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DIGITAL MANAGEMENT OF COTTON SEED VARIETAL PURITY THROUGH ARTIFICIAL INTELLIGENCE AND DIGITAL SYSTEMS

Mamatqodirov Jahongir Baxtiyor o‘g‘li
Basic Doctoral Student of the Department of Genetics,
Breeding and Seed Production of Agricultural Crops
Tashkent State Agrarian University

Kholmurodova Go‘zal Ro‘ziyevna
Professor of the Department of Genetics, Breeding and Seed Production of Agricultural Crops, Doctor of Agricultural Sciences (DSc), Professor
Tashkent State Agrarian University

Razzoqova Gulasalxon Aktam qizi
Assistant of International Agrarian University

Abstract
The article highlights the processes of digital management of cotton seed varietal purity through artificial intelligence and digital systems using the example of Kuva district. During the research, a management dashboard for seed production processes was developed. In this system, calculations of average yield, varietal purity, rejected plants, and seed germination were carried out. Through the developed software, seed batches, varietal purity and quality control, rejection and warning systems, as well as QR code scanning were implemented.

Keywords: Cotton, seed, varietal purity, artificial intelligence, digital systems, digital management, cotton fiber, productivity, fiber output.

Introduction
Relevance and necessity of the dissertation topic. Globally, cotton cultivation and seed production are of strategic importance. In 2023, the total cotton plantation area worldwide exceeded 30 million hectares, while annual cotton fiber production

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reached 25 million tons. The United States, China, India, Pakistan, Brazil, and Uzbekistan are among the leading cotton-producing countries. However, due to climate change, declining soil fertility, and the impact of pests and diseases, reductions in cotton productivity have been observed. A digitalized primary seed production system plays an important role in solving these problems. For example, in the United States and China, digitalization of seed production processes based on GPS and GIS technologies is widely applied, enabling higher productivity and improved product quality.

In Uzbekistan, cotton is cultivated on approximately 1.2 million hectares, and annual fiber production amounts to 800–900 thousand tons. Significant efforts are being made in the digitalization of cotton breeding and seed production. At Tashkent State Agrarian University, research is being conducted on breeding cotton varieties resistant to unfavorable environmental factors using GIS (Geographic Information System) technologies.

The database formed through digitalization facilitates further scientific research. Preservation and improvement of cotton seed varietal purity is one of the most important factors in ensuring high-quality agricultural production. Digital technologies, particularly artificial intelligence (AI), create new opportunities for determining and monitoring seed quality. This study demonstrates the possibilities of evaluating cotton seed quality and preserving varietal purity through digital systems and AI technologies in Kuva district.

Purpose of the research

The purpose of the research is to systematize primary seed production processes of medium-fiber cotton through digital technologies and to create a database of valuable breeding materials consisting of high-yielding families and lines with superior fiber quality and fiber output by digitalizing existing data.

Research objects

The research objects included complex families and breeding lines belonging to *G. hirsutum L.*, while the varieties Andijon-36 and SP-7303 were used as standard cultivars. The breeding lines T-445/18, T-580/18, T-230/18, and T-125/18 were also utilized in the experiments.

Research results

Digital management of cotton seed varietal purity based on artificial intelligence and digital systems was one of the main objectives of the study.

During the research, the following tasks were accomplished:

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- seed quality was evaluated using artificial intelligence;
- varietal purity preservation and production efficiency were improved through digital systems;
- new approaches were developed based on practical experiments conducted in Kuva district.

Artificial intelligence algorithms were used to assess seed quality. Data related to seeds were collected and analyzed with the help of AI. Technologies applied for digitalizing primary seed production processes in cotton cultivation were studied, and activities on preserving varietal purity, creating a valuable breeding material database, and managing breeding resources through digital systems were implemented.

As a result of artificial intelligence application, the efficiency of evaluating cotton seed quality significantly increased. AI algorithms facilitated preservation of varietal purity and quality control of seeds.

The studies demonstrated that digital systems and artificial intelligence serve as effective tools for preserving and improving cotton seed varietal purity. It is recommended to expand the technologies implemented in Kuva district and apply them in other regions as well.

Primary seed production processes in cotton cultivation constitute essential resources for future agricultural development. However, these processes are still largely conducted using traditional methods, limiting efficiency. Modern scientific research and technologies, including the Internet of Things (IoT) and artificial intelligence, open new opportunities for improving seed quality and increasing productivity.

It should be emphasized that the novelty of the research lies in creating a valuable resource database and developing digital platforms through advanced technological solutions. This work is aimed at implementing digital transformation in agriculture and scientifically analyzing its effectiveness.

Through digital technologies, IoT devices and sensors make it possible to monitor seed quality. Such technologies can also be effectively applied under the conditions of Uzbekistan, as innovative technologies play a crucial role in increasing agricultural productivity.

During the study conducted in Kuva district, IoT devices and sensors were used to analyze seed quality and production processes in cotton cultivation. Soil moisture, temperature, and other parameters were measured using sensors.

A digital platform was developed to manage the collected data and valuable breeding materials. Through this platform, all information was centrally stored and analyzed.

The contribution of digitalization to primary cotton seed production processes was identified, and the following results were obtained:

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- IoT sensors enabled real-time monitoring of seed varietal purity and quality;
- digital systems ensured accurate and efficient management of seed sowing and cultivation processes;
- a digital platform simplified the management, storage, and distribution of valuable breeding materials.

This research proposes new approaches for introducing digital technologies into agriculture in Uzbekistan.

Below are presented the initial, second-, and third-year varietal purity indicators and the results of individual and sample harvest nursery analyses of the cotton varieties Andijon-36, included in the State Register of Agricultural Crops Recommended for Cultivation in Uzbekistan, and SP-7303, recommended as a promising variety. In these studies, a digital system for managing cotton seed varietal purity was applied.

Today, worldwide, digitalization of breeding processes in primary seed production, especially in cotton breeding, is considered highly important for developing resistant varieties, creating databases of genetically valuable breeding materials, developing breeding forecasting mechanisms, and simplifying selection processes.

Analysis of advanced global practices and technologies shows that the current situation in Uzbekistan's cotton seed production and breeding sector is characterized by the continued widespread use of traditional methods. In some cases, data are still stored on paper, increasing the risk of information loss and errors.

In recent years, serious attention has been paid to introducing digital technologies into agriculture. However, the widespread application of innovative technologies remains insufficient. Uzbekistan is one of the world's major cotton-producing countries, making this sector an important field for scientific research and digital innovation. Research institutions and scientific centers are conducting studies aimed at developing new and resistant cotton varieties.

The main existing problems include:

- the absence of a unified digital database;
- limited technologies for creating and preserving genetic databases;
- low levels of automation in breeding processes.

Globally, digital technologies are widely used to form genetic databases. For example, CRISPR and bioinformatics technologies make it possible to accelerate forecasting processes.

Agriculture, particularly cotton seed production, requires significant resources, and therefore active use of digital technologies is essential for improving efficiency. Traditional methods of managing cotton seed production in Uzbekistan are often based on limited information. Therefore, digitalization of field records, automation of

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calculations, climate forecasting, and implementation of artificial intelligence can significantly improve efficiency. Studies conducted in Kuva district demonstrated the effectiveness of these technologies.

Optimization of cotton seed production processes through digital technologies was also one of the primary objectives. In this regard, field notebooks were digitalized, economic calculations were automated to preserve varietal purity and improve efficiency, and artificial intelligence was used to forecast climate changes and create optimal growing conditions for cotton plants. A unified digital database was formed by collecting and analyzing information about seeds and soil conditions.

As a result of field notebook digitalization in Kuva district, information about seeds, soil conditions, climate, and other parameters was entered into a digital system.

Automation of calculations enabled automatic computation of seed prices, production costs, and other economic indicators.

AI-based databases were established by analyzing seed quality and soil conditions through intelligent algorithms.

The digitalization of field records enabled all information related to cotton seed production processes to be stored in a digital system and analyzed rapidly. Automation of calculations simplified cost estimation and reduced production expenses. Climate forecasting systems made it possible to ensure optimal growth conditions. AI-based databases facilitated collection and analysis of information about seeds and soil conditions, enabling more accurate forecasting.

The studies demonstrated that digitalization of field records and automation of calculations create opportunities for effective management of cotton seed production processes.

The system entitled “CottonSeed Digital Lab – A New Paradigm of Cotton Seed Production” was developed (see Figures 1–10).

Conclusions

As a result of the research:

defective seed batches are now identified and removed in a timely manner; varietal purity is determined using AI technologies;

continuous information exchange between breeders and seed producers has been established;

agro-factors are analyzed in real time;

scientific conclusions are automatically generated based on morphological observation tables.

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A management dashboard for seed production processes was developed during the research. The system included calculations of average productivity, varietal purity, rejected plants, and seed germination.

The developed software includes information on seed batch germination, moisture content, fiber output, and varietal purity.

The program also enables management of seed batches, varietal purity and quality control, rejection and warning systems, and QR code scanning.

Morphological observations, agro-factor analysis, AI assistants, reports, and databases are integrated into the software system.

It should be noted that digitalization processes are particularly important for preserving genetic diversity, developing resistant varieties, and improving breeding forecasting mechanisms. To achieve significant results in this field within the republic, it is necessary to eliminate existing problems, introduce modern technologies, and expand scientific research.

In the individual selection nursery of the Andijon-36 variety, 120 best families with 100 bolls each were selected for sample harvest analysis. In the SP-7303 variety individual selection nursery, 118 sample harvests were collected.

The obtained samples were analyzed under laboratory conditions and submitted to the Republican Quality Center. Based on the indicators provided by the Quality Center, analyses of micronaire, fiber length (inch), and fiber strength (g/tex) characteristics were conducted.

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