

**The use of artificial intelligence in the fight against wheat rust:
A case study of the startup Farm AI**

Dib Salsabil^{1♦}, Laifa Abdelhak ²

¹Setif 1 University -Ferhat Abbas (Algeria),
dib.salsabil@univ-setif.dz

² Setif 1 University -Ferhat Abbas (Algeria),
abdelhak.laifa@univ-setif.dz

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Abstract:

This research paper aims to highlight the role of artificial intelligence in combating wheat rust disease by reviewing the experience of the startup Farm AI. To achieve the research objective, the focus was on evaluating the effectiveness of the Farm AI application in the early detection of wheat rust disease and assessing its impact on agricultural decisions related to spraying operations and identifying infected areas. This application was also compared to traditional methods in terms of efficiency and cost. Through this research paper, we concluded that applying artificial intelligence techniques in combating agricultural diseases significantly contributes to improving crop productivity and managing crops more effectively, thereby helping to address the agricultural sector's challenges.

Keywords: artificial intelligence, Farm AI, wheat rust, smart agriculture, early disease detection.

JEL Classification:Q10 ,Q13 ,Q16 ,Q55

♦ Corresponding author

1.Introduction:

1.1Preface:

Wheat is considered one of the most important crops in the world, due to its vital role in feeding the global population and in the production of bread and many other food products. With the challenges posed by climate change, wheat cultivation faces significant threats, the most notable being the spread of fungal diseases such as wheat rust, a serious fungal disease that directly threatens agricultural production and food security. These diseases cause substantial losses for farmers and negatively affect crop quality, leading to a decline in production and an increased reliance on imports.

In light of these challenges, Algeria stands out as one of the main wheat-producing countries in Africa. It ranked second on the continent in terms of wheat production for 2023, with a production of 7 million tons during the 2022-2023 season, while its annual wheat consumption reached 11.4 million tons, according to reports from the official Algerian television. These figures indicate that Algeria is close to achieving self-sufficiency in durum wheat, as it produced 80% of its annual needs during this season, reflecting the efforts made to develop the agricultural sector.

In this context, there is an increasing need to adopt modern agricultural techniques to overcome the challenges facing wheat cultivation and ensure the sustainability of agricultural production. Farm AI, a startup company, emerges as an inspiring model in this field, as it works to employ artificial intelligence technologies to develop innovative and effective solutions to combat wheat rust and improve the efficiency and productivity of crops. Through these technologies, the company aims to empower farmers to maximize the benefits from their resources, reduce their losses, and enhance the quality of their production.

1.2 Research Problem:

In light of the above, the following question can be raised:
How can the startup application Farm AI, based on artificial intelligence, effectively contribute to combating wheat rust disease?

1.3 Research Hypotheses:

This problem leads us to propose the following hypotheses:

- The use of artificial intelligence in analyzing environmental and health data of plants can improve the ability to detect wheat rust disease in its early stages, thereby reducing the spread of the disease and increasing the effectiveness of preventive measures.
- Artificial intelligence can help identify the epidemiological patterns of wheat rust disease by analyzing historical and environmental data, predicting the disease's future spread, and taking targeted preventive actions.
- Artificial intelligence can enhance the development of targeted therapeutic techniques for wheat rust by improving the selection of fungicides and determining optimal dosages, reducing treatment costs, and increasing production efficiency.
- Artificial intelligence can improve crop management by developing predictive models based on multiple data sources, helping farmers make agricultural decisions based on accurate information and reducing losses caused by wheat rust disease.

1.4 Importance of the Research:

This research aims to study the possibility of using Farm AI technology for the early detection of wheat rust disease and evaluate its impact on agricultural decision-making. This research is part of the ongoing efforts to improve agricultural production and protect food security, especially in light of the challenges facing the agricultural sector in many countries.

1.5 Research Objectives:

This research aims to achieve several main objectives:

- To study the effectiveness of Farm AI technology in the early detection of wheat rust disease with high accuracy.
- To evaluate the impact of this technology on agricultural decision-making, such as determining the timing of pesticide spraying and identifying affected areas.
- To compare this technology with traditional methods of disease control in terms of efficiency and cost.

1.6 Research Methodology and Data Collection Tools:

In our research on this topic, we relied on:

The descriptive analytical approach as it is suitable for such research, by identifying the phenomenon of wheat rust and attempting to define its specific concepts. Additionally, this approach allows us to analyze the data and information collected from the institution under study. We also relied on a set of study tools, represented in scientific observation and personal interviews.

2. Wheat Rust Disease and Its Impact on Agricultural Production

Wheat rust disease is considered one of the most dangerous fungal diseases threatening wheat crop production worldwide. This disease spreads rapidly and causes severe losses for farmers, negatively affecting global food security, and significantly reducing wheat yields and economic revenues worldwide. In this section, we will discuss in detail the nature of this disease, its causes, the mechanism of its spread, and finally its devastating effects on agricultural production.

2.1 Nature of the Disease and Its Causes:

2.1.1 Definition of the Disease:

Wheat rust is a fungal disease that affects the leaves and spikes of the wheat plant, caused by fungi belonging to the genus *Puccinia*. This disease results in the appearance of orange or black spots on the leaves and spikes, leading to weakened plants and reduced productivity. Wheat rust can cause significant crop losses, directly impacting food security and agricultural production.

2.1.2 Types of Wheat Rust:

The main types of wheat rust include several forms, each characterized by its own symptoms and methods of spread:

- Leaf Rust (*Puccinia triticina*): Also known as brown or orange rust, it appears as brown or orange spots on the surface of the leaves. This type of rust can reduce the plant's leaf area, weakening its ability to photosynthesize and decreasing its productivity.
- Stripe Rust (*Puccinia striiformis*): Known as yellow or striped rust, it is characterized by the appearance of yellow stripes on the spikes. This type of rust reduces the quality of the

grain and its ability to grow properly.

- Stem Rust (*Puccinia graminis*): Known as black rust, it appears as black spots on the stem and roots. This type of rust is considered one of the most harmful, as it can destroy large parts of the plant and lead to a sharp decline in productivity.

2.1.3 Causes of the disease:

The causes contributing to the spread of wheat rust are numerous, among the most prominent are:

- Weather factors: High humidity and elevated levels of gases in the atmosphere, along with rising temperatures, enhance the growth and spread of fungi. Additionally, excessively low temperatures during winter can lead to the spread of yellow rust. These conditions create a favorable environment for fungal development, with the ideal temperature range for fungal spore development being between 15 and 22 degrees Celsius, with an optimal temperature of 20 degrees Celsius. The disease requires a period of high humidity lasting from 6 to 8 hours for the symptoms to develop significantly.
- Susceptible varieties: The cultivation of wheat varieties that are not resistant to the disease increases the likelihood of infection. Susceptible varieties are less capable of resisting infection, allowing fungi to spread more easily.
- Infected seeds: Infected seeds can carry fungal spores and transmit them to new fields. Contaminated seeds are a major source of disease transmission to new agricultural areas.
- Crop residues: Residues from infected plants are a major source of infection. These residues provide a suitable environment for fungi, increasing the chances of disease spread to healthy plants.

2.2 Mechanism of Disease Spread:

The mechanism of wheat rust disease spread is a vital element in understanding how to control it. This mechanism involves several processes that contribute to the widespread outbreak of the disease.

2.2.1 Spore Dissemination:

The fungal spores are transmitted by wind and insects to the leaves and ears of wheat plants, where a new life cycle of the disease begins. Spores can spread over long distances, ranging from 200 to 2400 km, depending on wind direction and intensity. These factors contribute to expanding the range of the disease to new areas far from the original source of infection.

2.2.2 Spore Formation:

After infection occurs, new spores form within the infected plant tissues. These spores mature and spread to neighboring plants, leading to further disease outbreaks. Spores are considered the primary source of secondary infections, as they contribute to the continuation of the disease cycle and its widespread dissemination.

2.3 Effects of the disease on agricultural production:

The effects of wheat rust disease on agricultural production are significant issues that require considerable attention. These effects manifest in multiple aspects, including:

2.3.1 Production losses:

Wheat rust disease causes a reduction in the area of green leaves, which play a crucial role in the process of photosynthesis. This leads to a decrease in grain production, as leaf rust is one of the most damaging types of rust, potentially resulting in grain losses of up to 50% or more.

2.3.2 Deterioration of grain quality:

Infection by the disease leads to a reduction in grain size and weight, resulting in a decline in quality and nutritional value. Infected grains are less sturdy and more prone to damage, affecting their market quality.

2.3.3 Increased costs:

Combating wheat rust disease requires the use of fungicides, which raises production costs. Additionally, the need for intensive agricultural practices to monitor the disease may contribute to increased management and prevention costs.

2.3.4 Threat to food security:

The widespread spread of the disease leads to reduced wheat production, posing a threat to food security in many countries as a shortage in wheat production can lead to price increases and scarcity in the supply of essential food, directly impacting the food stability of communities.

2.4 Optimal Growth Requirements for Wheat:

Wheat is one of the most important agricultural crops in the world, and to achieve maximum productivity and quality for this crop, optimal environmental conditions must be provided. Wheat cultivation is significantly affected by the availability of suitable climatic elements and soil.

2.4.1 Temperature:

Temperature is a critical factor in wheat growth. Wheat prefers moderate temperatures ranging from 21 to 24 degrees Celsius. This is the ideal temperature range that supports all stages of plant growth, from germination to maturity. However, wheat can tolerate low temperatures down to 4 degrees Celsius during its life cycle, but high temperatures exceeding 35 degrees Celsius may negatively affect its growth and development.

2.4.2 Soil:

Suitable soil is the foundation for producing a healthy and fruitful wheat crop. Wheat requires deep, fertile, well-drained, and well-aerated soil. The soil pH should be balanced, with wheat preferring moderately acidic soil ranging from 5.5 to 5.7. Soil of this type allows wheat roots to grow well and absorb nutrients and water easily.

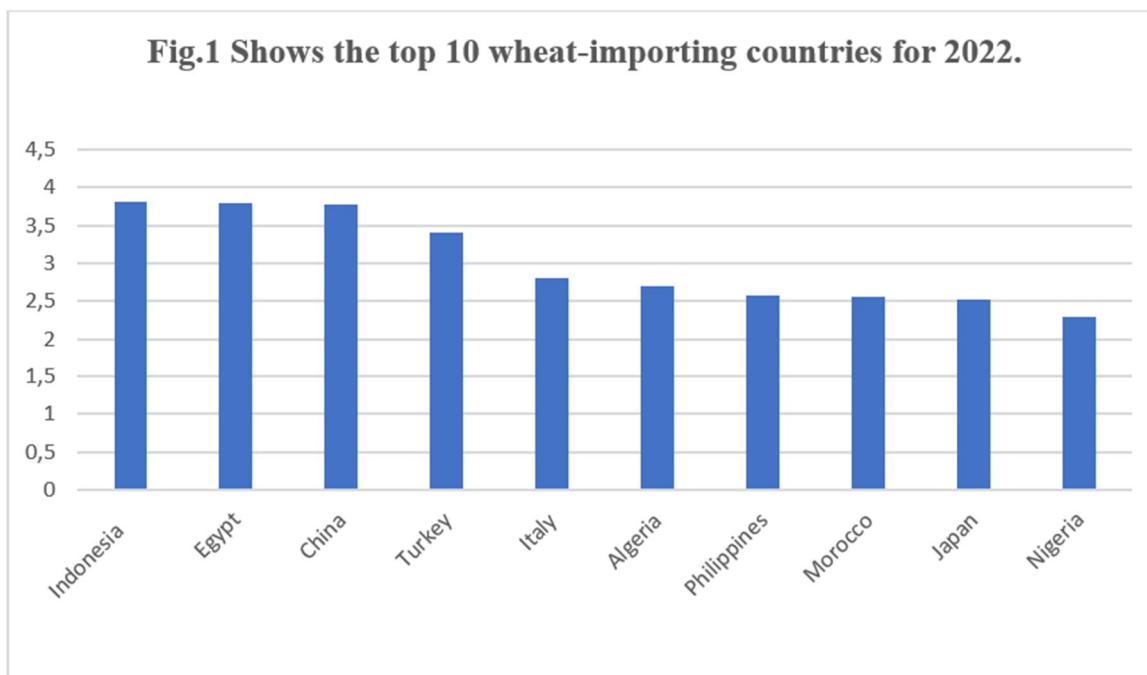
2.4.3 Other Factors:

In addition to temperature and soil, other factors affect wheat growth, such as:

- Light: Wheat needs an adequate amount of light for photosynthesis.
- Water: Sufficient water must be provided for wheat, but over-irrigation should be avoided to prevent root rot.
- Nutrients: Wheat requires a range of essential nutrients such as nitrogen, phosphorus, and potassium.

2.5 Wheat cultivation in Algeria:

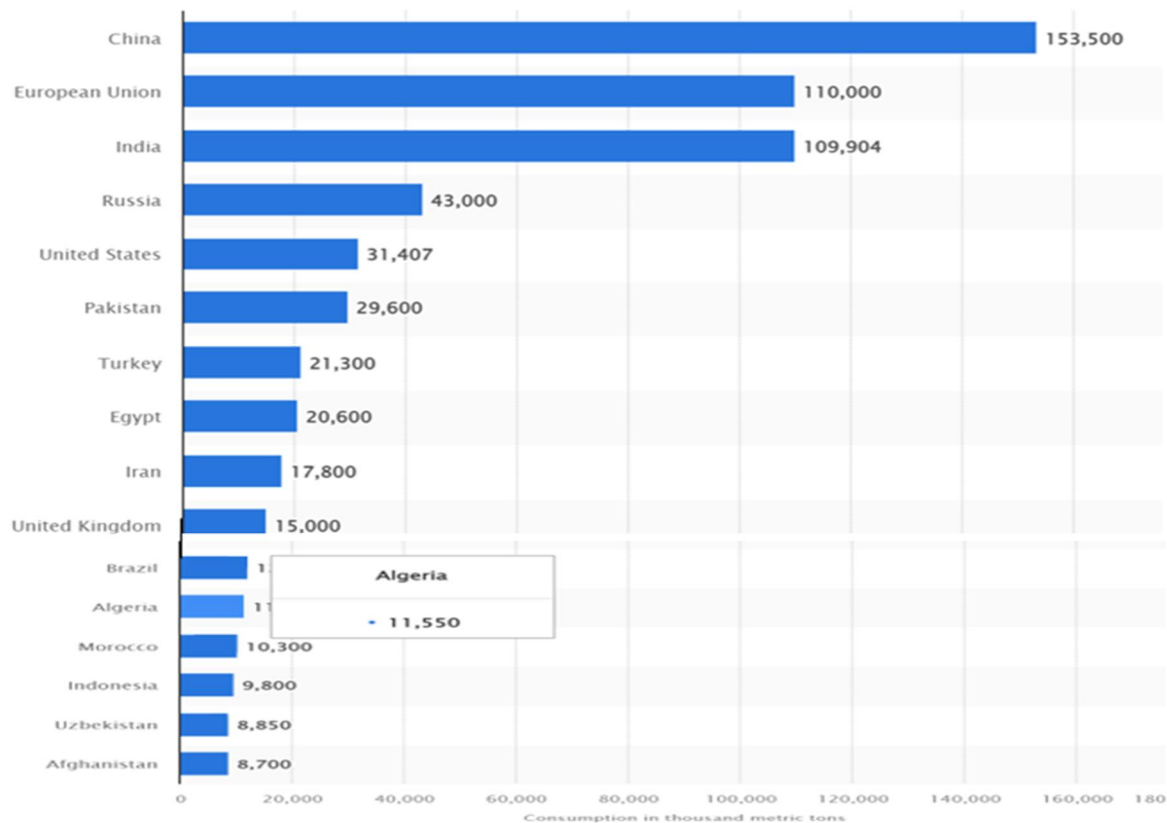
Indonesia tops the list of the largest wheat-importing countries, with imports amounting to \$3.81 billion, representing 5.3% of the total wheat imported globally. It is followed by other countries such as Algeria, which ranks sixth with \$2.7 billion (3.7%), and Nigeria in tenth place with \$2.3 billion (3.1%). This increase in wheat imports is attributed to the population's preference for bread as a staple in the Algerian diet, along with a shortage of local wheat production due to climatic factors, as well as rapid population and economic growth and a lack of agricultural technology in the country, which has led to an increase in imports to meet this local demand.



Source: <https://www.statista.com/search/?q=wheat-&Search=&p=1>. Date of access:14/06/2024

On the other hand, Statista data for 2023/2024 indicates that China is the largest consumer of wheat globally, while Algeria stands out as one of the most important countries consuming this staple commodity, ranking twelfth with a consumption of 11,550 thousand metric tons. This consumption level reflects wheat's vital role in securing food for the Algerian population.

In light of economic challenges and fluctuations in global wheat prices, Algeria's reliance on modern agricultural technologies becomes an option and a strategic necessity to enhance local production and reduce dependence on imports. The shift towards smart agriculture and the use of innovative technologies can significantly contribute to increasing production efficiency, improving crop quality, and reducing the gap between supply and demand, thereby enhancing the sustainability of the Algerian economy and alleviating pressure on financial resources.

Fig.2 Wheat consumption worldwide in 2023/2024, by country (in 1,000 metric tons)

Source : <https://www.statista.com/statistics/1094065/total-global-wheat-consumption-by-country/> Date of access: 21/08/2024

3. Artificial Intelligence and Its Applications in Agriculture:

Artificial intelligence is no longer just a futuristic technology, it has become an integral part of the agricultural sector, contributing to enhancing production efficiency and solving many traditional problems. In this context, we will discuss the applications of artificial intelligence in agriculture, highlighting how it is employed to improve resource management, combat diseases, and increase crop yields.

3.1 Artificial Intelligence:

It is a modern technology that enables machines to simulate human cognitive abilities, such as learning, reasoning, and problem-solving. This technology provides a powerful alternative to human intelligence in various fields, including troubleshooting and decision-making.

When artificial intelligence is integrated with the Internet of Things (IoT), significant improvements can be achieved in the entire food system, from agriculture to food waste management. For example, Farm AI technology can use artificial intelligence to analyze crop data and climatic conditions and provide immediate recommendations to farmers. These recommendations may include how to combat diseases such as wheat rust, helping to improve productivity and reduce losses.

By analyzing images and data extracted from field sensors, the Farm AI system can identify patterns that indicate the emergence of diseases and provide effective strategies to address them. This approach significantly contributes to enhancing agricultural production efficiency and achieving food security.

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3.2 Applications of Artificial Intelligence in Agriculture:

Artificial intelligence techniques are increasingly used in many agricultural fields to enhance efficiency and productivity. Here are some notable applications:

3.2.1 Aerial and Satellite Image Analysis for Crop and Disease Monitoring:

AI techniques enable the analysis of aerial and satellite images to monitor crop conditions and detect diseases early. These techniques provide accurate insights into plant health, allowing farmers to take corrective actions promptly.

3.2.2 Weed Control:

Machine Vision technology is used as part of artificial intelligence for precise weed management. This technology relies on smart sprayers that apply chemicals only to targeted weeds, avoiding other plants. This ensures effective use of agricultural chemicals, reduces damage to crops, and minimizes chemical waste. Additionally, drones are used for pesticide spraying, crop monitoring, and mapping, although their costs are high due to the need for advanced cameras and sensors.

3.2.3 Improving Irrigation and Water Management:

AI technologies contribute to improving irrigation and water management by analyzing field and climate data to provide accurate recommendations on the amounts of water needed for each stage of crop growth. This leads to more efficient use of water resources and reduces waste.

3.2.4 Predicting Agricultural Production:

Methods based on artificial neural networks and genetic algorithms are being developed to map crops and determine their age using historical data on crop cover. Images of wheat in the field are captured, and the system evaluates the crop condition and predicts its productivity. This helps in optimal resource allocation and ensures timely harvesting, increasing the accuracy of crop yield predictions.

3.2.5 Developing Smart Pesticides and Fertilizers:

AI technologies contribute to the development of smart pesticides and fertilizers that adapt to the needs of different crops. These smart products help improve plant health and increase productivity while reducing negative environmental impacts.

4. Traditional methods in combating fungal diseases:

In this section, we will review the most prominent traditional methods used to face the inherent challenges in agriculture.

4.1 Relying on human expertise:

Diseases are diagnosed and treated based on the experience of farmers and agricultural technicians, which in turn relies on visual observation and previous experience.

4.2 Use of insecticides and fungicides:

Chemical pesticides are the most common means of eliminating pests and diseases, but they may leave negative effects on the environment and public health.

4.3 Crop rotation:

This technique aims to break the life cycle of pests and diseases by periodically changing crops.

5. Case Study of the Farm AI Application for Wheat Rust Control

To understand how modern technology can be applied to face agricultural challenges, this study will review the application of "Farm AI" as a practical example that highlights the role of artificial intelligence in combating wheat rust and maintaining agricultural productivity.

5.1 The Startup Farm AI:

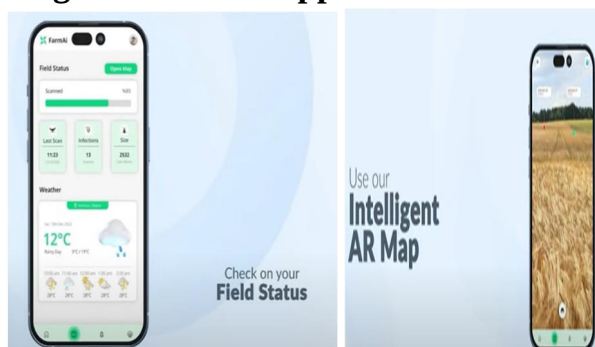
The startup "Farm AI" offers innovative smart solutions based on artificial intelligence for detecting and diagnosing plant diseases, focusing on fungal diseases in agricultural fields. These solutions enable farmers to confront these diseases quickly and efficiently through a smart application that allows them to identify the type of fungi causing the diseases. "Farm AI" ranked second globally among 12,000 competitors from various nationalities in the global "Tech4Good" startup competition, thanks to its innovative solution to the problem of "wheat rust."

5.2 The Smart Application Farm AI and Its Principles of Operation

After understanding the severity of the wheat rust disease and its impact on agricultural production, this section will address a promising technology that can contribute to combating this disease, which is the Farm AI application that relies on artificial intelligence and machine learning to provide innovative solutions to agricultural problems.

A smart mobile application has been developed that specializes in diagnosing fungal diseases in crops. The application supports the English language, and Arabic and the local dialect will be available soon, making it user-friendly for a wide range of farmers. The application provides an alert screen that includes up-to-date information about detected diseases, with details including geographic location, time, weather conditions of the agricultural area, and the percentage of detected diseases, along with the confidence level in the accuracy of the diagnosis, which can reach up to 99%. The application also allows farmers to easily diagnose diseases by taking a picture of the affected plant and offers tailored treatment recommendations for each type of fungus using advanced artificial intelligence techniques.

Fig.3 The mobile application for Farm AI



Source: Source: The startup Farm AI

5.3 Components of the Farm AI System:

The Farm AI system includes several key components that work together to enhance

agriculture through artificial intelligence. These components include:

5.3.1 Cameras:

Cameras are used to capture high-resolution images of crops from different angles. These images are essential for analyzing the condition of plants and detecting any early signs of diseases or pests.

5.3.2 Sensors:

Sensors measure environmental factors such as humidity and temperature, which affect plant growth and the spread of diseases. Data is collected from these sensors along with Internet of Things (IoT) devices, and this data is related to soil, diseases, pests, previous yields, and weather. Sensors sense the surrounding environment and provide accurate information about field conditions.

5.3.3 Software:

The software contains complex algorithms for machine learning and computer vision. This software analyzes images and environmental data to identify the presence of diseases and pests. This helps farmers make informed decisions to maintain crop health and increase productivity with minimal negative impacts.

5.3.4 Cloud Systems:

Cloud systems are used to store and analyze large amounts of data. These systems help convert raw data into useful information that can be used to make the right technical decisions. The cloud provides significant processing power and access to data from anywhere, aiding in improved farm management.

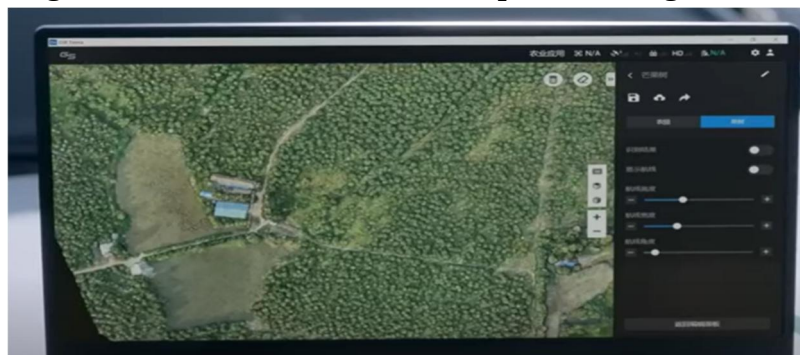
5.4 Mechanism of the Farm AI System:

The Farm AI system operates integratively to collect and analyze data aimed at improving farm management and early disease detection. The operation of this system is carried out through:

5.4.1 Data Collection:

- Image Capture: High-resolution images of crops are collected using cameras mounted on drones. These images are used to assess the health of the vegetation by measuring environmental stress and growth.
- Remote Sensing: AI-supported remote sensing is used to process crop nutrients, crop yield, water stress, soil characteristics, and crop diseases. Environmental sensors gather the necessary data to evaluate the conditions surrounding the crops.

Fig.4 Illustrates the data collection process using a drone.



Source: Source: The startup Farm AI

5.4.2 Creating Detailed Maps:

Farm Maps: Detailed maps of the farm are created to accurately show the affected areas. These maps help farmers and stakeholders make informed decisions based on precise and complex data. Transforming big data into actionable knowledge is a critical step in guiding appropriate agricultural actions, as it can recommend a specific type of pesticide to combat a particular pest or determine the optimal amount of irrigation based on soil moisture conditions.

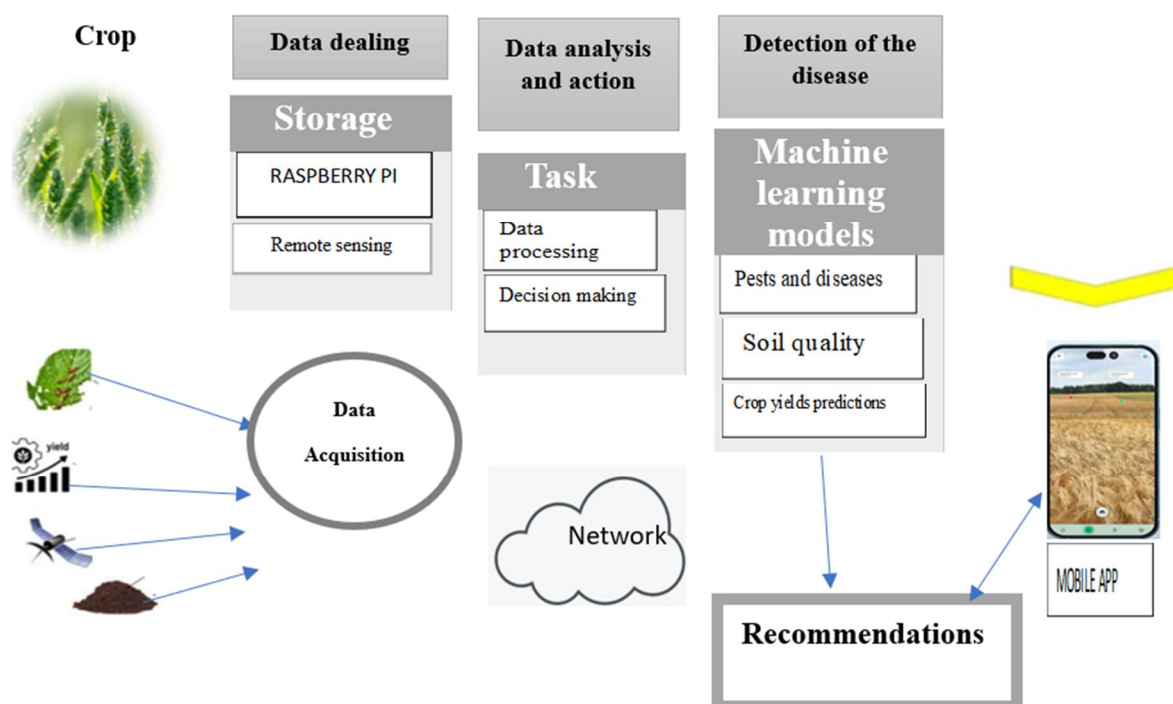
5.4.3 Data Analysis:

- **Using Machine Learning Algorithms:** Images are analyzed using machine learning algorithms to identify areas affected by wheat rust disease. These algorithms extract useful features from the data and provide accurate insights into crop conditions.
- **Extracting Hidden Information:** AI-based analysis enhances the extraction of hidden information within the data, helping to increase overall productivity and provide informed recommendations to farmers.

5.4.4 Disease Detection

Machine Learning Models: The system uses machine learning models trained on a large dataset of images to distinguish healthy leaves from infected ones with high accuracy. This allows for early disease detection, reducing potential damage and improving the chances of timely therapeutic intervention. The following figure illustrates this:

Fig.5 Illustrates the process of the Farm AI system.



Source: Prepared by the researchers based on information from the startup.

5.5 Comparison between the Farm AI application and traditional methods

The Farm AI technology offers many advantages compared to traditional methods in combating fungal diseases, including increased efficiency, accuracy, reduced costs, and environmental impacts. The following table illustrates this:

Table1. Comparison between the Farm AI application and traditional methods

The Standard	Traditional Methods	Application of Farm AI
Efficiency.	May be less accurate and slower in detecting diseases, especially in the early stages.	More accurate and faster in detecting diseases, allowing for quick and remedial actions.
Cost	Lower initial cost, but may require high maintenance costs in the long term.	Requires high initial investments for purchasing hardware and software, but provides lower operating costs in the long term.
Accuracy	Depends on the technicians' expertise and may be prone to human errors.	Depends on data analysis, reducing the likelihood of errors.
Sustainability	May lead to environmental pollution and excessive use of pesticides.	Helps in using resources more efficiently and reduces environmental impact.

Source: Prepared by the researchers based on information from the startup.

6. Conclusion:

The "Farm AI" application is considered an innovative step towards achieving smart agriculture, as it effectively contributes to enhancing agricultural productivity and protecting the environment by employing artificial intelligence technologies. The success of these initiatives and their effectiveness in combating diseases is reflected in the following results:

6.1 Testing the Hypotheses:

Through the interview conducted with "Farm AI" and the studies it carried out on wheat rust disease, the validity of the proposed hypotheses was tested as follows:

6.1.1 Improving the ability to detect wheat rust disease in its early stages:

The "Farm AI" technology demonstrated a remarkable ability to analyze environmental and health data of plants, which contributed to the early detection of wheat rust disease. This early detection significantly reduces the spread of the disease and increases the effectiveness of preventive measures, thus supporting the validity of the first hypothesis.

6.1.2 Identifying the epidemiological patterns of wheat rust disease:

By analyzing historical and environmental data, the "Farm AI" application helps identify the epidemiological patterns of wheat rust disease, enabling predictions of the future spread of the disease and targeted preventive measures. These results confirm the validity of the second hypothesis.

6.1.3 Developing targeted therapeutic techniques for wheat rust:

Artificial intelligence in "Farm AI" effectively contributes to improving the selection of fungicides and determining optimal dosages, leading to reduced treatment costs and

increased production efficiency. These data support the third hypothesis and highlight the role of artificial intelligence in enhancing treatment effectiveness.

6.1.4 Improving Crop Management:

Predictive models based on multiple data sources, developed using artificial intelligence, have proven their ability to enhance crop management. They assist farmers in making agricultural decisions based on accurate information, thereby reducing losses caused by wheat rust, which confirms the fourth hypothesis.

In light of the above, we will attempt to present a set of suggestions:

- Expanding the use of the "Farm AI" application to include different geographical areas suffering from the wheat rust problem, with the aim of achieving the greatest positive impact on agricultural productivity. This expansion could include providing technical support and training for farmers in those areas to ensure optimal use of the application.
- Conducting training and awareness programs for farmers on how to use artificial intelligence technologies such as "Farm AI" in crop management.
- Encouraging collaboration between "Farm AI" and research institutions and major agricultural companies.
- Monitoring and evaluating performance: It is important to establish mechanisms for regularly monitoring and evaluating the effectiveness of the "Farm AI" application in combating wheat rust. These mechanisms may include data collection and analysis to determine the success of the application in achieving its goals and providing recommendations for improving its performance.
- Providing government support for startups working on developing innovative agricultural solutions using artificial intelligence. This support could include funding research and development projects, offering tax incentives, and facilitating access to markets.
- Encouraging farmers to adopt smart agriculture technologies in general, due to their significant role in improving agricultural productivity and protecting the environment. This can be achieved by providing financial or technical incentives to farmers who adopt these technologies.

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