Original Research Article

Research on the sustainable development of the integration of agricultural biotechnology and electronic machinery from the perspective of environmental science

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Abstract: In recent years, the trend of agricultural technology innovation is developing towards the integration of biotechnology and electronic machinery, in order to achieve efficient, accurate and sustainable agriculture. This study explores the sustainability of biotechnology and electro-mechanical integrated agriculture (BEMA) from an environmental science perspective. Firstly, the application of BEMA in agricultural ecosystem and its impact on environment were studied by means of investigation and statistical analysis. Studies have shown that BEMA can bring multiple environmental benefits to agricultural production systems, including resource optimization, circular agriculture promotion, ecological plant protection, and environmental load reduction. Then, through systematic analysis and model construction, this study analyzed the role of BEMA in promoting the efficient use of land and water resources, improving agricultural production efficiency, and mitigating the negative impact of agricultural emissions on the environment. In addition, we also explored the possible paths and strategies to promote the sustainable development of BEMA from the three levels of policy, economy and society. The results of this study will provide diversified and feasible suggestions for agricultural technology innovation and environmental protection.

Keywords: Agricultural biotechnology; Electronic and mechanical integration; Sustainable development; Environmental Science; Environmental protection

1. Introduction

In the new economic environment, agriculture has gone beyond a simple production process and evolved into a complex ecosystem, in which the integration of biotechnology and electronic machinery is becoming a key path to improve agricultural production efficiency, optimize resource use, reduce environmental burden, and promote sustainable development. More than 60% of the world's agricultural ecosystems have adopted this new production mode, namely biotechnology and electromechanical integrated agriculture (BEMA). However, there are still insufficient studies on the deep meaning, specific applications, environmental benefits and sustainable development strategies of BEMA, which undoubtedly limits our comprehensive understanding and understanding of BEMA. It also affects the wide application and further development of BEMA. Therefore, this study attempts to conduct in-depth analysis and discussion of BEMA from the perspective of environmental science, further clarifying its important role in agricultural sustainable development, and providing more comprehensive and in-depth theoretical guidance for agricultural scientific and technological innovation and environmental protection.

2. Background and current situation of the integration of agricultural biotechnology and electronic machinery

2.1. Overview of the concept and development of agricultural biotechnology and electro-mechanical technology

Agricultural biotechnology and electro-mechanical technology are high-tech applications in the field of agricultural production, aiming to improve overall efficiency and achieve sustainable development. Agricultural biotechnology, based on biology, uses genetic engineering, cell engineering, enzyme engineering and microbial engineering to optimize crop varieties, improve soil conditions and enhance crop resistance. Using gene editing technology to create crops with disease-resistant and pest-resistant properties or with high-quality genes, the aim is to reduce the use of pesticides and increase yields.

For electromechanical technology, agricultural production is carried out using electronic control and automation equipment. Sensor technology, remote sensing technology, drone technology, GPS technology and multi-functional agricultural machinery are included. These technologies can achieve real-time monitoring and accurate adjustment of agricultural environmental conditions, for example, through sensors to monitor soil moisture, temperature and nutrient content, can achieve accurate control of irrigation and fertilization, thereby optimizing resource use and improving crop production efficiency. The integration of agricultural biotechnology and electro-mechanical technology, namely biotechnology and electro-mechanical integrated agriculture (BEMA), is an important trend of agricultural science and technology innovation.

This paper discusses the development of BEMA, its important stages and main application fields. From the end of the 20th century to the beginning of the 21st century, biotechnology was integrated into agricultural production, and genetic engineering and crop improvement became a new research trend. Agricultural mechanization and information technology rise at the same time, these equipment and technology harmoniously applied to the agricultural field. With the need for sustainable agriculture, agricultural biotechnology and electro-mechanical technology show deep integration. Smart farming devices integrate sensors and GPS technology to carefully monitor and manage crop growth. Biotechnology promotes the wide application of microbial fertilizers and biopesticides, in collaboration with electro-mechanical technology, significantly improving the utilization of agricultural resources and reducing environmental pressure. In the practice of precision agriculture, drones are applied for farmland monitoring and management, and combined with image recognition technology and data analysis capabilities, efficient and accurate farmland management is realized [2].

The integration of agricultural biotechnology and electromechanical technology is not only an inevitable trend brought about by the development of science and technology, but also an important way to solve modern agricultural problems and realize sustainable agricultural development. In the future, with the further progress of science and technology and the deepening of application, BEMA is expected to show its potential in more fields and bring greater changes and improvements to agricultural production.

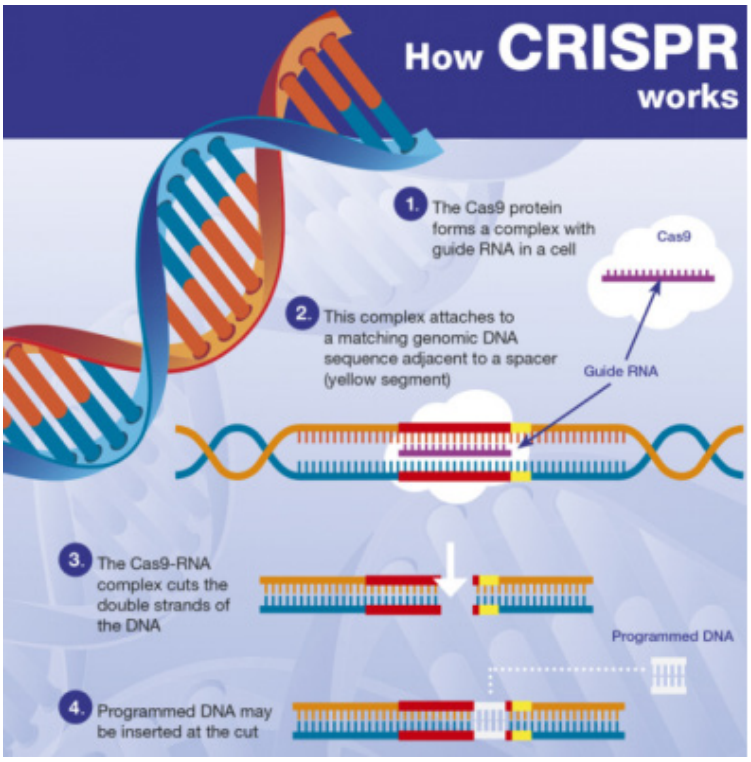

Figure 1. Comparison between gene-edited crops and traditional crops.

2.2. Practical exploration of the integration of agricultural biotechnology and electro-mechanical technology

In agricultural science and technology, the deep integration of agricultural biotechnology (BT) and electronic mechanical technology (EMT) has become an important way of technological innovation. The resulting technological renewal not only promotes the great leap in the quality and quantity of agricultural productivity, but also optimizes the agricultural ecological environment to some extent. Agricultural biotechnology includes practices such as gene editing, microbial technology, and plant breeding, which contribute significant disease, insect, and stress-resistant crop characteristics, while ensuring stable yield and quality. However, electro-mechanical technology takes automation machinery, sensing technology, Internet of Things (IoT) and other fields, which forms a precise monitoring and control method, on the one hand to reduce the degree of hard work, on the other hand to improve the degree of precision. In practice, the combination of BT and EMT is mainly reflected in the construction of intelligent agricultural system.

The popularization of sensor technology has brought about real-time monitoring of key parameters such as soil moisture, temperature and light, making it possible to accurately control water and fertilizer supply, providing a reliable way to save water and fertilizer. On the other hand, the advent of gene editing technology offers a new way to breed more adaptable crops, with the result that there is less need for pesticides and fertilizers, and thus less damage to the environment. With the development of agricultural mechanization, automation and intelligence have formed the mainstream, such as plant protection drones and autonomous farm tractors, which have made field management and operations step on the road of efficiency through the introduction of precision agriculture technology. In addition to excellent spraying effectiveness over large areas, the drone's flight system can also analyze farmland conditions through its high-resolution cameras to identify pests and diseases, thereby reducing the amount of pesticides used.

The application of information technology has greatly promoted the fine process of agricultural management. With the help of big data analysis and artificial intelligence technology, in-depth analysis and accurate prediction of crop growth data are carried out, so as to formulate the best planting plan and realize the optimal allocation of resources. Meanwhile, the application of agricultural robots in harvesting, sorting and other links has greatly improved labor efficiency, reduced labor costs, and improved harvest quality. The deep integration of agricultural biotechnology and electronic mechanical technology provides a strong technical support for modern agriculture, which not only improves production efficiency, but also optimizes resource utilization, reduces environmental load, and effectively promotes the sustainable development of agriculture. The combination of BT and EMT is gradually becoming an important trend of future agricultural development. It indicates that agricultural production will move towards a more modern and intelligent new stage.

Figure 2. Schematic diagram of precision agriculture technology.

2.3. Analysis of the current situation of biotechnology and electromechanical Integrated agriculture (BEMA)

At present, the application of BEMA technology in agriculture is gradually popularized, covering precision agriculture, intelligent irrigation, disease and pest monitoring and other fields, significantly improving production efficiency and environmental benefits, and promoting the development of agriculture in the direction of intelligence and sustainability.

Figure 3. Real picture of intelligent irrigation.

3. The impact of the integration of biotechnology and electronic machinery on agricultural production environment

3.1. Practical application of BEMA and analysis of its environmental benefits

This article discusses the application of biotechnology and mechatronic Agriculture (BEMA) in modern farming and its environmental benefits. By combining biological and electromechanical technologies, BEMA greatly enhances the efficiency of agricultural production and opens new avenues for environmental sustainability. BEMA is used in the whole process of agriculture, planting, irrigation, fertilization, harvesting and so on. The use of sensors and drones in precision agriculture technology allows real-time monitoring and data analysis of crop growth, soil moisture and weather, making fertilization and irrigation more accurate. Such applications not only reduce the waste of resources, but also reduce the excessive use of fertilizers and pesticides, reducing the pollution of soil and water bodies.

In terms of environmental benefits, BEMA also promotes the optimal use of resources. Intelligent irrigation systems and precision fertilization technology significantly improve the utilization of land and water resources by precisely controlling the amount of water and fertilizer used. These technologies can adjust the supply according to the real-time demand of plants, reduce the waste of water resources and the impact of agricultural activities on groundwater, and protect precious water resources [4].The application of automated machinery and equipment has significantly optimized the agricultural production process, effectively reduced carbon emissions by reducing manpower requirements and fuel consumption, and demonstrated its environmentally friendly side. At the same time, the promotion of circular agriculture has brought important environmental benefits to the BEMA technology, which converts agricultural waste into reusable resources, and not only solves the problem of waste disposal, but also solves the problem of waste disposal. It also reduces the use of chemical fertilizers and improves the efficiency of nutrient recycling. In addition, BEMA also performs well in ecological plant protection. Through the combination of biotechnology and precision machinery, it effectively controls pests and diseases, reduces the use of pesticides, further reduces the negative impact of agricultural production on the ecosystem, and provides strong support for sustainable agricultural development. This not only protects the healthy growth of crops, but also maintains biodiversity and ecological balance.

In general, the practical application of biotechnology and electromechanical integrated agriculture (BEMA) has demonstrated significant environmental benefits in agricultural production. Through the application of various technical means, resources are optimized, circular agriculture is promoted, environmental load is reduced, and sustainable development of agricultural production environment is promoted.

3.2. BEMA's contribution to the optimization of agricultural resource utilization and promotion of circular agriculture

The application of biotechnology and electro-mechanical integrated agriculture (BEMA) presents a strong driving force for the efficient use of agricultural resources and the implementation of energy-saving agriculture. Today, BEMA's precision agriculture technology enables more accurate water, fertilizer and medicine delivery in agricultural production, greatly saving resource waste and reducing environmental damage. The use of sensors and data analysis technology makes the monitoring of soil moisture and nutrient status more accurate in real time, so as to perform precise irrigation and fertilization, resulting in a significant increase in water and fertilizer utilization.

Regarding the implementation of energy efficient agriculture, BEMA has achieved the sustainable development of agricultural production through the reuse of resources and the construction of internal recycling systems. The treatment of agricultural waste, such as stump straw and livestock manure, through biotechnology to transform it into organic fertilizer or renewable energy, and reintroduce it to farmland, which can not only reduce the burden on the environment, but also achieve the goal of recycling. The intelligent control and automatic management of electronic machinery make agricultural production into a closed loop, making the effect of agricultural cycle system more significant. For sustainable agriculture to develop, how to establish a model of efficient use of resources and minimize the environmental burden is crucial. BEMA plays a central role in this process, improving the efficiency of resource treatment and reducing the damage degree of agro-ecosystem through technological renewal, which provides practical technical support for the successful promotion of sustainable agriculture. The integrated application of these technologies can not only significantly improve the efficiency and benefit of agricultural production, but also effectively reduce resource consumption and environmental pollution, so as to promote the green development of agriculture and ecological protection.

3.3. Impact and assessment of BEMA on environmental load of agricultural production

The integration of agricultural biotechnology and electronic machinery has brought a lot of environmental benefits to agricultural production, but it may also lead to new environmental loads. An important environmental problem is the electronic waste generated during the production and use of electronic machinery. This waste, if not properly disposed of, will pollute soil and water. The energy consumption of electromechanical equipment, which correspondingly increases the emissions of greenhouse gases such as carbon dioxide, partially offsets BEMA's contribution in reducing agricultural emissions.

To assess the impact of BEMA on the environmental load of agricultural production, systematic environmental assessment methods such as life cycle analysis (LCA) are required. LCA can help quantify the environmental impact of the entire BEMA system at all stages from raw material extraction, production, transportation, use to disposal [6]. Through the establishment of detailed database and model, the key environmental load sources can be identified and corresponding improvement measures can be proposed to reduce the environmental load in the whole life cycle of electronic machinery. Technological innovation and equipment optimization are also key ways to reduce environmental load [7]. The development of efficient, low-energy, recyclable smart devices can significantly reduce the environmental burden while maintaining BEMA's superiority.

It is necessary to integrate various assessment methods and technical means to cope with the environmental load of agricultural production to realize the sustainable development of BEMA. Only on the basis of systematic evaluation and continuous optimization can BEMA's environmental benefits be maximized and negative impacts minimized.

4. Application analysis of the integration of biotechnology and electronic machinery in the sustainable development of agriculture

4.1. Analysis of the role of BEMA in promoting the efficient use of water and land resources

Biotechnology and electro-mechanical agriculture (BEMA) play a key role in modern agriculture, especially in the efficient use of land and water resources. First, the application of precision irrigation and water management systems can significantly improve the efficiency of water use. Through an integrated sensor network

and data analysis platform, BEMA monitors soil moisture, climate conditions and crop water requirements in real time, implementing precision irrigation and avoiding water waste. Studies have shown that such technologies can increase irrigation efficiency to more than 80%, effectively reduce water loss, and maintain healthy crop growth.

The application of soil optimization management in BEMA is also significant. Continuous monitoring and dynamic adjustment of soil nutrients are achieved through biotechnology-based soil improvement measures, such as the application of microbial inoculants and the scientific ratio of organic fertilizers, combined with electro-mechanical technology. These measures not only effectively improve the soil structure and increase the soil's ability to retain water and fertilizer, but also help prevent soil degradation and improve the productivity and sustainability of farmland. BEMA has also been instrumental in promoting the recycling of water resources. Modern agriculture often faces the problem of water shortage, and through the introduction of advanced water treatment and recycling system, agricultural water can be efficiently recycled and reused. For example, biotechnology-integrated wastewater treatment systems can turn agricultural wastewater through multiple treatment steps into a reusable water source for irrigation. This recycling not only saves a lot of fresh water resources, but also reduces the pollution of wastewater discharge to the environment. In the process of water and land resource management, the integration of data and information technology also plays a role that cannot be ignored. BEMA uses the agricultural Internet of Things, big data analysis and artificial intelligence technology to realize intelligent monitoring and scientific decision-making of all aspects of agricultural production. The real-time collection and analysis of farmland information enables farmers to make management decisions based on accurate data, thereby optimizing resource utilization and ensuring environmental sustainability. Through these various functions, BEMA has not only achieved remarkable results in improving the efficiency of land and water resource utilization, but also provided a new path for sustainable development of modern agriculture. The comprehensive application of this technology will greatly promote the transformation and upgrading of agricultural production, and promote the development of agricultural ecosystems in the direction of green and efficient.

4.2. Research on the function of BEMA in improving agricultural production efficiency

Biotechnology and electro-mechanical Agriculture (BEMA) have demonstrated significant capabilities in improving agricultural productivity by optimizing production processes, improving resource utilization, and accurately managing crops. Using advanced biotechnology and electromechanical technology, BEMA can achieve accurate monitoring and management of the growing environment of crops, greatly reducing manual intervention and resource waste in traditional agriculture. Specifically, BEMA cultivates crop varieties with resistance to pests and strong adaptability through gene editing technology, which improves crop yield and quality while reducing pesticide use [8]. Precision agriculture technology uses drones, sensors and satellite remote sensing equipment to conduct real-time monitoring and data collection of farmland soil, crop status and environmental conditions. These data are fed back to farmers or agricultural managers through an intelligent analysis system to guide the precise implementation of agricultural activities, such as accurate fertilization, accurate irrigation and accurate harvest, which greatly improves the utilization efficiency of resources and operational efficiency.

The application of automation and robot technology has further improved the degree of automation of agricultural production. Agricultural robots can perform a variety of agricultural operations such as sowing, fertilizing, weeding, and harvesting, greatly reducing labor intensity and improving operation quality and efficiency. The integrated application of these technologies makes all aspects of agricultural production more

coordinated and efficient, reducing resource waste and environmental pollution. Through the application of BEMA technology, agricultural production has realized the transformation from extensive management to fine management, and improved the output efficiency and comprehensive production benefit per unit land area. The functional research of BEMA in improving agricultural production efficiency not only provides strong technical support for the agricultural sector, but also provides an important reference for achieving sustainable agricultural development.

4.3. Discussion on the potential of BEMA in mitigating the negative impact of agricultural emissions on the environment

Biotechnology and electro-mechanical Agriculture (BEMA) show significant potential for mitigating the negative environmental impacts of agricultural emissions. Through intelligent monitoring and management of the whole process of agricultural production, BEMA technology can accurately regulate the use of inputs, thereby reducing environmental pollution from pesticides and fertilizers. The optimal allocation of biotechnology between crops and soil makes the nutrient requirements of crops more precise and reduces soil and water pollution caused by excessive fertilization. The application of electromechanical equipment can monitor and regulate greenhouse gas emissions in real time and reduce the carbon footprint of agricultural activities. The promotion of renewable energy utilization is also a key part of BEMA, and the introduction of clean energy such as solar and wind energy reduces the use of traditional energy and fundamentally improves the environmental friendliness of agriculture. In addition, the application of intelligent irrigation technology and drone fertilization system not only improves the efficiency of water and fertilizer utilization, reduces waste, but also significantly reduces emissions of greenhouse gases and other pollutants. Through the comprehensive application of these technical means, BEMA technology provides a strong support for the realization of the minimization of pollutants in the agricultural production process, and helps to build a green and low-carbon agricultural production system.

5. Research on the development path and strategy of biotechnology and electromechanical Integrated agriculture (BEMA)

5.1. Support and framework for sustainable development of BEMA at the policy level

Policy support and framework design are critical in promoting sustainable development of agricultural biotechnology and electro-mechanical integrated agriculture (BEMA). Government policies can not only provide a clear direction for the development of BEMA, but also guide its healthy development through various incentive and regulatory mechanisms.

Governments at all levels should clearly support the legal framework and management system for the development of BEMA through legislation and policy formulation. In particular, relevant regulations can be issued to clarify the technical standards, production norms and environmental protection requirements of BEMA, so as to ensure the safety and effectiveness of BEMA in promotion. The legislative work of the government should be synchronized with scientific research, strengthen cooperation with scientific research institutions and agricultural enterprises, and ensure the scientificity and operability of laws and regulations [9]. In order to support the development of BEMA, the government should also set up special funding and subsidy policies. Through the establishment of special funds, enterprises and scientific research institutions engaged in BEMA research, promotion and application are funded to reduce their research and development and application costs. The government can adopt tax relief, financial subsidies and other ways to encourage agricultural enterprises

to actively adopt BEMA technology to improve the scientific and technological content and environmental protection level of agricultural production. The government should strengthen technology extension and knowledge dissemination. The awareness and acceptance of BEMA technology among farmers and agricultural practitioners can be enhanced through the establishment of agricultural technology promotion stations, technical training courses, and demonstration projects. Government departments should cooperate with scientific research institutions and agricultural enterprises to regularly publish the latest research results and application cases of BEMA to promote the wide application of the technology [10]. In terms of environmental protection and resource management, the government should formulate detailed environmental protection policies and resource management plans. In view of the positive effects of BEMA in water resources utilization, soil protection, pollution discharge and other aspects, corresponding ecological compensation mechanisms and incentive policies have been introduced to stimulate the enthusiasm of agricultural practitioners to adopt BEMA technology. The government can assess and regulate the environmental benefits of BEMA technology applications through environmental monitoring systems to ensure that sustainable development goals are achieved in practical applications.

Through legislation, financial support, technology promotion and environmental management, the government can provide strong support and sound framework for the sustainable development of BEMA. This will not only help improve the efficiency of agricultural production and the level of environmental protection, but also promote the process of agricultural modernization and achieve the sustainable development goals of agriculture.

5.2. Discussion on incentive mechanism and problems of BEMA development from the economic level

For the development and advancement of BEMA, the integration of biotechnology and electro-mechanical agriculture, economics is the key to success. How TK continues to promote BEMA's progress is particularly critical. To achieve the sustainable development of BEMA, it is necessary to deeply study and elaborate its economic incentive mechanism and the main problems it faces. To promote the progress of BEMA, a powerful economic incentive mechanism must be used: financial subsidies. The government should introduce policies to encourage farmers and agricultural enterprises to adopt this advanced technology as much as possible by providing special funds and financial subsidies. This can not only reduce the initial investment cost, but also accelerate the promotion and implementation of the technology in agricultural production. In addition, tax incentives are also an effective incentive strategy. Businesses and farmers can enjoy tax breaks or rebates when purchasing, using and researching BEMA technology, thereby reducing operating costs and enhancing competitive advantage.

Financial support is also a key measure to promote the development of BEMA. The use of financial instruments such as low-interest loans, project financing and venture capital can effectively alleviate the shortage of funds and guarantee the research and development and promotion of BEMA technology. Establish and improve the green financial system, attract more social capital investment, and promote the development of green agriculture. The introduction of an insurance mechanism is also crucial to increase farmers' confidence in BEMA technology by providing agricultural insurance to reduce risks arising from environmental changes and technology applications. The optimization of market mechanisms is another important aspect. We should establish and improve the market system of agricultural products, standardize the market order, and reduce the uncertainty

of agricultural production and product circulation. Through the formulation of fair trading policies and price mechanisms, to protect the economic interests of agricultural producers. Promote the construction of agricultural e-commerce platform, open up markets for high-quality agricultural products under the application of BEMA technology, and increase their market share. The economic development of BEMA also faces several problems. On the one hand, the technical cost is high and the return cycle is long, which is difficult for some farmers and enterprises to bear. On the other hand, market demand instability and price volatility may negatively impact the adoption of BEMA technology. Financial support needs to be strengthened, and some financial institutions' risk assessment of BEMA projects is not accurate enough, resulting in financing difficulties.

Through scientific and reasonable economic incentive mechanism, improving the economic benefits of BEMA technology will effectively promote its application in agricultural production and promote the sustainable development of agriculture.

5.3. Social needs and expectations for the development of BEMA

Public expectations for BEMA are mainly focused on improving food safety, ensuring stable production, increasing employment opportunities, and improving the quality of life in rural areas. Social needs include the promotion of science and technology, education and training, raising public awareness, and promoting coordinated urban and rural development.

6. Closing remarks

In this study, we discuss the sustainable development of the integration of agricultural biotechnology and electronic machinery from the perspective of environmental science. The analysis shows that the integrated application technology (BEMA) plays an important role in the agricultural ecosystem, effectively improving the environmental benefit of the agricultural production system and reducing the environmental burden through the optimal use of resources, the implementation of circular agriculture, ecological plant protection and other ways. Through systematic analysis and modeling, we built an agro-ecosystem integrated with agriculture, and further analyzed its effects in improving agricultural production efficiency, promoting the efficient use of water and land resources, and mitigating the negative impact of agricultural emissions on the environment. This will provide a sustainable development path for agro-ecosystems. In addition, we also discuss the sustainable development path and strategy of BEMA from three dimensions: policy, economy and society. It is suggested that agricultural technology should continue to innovate and develop, and adjust policies according to actual needs to better support the development of BEMA. At the economic and social level, personnel training and technology promotion should be strengthened so that more agricultural workers can understand and apply BEMA, and further promote its sustainability. In general, the integration of agricultural biotechnology and electronic machinery has opened a new chapter in agricultural production, but it needs further research and reflection to explore a more effective and sustainable development path. This will help transform agriculture into an environmentally friendly, efficient and sustainable industry that offers new ideas for addressing today's environmental challenges.

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