English-language scientific literature. International seed laboratories evaluate the quality of their seeds by examining such factors as impurities weed content, pathogen infestation rate , germination ability and co-occurrence of bacterial species. These measures apply to all types of seeds. The physiological aspect of seed quality is determined by indicators that describe the likelihood and rate of plant germination, and the term "physiological quality" is commonly used for this purpose. Seed yield capacity is a measure of their physiological quality. First, germination quality is tested before it can be used for physiological seed evaluation. Viability is primarily assessed by its ability to germinate, which refers to the state of the seed, whether it is alive or dead.

Stressors first affect seedling occurrence and then cause changes in seed growth rate and plant productivity. Despite the fact that tall seeds are more susceptible to adverse environmental conditions and are more likely to germinate in the field and while short seeds germinate better in the field, laboratory-grown seeds may not demonstrate similar properties. Taking into account the information presented above, the use of methods that allow to assess the physiological quality or in vitro vigor is of high practical importance.

4 Materials and methods

The quality of seed material and its yield can vary significantly depending on its quality. This is confirmed by a number of experiments conducted in natural and artificial conditions. Particularly interesting is the analysis of data obtained during precision and mass experiments, where the effects (stimulating or inhibitory) on seed material with different quality levels are studied. Approximately 20-25% of the results of these experiments are due to the individual characteristics of each individual specimen. The variability of seed material is a consequence of various factors, such as matrix, environmental, seasonal, trophic and others, which makes it a constant characteristic of agriculture [13, 22-23].

Experts believe that Internet of Things technologies can be a key factor in increasing agricultural productivity. This will be a real breakthrough, comparable to the invention of tractors, herbicides and genetically modified seeds. Agriculture is undergoing a digital revolution, moving from the analogue to the digital era. Goldman Sachs predicts that the use of advanced technologies in agriculture could increase productivity worldwide by 70% by 2050. To achieve this, data began to be actively used in industries that were previously far from the IT sphere. The largest agro-industrial and engineering companies rely on digitalization and automation of the maximum number of agricultural processes in their development strategy.

5 Results

According to a study conducted by J'son & Partners Consulting, the leading players in the world of the agro-industrial complex are investors whose priorities are formed around future investments including:

- Useful data and statistics – 46%.
- Nutrition and protection – 29%.
- Modern technologies or biotechnologies – 29%.
- Management and optimization tools – 27%.
- Devices for communication, accounting and data collection – 25% [6].

The share of the digital economy in the Gross Domestic Product (GDP) of the G20 countries for the period from 2010 to 2016 shall be considered. In Russia, this part will be 2.8%, which will be approximately 4.4 times less than in the UK, and approximately 2.5 times more than in eastern countries, in particular in China, and 2 times more than in the USA, according to a study conducted by the Russian Ministry of Agriculture, conducted by The Boston Consulting Group. Forecasters and experts note that the modern and digital economy can possibly lead to an increase in gross domestic product of almost 1.8% for progressive countries and 3.14% for countries with growing economies by 2020. In 2016, Russian organizations received three times more new technologies and software than in 2010. The total volume of inventive products based on various technological advances increased by 3120 billion rubles. Data provided by the Analytical Center of the Russian Ministry of Agriculture shows that the introduction of digital economy technologies leads to positive economic results and to possibility of costs reduction by at least 23% while applying a comprehensive strategy.

In 2017, the actual volume of agricultural production is estimated at 3033 billion rubles. At the same time, the volume of agricultural production using digital technologies reaches 3227 billion rubles. It is important to note that the projected growth of crop production due to digitalization in 2018 will amount to 193 billion rubles. Currently, about 113.9 thousand specialists are employed in agriculture in Russia, which is 2.3% of the total number of workers in the agricultural sector. However, to achieve the same results as leaders (such as the USA, Germany and the UK) the country must move closer to their agricultural production figures.

According to the latest data, our country needs an additional 9 million IT specialists in agriculture. The small number of specialists (only about 1000 per employee in the industry) is clearly disproportionate to modern requirements and causes significant problems. It is interesting that the total investment in information technology and communications, according to Rosstat for 2017, amounted to only 3.6 billion rubles. This is only 0.5% of the total investment in fixed assets. Such a minimum undoubtedly indicates insufficient digitalization in the domestic agro-industrial complex and creates an advantage for foreign manufacturers. To achieve its goals and strengthen the national economy, Russia needs to actively encourage and promote the development of the IT sector in agriculture.

The average cost of grain production is on average 6579.5 rubles/ton, and after the introduction of the digital economy - 5066.2 rubles/ton (savings of about 30%).

In the agro-industrial complexes of different countries, there are different indicators of innovative products. According to data from the Higher School of Economics, Spain holds the leading position with a share of 12.7%, followed by Denmark with 11.6% and the Netherlands with 9.2%. However, Russia still lags significantly behind with a share of innovative products of only 1.4%. In the agricultural sector, the use of elements of the Internet of Things (IoT) can also be highlighted. According to the Institute of Agrophysics of the Russian Academy of Sciences, only from 0.05% to 5% of Russian agricultural producers have already used this innovative solution.

For comparison, up to 60 % in the US and up to 80 % in the EU. Consciously or not, about 10% of Russian agricultural enterprises, holdings and farms use solutions related to precision farming. This is the result of a survey of more than 200 market participants conducted by Agroinvestor magazine in 2017 [6].

Analyzing the state and problems of the digital economy in the agro-industrial complex based on data from the Analytical Center of the Russian Ministry of Agriculture, the following aspects can be highlighted:

- Low popularity of digital technologies in rural areas and in agricultural production enterprises, where less than 10% of operations are digitized, as well as the lack of effective data transmission channels.

- Lack of information about existing and developing digital technologies, which limits their implementation and effective use in agriculture.
- The need to ensure coordination and cross-sectoral implementation of digital technologies in agriculture plays an important role in improving interaction and information collection. Thanks to this, two important goals are achieved: providing the population with food and increasing the sale of agricultural products to other countries.
- Lack of programs to support the digitalization of agro-industrial complexes for small and medium-sized agricultural producers, as well as personal subsidiary plots. Subsidies on production costs can encourage digital adoption in these sectors.
- Lack of a legal basis for interaction and collection of information on the activities of households introducing agricultural methods. There are also limited opportunities to support these farms.
- Low margins of the agricultural industry, which makes it not attractive enough for investors who are interested in developing technologies and infrastructure.

The purpose of compiling this analysis is to provide information on the current situation and problems of the digital economy in the agricultural sector. This will help identify areas for improving the situation and developing effective development strategies in this industry.

6 Findings

Modern experience, both in our country and in foreign countries, shows that to identify hidden grain defects it is not enough to use classical assessment methods based mainly on visual analysis. To successfully identify such defects, it is recommended to use specialized microscopic instruments, including X-ray equipment, as well as computer processing of images obtained from individual particles.

The advantages of this method are as follows:

- Objectivity of control is ensured due to the difficulty of falsifying X-ray images, it is especially important to use an electronic digital signature.
- Electronic radiographs can be stored for a long time, which is of particular importance when considering arbitration issues.
- It is possible to carry out constant monitoring of grain quality, both during short-term and long-term storage.
- Radiographic indication of potential defects allows you to select control grain samples.

Research carried out by employees of the Rosrezerv Institute for Storage Problems (Agro-Scientific Research Institute), under the leadership of V.I. Isaev in collaboration with experts from the St. Petersburg State Electrotechnical University named after Vladimir Ulyanov (Lenin) [15].

The research was based on X-ray diffraction analysis of grain batches of various agricultural crops. It is important to take these defects into account when storing cereals obtained from various regions of Russia, because the presence of such defects can affect the quality of the cereal and significantly increase losses [16-17, 24-25]. Also, hidden grain defects can negatively affect the phytosanitary situation in the strategically important agricultural sector. During testing at the Reservniy Khleb elevator (Moscow) a complex of hardware and software for X-ray diagnostics of grain and seeds of various field and agricultural crops was successfully tested for the first time in the Russian Federation. This experiment has been carried out in the city of St. Petersburg from December 26 to 27, 2017. One of the main goals of the test was to determine the readiness of technical means of X-ray control of grain (wheat and rye), as well as the corresponding program for use at the Rosrezerv plant. The test was carried out using a mobile X-ray diagnostic device PRDU−02 (ELTEKHMed CJSC, St. Petersburg) [18].

The methodology was tested using the equipment unit with certificate No. 241.0283/RA.RU.311866/2017. PRDU-02. It allows to monitor from several units to several hundred grains in a sample and zoom the image up to 10 times.

The PRDU-02 unit automatically processes X-ray images of grains and identifies their geometric characteristics (length, width, area), fractional composition, fracturing, depletion of enzymatic mycosis and fragility. All these parameters are assessed taking into account their degree of expression [19-20].

While researching the market for specialized X-ray equipment, it was found that the foreign analogue of the PRDU-02 (FaxitronMX-20 installation (USA)) [20] has high characteristics. Moreover, according to the International Seed Testing Association (ISTA), the FaxitronMX-20 has software to automatically detect defects in seed samples and quantify them. However, the price of FaxitronMX-20 is almost 1.5 times higher than the cost of PRDU-02 unit.

Research shows that it is necessary to make additions and changes to technical documents and standards to take into account the integrity of the internal grain structure while assessing the quality of grain lots, taking into account hidden structural defects. It is important to consider the following signs:

- Powerful crushing of the endosperm due to mechanical damage to the grain occurs during harvesting or drying. It is an important feature. It may be associated with increased protein content in cereals.
- Internal germination, may be at an early stage, which usually cannot be detected by other methods. It indicates a partial reduction of endosperm.
- Reduction or depletion of enzymatic mycosis, which is manifested by the hydrolyzing effect of fungal enzymes and internal grain enzymes on the main layer. The feature may indicate a decrease in endosperm substance, a deterioration in its quality and the formation of new toxins that appear as a result of insect activity.
- The damage caused by the beetle is also an undesirable sign. It reflects the hydrolyzing effect of enzymes on the internal and surface layers of seeds.
- Damage to the embryo, which can manifest itself in a decrease in the degree of darkening of its x-ray projection. These signs may indicate possible damage to the embryo by pathogens or its rapid aging, which is especially typical for well-dried grain mass.
- Mechanical damage to the grain or embryo caused by the impact of the working part of the combine on the grain part. These are the movements of the embryo and mechanical separation from each other.
- Unfulfilled grain, a sign of an error in the growing technology and methods of storing grain, this especially appears during long-term storage.

7 Discussion

7.1 Digital microfocus radiography method

These methods for visualizing and assessing structural defects in grain crops demonstrate the potential of digital microfocus radiography in solving both scientific and economic problems. This allows you to clearly evaluate the effectiveness of different technologies for harvesting, subsequent processing and storage of grain.

This approach leads to the following results:

- Determining whether the grain belongs to another variety or to low quality batch, based on hidden damage.

- Giving an optimal solution for combining different batches of grain that do not belong to the class or significantly reduce the class of the newly formed batches.
- Determining storage options and modes for batches of different classes .
- Establishing priority for the use of a specific batch for non-standard replacement.

These methods have enormous potential for improving the efficiency of processes in the grain processing industry and can be used for scientific and practical purposes.

7.2 Method for photoluminescent diagnostics of seeds

A new method for optical and luminescent diagnostics of plant seeds significantly reduces the time for measuring key parameters, including germination, moisture, degree of ripeness and ruminal quality. The developed device based on this method increases efficiency and reduces the analysis complexity, as well as consumed energy and materials. Based on the typical spectral properties of reflection, absorption and luminescence, new safe methods for diagnosing seeds can be created.

Methods and technical means used in optical-luminescent diagnostics of seeds are widely used in experimental research, practical plant growing, and agrotechnical methods. They also make it possible to assess the resistance of seeds to unfavorable factors, evaluate the commercial quality and maturity of seeds, as well as research and grow plants. The use of these methods is also relevant in scientific and environmental research.

Developed new methods and technical means allow:

- To assess the condition of seeds without damage in one measurement.
- To carry out real time measuring without complex equipment and preparation of objects by non-specialists.
- To exclude subjective assessment of the functional state of seeds.
- To use digital technologies to process information.

7.3 Optoelectronic devices

Optical-electronic devices adapted for measuring seed quality parameters, such as excitation sources and luminescence detection receivers, amplifiers, microcontrollers, selected in accordance with the maximum effective radiation power, allow to carry out quick diagnostics in laboratory, field and production conditions, plot the graphs, and also make the right decisions for subsequent actions with the seeds. This is a good idea.

7.4 Agromonitor

The Agromonitor software was created to monitor agricultural machinery and crop cultivation methods. It allows to establish the location of technical equipment on the electronic map of the enterprise, the speed of movement and the route, determine the duration of work, fuel consumption, and the area to be processed. Each point on the moving track has speed data, which also characterizes the quality of work. The report shows the operation and downtime of the unit. It allows to use a time-based payment system, which not only eliminates errors in wage calculations and simplifies the calculation procedure, but also creates conditions for the high-quality performance of technical operations.

The software works with domestic equipment, reduces the cost of equipment configuration and does not depend on imported equipment. In 2018, a unique module for calculation of the cultivated area has been developed. It made it easier to monitor the implementation of the field work schedule, as well as resource consumption per hectare and the transition to a more modern terminal.

Research of agricultural crops using classical methods, including sampling , laboratory analysis and the study of physicochemical properties, takes a significant amount of time, requires considerable effort and does not always allow to obtain the results on time.

The main and important features of digital crop monitoring compared to the traditional method are shown in Table 1.

Table 1. Differences between digital crop monitoring and the traditional method.

Signs	Traditional crop monitoring	Digital crop monitoring
1. Monitoring time	Long and labor-intensive process	Fast process
2. Access to information	Access is not always convenient and often provided not in due time	Convenient access in a timely manner
3. Possibility of physical damage to the studied plants	High probability of damage	Without damage (or with minimal damage while using agricultural equipment)
4. Spatiotemporal analysis of vast, remote territories and interaction with each other	Not available	Available
5. Obtaining final results	Long and labor-intensive process	Fast process

8 Conclusion

The result of studying of scientific and media materials allows us to conclude that the process of digitalization of agricultural management in Russia is progressing continuously, but its development is still at an early stage. Despite significant progress in the scientific and technological field and the emergence of new elements of precision agriculture, robotic equipment, unmanned aerial vehicles, video surveillance and various sensors for agriculture, there are a number of problems associated with software, technical, material and personnel support in the crop production industry, which needs to be addressed in the coming years.

Together with the proposed innovative products, the use of available domestic developments in digital technologies, taking into account their quality and reliability of equipment and software, will allow agricultural enterprises to carry out successful transition to adaptive and precision farming, as well as master new knowledge. This will significantly increase the productivity and efficiency of crop production, optimize the use of resources and production factors, providing a more reliable system of plant protection and nutrition, as well as the possibility of remote integrated management of agricultural technologies.

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