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Foresight into Disruptive Technologies in Agricultural Engineering

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Abstract: This study presents the preliminary results of the "Research on Disruptive Technologies in the Agricultural Field", a consulting research project of the Chinese Academy of Engineering. Our report mainly focused on the active fields of current and future technological innovations in agricultural engineering, including agricultural biotechnology, agricultural information technology, and nanomaterial technology. Specifically, five critical directions were investigated in the report, namely, animal and plant breeding, agricultural biological medicine and bio-fertilizer, agricultural biomass engineering, intelligent agricultural technology, and non-traditional planting spaces. Through the analysis of conferences, patents, interviews, and the literature, current and future development directions of disruptive technology in the agricultural field are suggested. Our results provide a reference for investment decisions of the government and businesses, as well as research directions for scientists.
Keywords: science and technology in agricultural engineering; disruptive technologies; strategy research

1 Introduction

At present, continuous innovation and development in the fields of biotechnology, information technology, materials science, and energy are driving major technological changes characterized as green, intelligent, and ubiquitous, which will have profound effects on agricultural science and industry. In the next 15−20 years, with the penetration of these revolutionary technologies into the agricultural field, a new wave of agricultural biotechnology will be launched. Those technologies will promote "Internet plus" industry, and lead and support agriculture in achieving sustainable development, which should include energy conservation, emissions reduction, green technology, and low-carbon solutions.

At present, China has formed a basic pattern of producing a small number of innovations, mostly keeping pace with or catching up to the advances in the agricultural science and technology field. Compared with developed countries, however, there are still gaps in China's original innovation ability and the problem of weak industrial support. To keep pace with science and technology innovations, China must rise to the frontier of world agricultural science and technology, meet the major needs of national agriculture science and technology, engage in research at the leading edge of the disruptive technologies in the agricultural field, seize the opportunity to engage in global competition in agricultural science and technology, and enhance innovation in agricultural science and technology.

Through analysis of conferences, interviews, literature, and patents, this study aims to find out what criteria we can use to assess whether there have been significant technological innovations and breakthroughs, whether the traditional technological route has been overturned, whether existing forms of business have changed, whether new

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industries have been created and constructed, whether significant comprehensive benefits have been produced, or whether directions and strategies of social and economic development have changed. Following the above criteria, we hope to elucidate the influence disruptive technology will exert on future agriculture development.

2 Development trends of disruptive technologies in the agricultural field

The direction of the active fields in current and future technological innovations, including agricultural biotechnology, agricultural information technology, nanomaterial technology, etc., will be of great significance for research in agricultural sub-fields. These fields have displayed different development trends.

2.1 Animal and plant breeding

Breeding technology innovations can help ensure food safety and stabilize food supply. According to a projection made by the World Bank, continued urban development, national economic expansion, and population growth will result in grain demand in China reaching 670 million tons by 2020, and 700 million tons by 2030 [1]. Due to the limitations of land resources, the only way to improve total animal and plant food production in China under current resource conditions is to continuously increase per unit animal and plant yield and to increase their productivity through breeding technology innovations. Taking animal breeding as an example, technological breakthroughs in animal genome sequencing techniques have developed such that genome information can be employed to directly select genomes and accurately screen target traits, which overturns the traditional breeding route that relied on large population genetic evaluations and progeny testing. Genomic breeding has become a strategic advantage fiercely pursued by large breeding corporations [2]. Due to the breakthroughs in embryonic gene editing, genetic traits of livestock can be precisely improved by directly editing the embryonic genes that determine genetic traits. Thus, a batch of cows, sheep, or pigs can be bred with a greatly improved meat type and resistance to diseases, which could be difficult to cultivate with traditional breeding methods. This breeding method totally subverts the traditional breeding route that relies on phenotypic traits, and is the engine of a revolution in the livestock breeding industry [3−5]. Stem cell-based breeding has been gradually accepted due to its earlier occurrence and more efficient breeding potential. In particular, the combination of technologies that includes stem cell and induced differentiation, in vitro fertilization, genome selection, etc., can fundamentally change the previous selection time limit (e.g., primary selection at birth and re-selection after weaning) and the direction of technology [6]. All these technologies can exert a disruptive impact on the direction of technology and the form and efficiency of animal and plant breeding. In China, the genomic breeding technology has first been applied to the breeding of dairy cows [7], and has kept pace with worldwide innovations. Embryonic gene editing of livestock and iPS induction technology represent the current advanced technologies. The application of stem cell technology to livestock and poultry farming, however, is still catching up. In-depth research in relevant fields would be required for China to be at par with international competition in the animal breeding industry.

2.2 Agricultural biological drugs and bio-fertilizers

Chemical fertilizers and other agricultural chemicals have attracted increasing attention due to the severe environmental pollution, health issues, and drug resistance caused by them. It is of great importance to develop bio-fertilizers and biological drugs (such as biopesticides, biological veterinary drugs, etc.) to replace or reduce the use of chemical fertilizers and chemical drugs, ensure high and stable agricultural production, safeguard food safety and public health, improve the ecological environment, ensure environmental safety, and realize sustainable agricultural development. The technologies of bioscience and new nanomaterials provide brand new paths and technical support for the development of agricultural bio-fertilizers and biological drugs, which will promote the rapid development of relevant emerging industries. For instance, synthetic biology can be employed to prepare microorganisms' secondary metabolites, and RNA interference technology can be used to prevent viral diseases, which opens new biological pathways to develop pest control technology and produce drugs at the gene level. New materials can be used to develop efficient drug delivery systems, leading to targeted application of pesticides, and pesticide spraying devices can be invented that promote targeted deposition of pesticides and increase the utilization of the drugs, thus reducing environmental pollution. Crop microbiology and synthetic bacteriology can be combined to construct multiple-strain, compound microbial fertilizers; and mutual signal control can be adopted to enhance the colonization and effect of microbial fertilizers at the plant rhizosphere. The successful industrialization of agricultural bio-fertilizers and biological drugs will fundamentally change the condition of agricultural production that currently relies heavily on chemical fertilizers and chemical drugs. This will improve the structure of the industry and increase

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the international competitiveness of relevant industries in China.

2.3 Agricultural biomass engineering

The biomass industry is a strategic emerging industry that has many advantages, such as being renewable, clean, low-carbon, beneficial for peasants, and providing a multi-path substitution for fossil fuels. It can turn forestry and agricultural residues, such as straws, feces, etc., into resources, thus greatly reducing non-point source pollution [8,9]. In the near future, biomass engineering could provide biomass fuels for transportation of 100 million tons and biomass gas of 100 billion cubic meters in China. With the current changes in the pattern of world trade, the development of biomass energy will be of great significance to China reducing its dependency on imported oil and natural gas, and increasing national security in energy and even finance. Biomass energy has become the largest renewable energy resource in the world, surpassing the volume of wind and solar energy [10,11]. By the middle of 21st century, it will probably become the world's largest energy source. Bio-based materials are the only alternative for non-renewable chemical materials, and thus become a main direction for biomass transformation and a major source for chemical materials. They have become a major product of agricultural production around the world. Efficient utilization of raw lignocellulose materials at low cost has become a source of difficulty and a research hotspot, and the production of platform chemical compounds using raw biomass materials will be a development priority in biomass engineering in the coming 20 years. Once breakthroughs are made in key technologies, many major issues will be readily resolved, including the threat posed by non-renewable energies and materials, the conflict between biomass energy and food security, the limitation of biomass industry scale, the conversion efficiency of biomass engineering, the conversion rate of energy, etc. As a late starter, China has invested less in the research and development of the biomass industry, and relevant technologies lag behind that of other developed countries. Only by accelerating research and development in disruptive technologies in biomass can China rise to the world class level in its biomass industry, which will become a support for national strength and prosperity.

2.4 Intelligent agricultural technology

Informatization represents the cutting edge of agricultural modernization, and intellectualization is a leading force that drives agricultural modernization [12]. The intellectual technology-driven agricultural science and technology transformation has demonstrated a systemic, disruptive effect on agricultural development. The Internet of Things, big data, artificial intelligence, and robots are four typical examples of such technologies. The Internet of Things connects the Internet and things together through sensing systems, and provides channels and a data base for big data processing [13]. Data processing and big data analysis provide accurate data processing methods and provide a decision-making basis for artificial intelligence [14]. Artificial intelligence helps achieve intelligent agricultural decision-making, which provides core processing means for unmanned operation of robots. The integration of these four technologies constitute the core support techniques for unmanned, precise, intelligent, and ecological agriculture in the future [15]. Biosensors for animals and plants in agriculture, optimization models for animal and plant growth, equipment management and optimization, and intelligent robots will be research hotspots in the field of agricultural technology in the future. The agricultural Internet of Things is becoming increasingly platformed, standardized, cost effective, and reliable, and the focus of agricultural big data is transitioning from efficient data storage to agricultural data mining and knowledge discovery technology. Artificial intelligence is developing towards information identification, classification, and decision-making based on the integration of the Internet of Things and big data, and agricultural robots are developing towards whole process intellectualization based on language understanding [16].

2.5 Non-traditional planting space

Currently, around 25% of the world's farmlands are suffering from severe degradation due to over-cultivation, drought, or contamination. World food demand will increase by at least 60% in the coming 30 years. In addition to preserving current cultivated areas, expanding traditional cultivation space, improving efficient utilization of resources per unit area, and indirectly increasing planting space, it is also necessary to develop currently underutilized saline and alkaline lands in a scientific way. So far, a number of disruptive technologies have gradually developed, including urban agriculture, plant factories, desert cultivation, and virtual plantation, which have been breakthroughs in science and technology and research hotspots. Such disruptive technologies are of great significance for relieving the grave situation of global food security [17,18]. In the coming 10−15 years, more disruptive technologies will emerge due to changes in technology, integration of technologies from different fields, and the widespread practice of traditional technologies, which will promote the development of agricultural lands in new spaces (including outer space). The development and improvement of saline and alkaline soils, comprehensive treatment of lands with unbalanced nutrients, and the deepening of traditional cultivation will increase the reserve of cultivated lands, which will be of great significance to ensuring food security.

3 Major directions for disruptive technologies in the agricultural field in the coming ten to fifteen years in China

3.1 Major directions for disruptive technologies in the field of high-efficiency breeding of animals and plants

3.1.1 Animal and plant gene editing technology

Evolving from initial zinc-finger nucleases (ZFN) to transcriptional activator-like effector nucleases (TALEN) technology, and to the current CRISPR (clustered regularly interspaced short palindromic repeats) Cas (CRISPR associated) system, gene editing technology has become more target specific, efficient, and cost effective. The development of such technology has successfully helped improve traits that encode resistance to diseases, meat quality, etc., in pigs, cows, sheep, and fish. Traditional breeding techniques, such as trait measurement, variation detection, variation screening, etc., have evolved to direct editing of target traits and phenotype confirmation, which greatly reduces the necessary size of the breeding population and shortens the breeding cycle. The analysis of trait genes, however, is still inadequate to provide more editable gene loci yet. With further development of functional gene analysis in the coming 10−15 years, this technology will be gradually applied at a large scale and exert a disruptive impact on the breeding of relevant traits. Currently, the original technology comes from other countries. Therefore, high-efficiency proprietary intellectual property rights are research and development priorities for China in the near future.

3.1.2 Livestock stem cell breeding technology

Stem cell-based breeding includes several technical steps, including the establishment and culture of stem cells, induction of directional differentiation of germ cells, in vitro fertilization, genome selection, etc. Currently, few breakthroughs have been made in the establishment and culture of livestock stem cells and the induction of directional differentiation of germ cells. It is projected that in the coming 15−20 years, the above-mentioned technical bottlenecks will be overcome, and mature technical systems of stem cell-based breeding will be established. Stem cell-based breeding is conducted in the laboratory, and greatly reduces the adult animal population due to the development of cell breeding. The breeding cycle is shortened, costs are reduced, and the breeding places are changed, all of which exert a disruptive impact on the breeding industry. Though China is a leader in the iPS induction technology around the world, its livestock and poultry stem cell technology is still catching up and its development should be accelerated.

3.1.3 Molecular design of animal and plant varieties

Guided by molecular design theory, molecular design of varieties comprehensively employs various kinds of biological information and gene operation techniques, and carries out the design and operation over target traits at different levels (from genes [molecules] to the whole [system]), so as to obtain the optimum allocation of desired genes and cultivate new varieties. A technical system of molecular design of varieties will promote the transformation from traditional breeding to “precise breeding”, greatly increase the efficiency and technical control over animal and plant breeding, and usher in new innovations and developments in animal and plant breeding. It is estimated that after 15−20 years of efforts, China will be able to break technical bottlenecks in animal and plant polygene pyramiding and gene editing operations and establish a technical system for molecular design of animal and plant varieties. In fact, China has made some breakthroughs in these areas. It is, however, imperative to enhance research on the formation of important economic traits in animals and plants so as to identify more functional genes for molecular design.

3.1.4 In vitro meat synthesis and cultivation technology

Muscle stem cell cultivation and differentiation induction have been applied to meat production in beef, poultry, fish, etc. This technology skips several production steps, including forage grass production, feed production and processing, animal feeding, animal slaughter etc. By this method, the entire process of meat production can take place in a laboratory. Therefore, the application of this technology not only reduces resource and environmental stress, but also helps achieve product customization and batch production. Multi-tissue culturing, deep tissue metabolism, and circulation technology, however, are still under development and research. It is projected that in

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the coming 15 years, this technology will be applied at a large scale, and exert a disruptive impact on the industry. In China, researchers have carried out studies on muscle stem cells, but no research has been reported on cultured meat.

3.2 Major directions for disruptive technologies in the field of agricultural biological drugs and bio-fertilizers

3.2.1 RNA interference-based gene drugs

RNA interference technology has been employed to prevent viral diseases, control weeds, and regulate plant growth (including defoliation and topping) at important stages, which overturns the prevention and control methods of chemical pesticides. Technical bottlenecks include issues with target gene selection and the development of an efficient delivery system. Scientists from Australia and the United Kingdom have employed nano-material BioClay to load dsRNA, make homologous RNA silent, and control tobacco viral diseases [19]. Currently, international agrochemical giants have launched research and development programs on relevant technologies and products [20]. It is expected that products will be applied in the next 5−10 years, with large-scale application in the next 15−30 years. Chemical pesticides will be gradually phased out. No relevant research has been reported in China yet.

3.2.2 Controlled pesticide release technologies based on intelligent biomaterials

Intelligent biomaterials refer to materials sensitive to biotic or abiotic stress signals, such as temperature, alkalinity or acidity, redox potential, etc. These materials can be used to deliver the drugs to target locations and precisely control the drug dose through changes in biological signals. Targeted drug delivery and precise pesticide application are of great significance for increasing crop disease resistance and enhancing defense against abiotic stresses such as drought, low temperature, etc. In Australia, researchers have modified mesoporous silica carriers to prepare functional materials sensitive to redox potential, intelligently control the release of salicylic acid, and improve the disease resistance of Arabidopsis thaliana [21]. At present, there are many relevant studies on this technology in the field of medicine. It is estimated that agricultural agents will come into use in the coming 10−15 years. No relevant research has been reported in China yet.

3.2.3 Man-made viruses as preventive vaccines or therapeutic vaccines

On the basis of computer simulation programs, reverse genetic and synthetic biology technologies are used to mutate viral genome triplet codes and artificially control virus replication so as to convert viruses directly into prophylactic vaccines and drugs that can cure virus infections. This general method can be employed to develop vaccines and therapeutic drugs to fatal viruses. It can also be used to develop preventative chemical and biological agents for national security. Thus far in China, Peking University has succeeded in developing an influenza vaccine at the laboratory level [22].

3.2.4 Nano adjuvant

Nano-particles are comparable to microorganisms in size and can be better phagocytized by antigen-presenting cells. Their size can also be increased to that of small molecule antigens. By modifying their surface, the effect of vaccines on the body’s immune response can be enhanced [23,24]. Therefore, nanoparticles are likely to become a new type of nano adjuvant. Their functional mechanism and side effects, however, are still unclear, and few nano a juvants have entered the clinical test stage. A standardized safety assessment for nano-materials has been proposed in China to evaluate their biotoxicity and effects, which can help solve this problem.

3.2.5 Crop microbiome technology

Crop microbiome technology is used to conduct high flux separation and big data analysis on different crop microbiomes and reveal the microbiomes beneficial for different crops [25−27]. Using the principles and technologies of synthetic bacteriology of microorganisms, combined micropopulations are rationally designed, which are structurally stable and have specific functions for different crops, and efficient microbial fertilizers are developed based on crop microbiome technologies.

3.3 Directions of disruptive technologies in the agricultural biomass engineering field

3.3.1 Engineering technologies of biomass oil and biogas co-production

With lignocellulose as raw material, bio-oil and bio-gas can be generated at a large scale and in a highly efficient and cost-effective manner, which overturns the application system of traditional fossil fuels for transportation. With breakthroughs in key processes, equipment, enzymes, and bacteria, compound utilization of biomass resources and co-production of multiple products can be adopted to make bio-oil and bio-gas products more economically competitive. Thus, these products can enter the market on a large scale. In the middle term, the yield of biofuels will reach 100 million tons per year and for biogas, 100 billion cubic meters. In the middle and long term, the production capacity will be doubled, which will substitute for over 60% of imported oil and natural gas. Thus, this process will ensure national energy and financial security, and reduce contamination caused by forestry and agricultural residues, such as straw and livestock excrement. China has almost achieved the industrialization of this technology and also has advantages in the field of biogas.

3.3.2 Molecular and genetic breeding technology in energy crops

By subverting the crop breeding methods that reduce total biomass of crops and increase harvest index, new types of crop varieties can be cultivated that have high photosynthetic efficiency, high biomass, and are easily degraded, transformed, and utilized. Through gene regulation, crop photosynthetic traits and crop lignocellulose composition can be changed, so as to cultivate special energy crops that are suitable for specific degradation and conversion paths, such as high-lipid containing microalgae and low-lignin containing woods. Thus, total biomass and conversion efficiency can be greatly improved, and conversion cost can be dramatically reduced. New energy crops will change the methods of agricultural production, affect the industry supply chain, and promote the development of biomass engineering. China is still in an initial phase in the development of this field. However, it has a relatively strong foundation in genetic breeding technologies.

3.3.3 Conversion and utilization technology of the biomass one-pot reaction

Using the traditional technological method, biomass is first separated into cellulose, hemicellulose, and lignin, which then undergo single-phase catalytic conversion. The process is heavy and complicated, the cost is high, and the yield rate is low. The conversion and utilization technology of the biomass one-pot reaction fundamentally overturns the traditional technical path. Based on the characteristics of cellulose and its degradation products, a carbon-based, non-metal catalysis and highly efficient multi-phase catalytic system can be designed with graphene as the carrier. Then, carbohydrates such as cellulose can be converted through the one-pot reaction to more basic chemical compounds, such as 5-hydroxymethylfurfural and its furan derivatives, which greatly simplifies the operation steps, increases efficiency, and reduces energy consumption. This technology can sharply increase the utility of biomass and its benefits and promote the development of this industry. China plays a relatively leading role in this technology.

3.3.4 Lignin utilization technology

Current limitations of lignin conversion and utilization technology constrain the utilization of lignocellulose. Through catalytic conversion, lignin can be used to generate cycloalkane compounds and produce high-performance aviation fuels, the overall performance of which can surpass that of petroleum-based aviation kerosene. Using lignin’s natural benzene ring structure, nanotechnology carbonization reorganization can be employed to manufacture high-performance or degradable materials, such as carbon nanotube materials, photolysis materials, etc. Direct utilization of the natural structure of lignin overturns the traditional recycling method of degraded lignin. This field is a new direction in biomass engineering, in which China plays a relatively leading role.

3.3.5 Coupling technology in biomass thermochemistry and bioconversion

By coupling technology in biomass thermochemistry and bioconversion, a thermochemical approach is first used to degrade biomass materials, and then a biological method is employed to convert small molecule compounds into long carbon chain compounds. This technology can help achieve a highly valuable utilization of biomass resources through its high conversion rate and low cost under ambient conditions. For instance, the production of bio-based energy and material products from one-carbon materials, like CO, CO_2, and CH_4, overthrows the traditional petrochemical path of macromolecule pyrolysis. The liquidation of biomass materials through coupling multiple technologies can help overcome the problems of looseness, dispersion, and low energy density in biomass so that biomass materials can be collected, transported, and processed like raw oil. A breakthrough in this field would revolutionize the entire industrial process of biomass engineering. This field is a new direction of international exploration in which China plays a relatively leading role.

3.4 Directions for disruptive technologies in the field of intelligent agriculture

3.4.1 Agricultural Internet of Things technology

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Agricultural Internet of Things technology employs various sensing technologies to acquire agricultural field information in real time. It then transmits the information through various networks, combines and processes the information and achieves precise, optimized operation and control through agricultural operation terminals. By 2030—2050, agricultural Internet of Things technology will be applied comprehensively and thoroughly revolutionize the field of agriculture. By 2035, the market scale will reach RMB 200−300 billion. The agricultural production process will be entirely perceivable, and achieve refined, precise, and unmanned operation. Agricultural Internet of Things technology has reached the stage of full maturity, and its mechanism of commercialization has been completely formed in China.

3.4.2 Agricultural big data technology

With agricultural big data technology, large-scale multi-source heterogeneous agricultural data is collected, cleaned, stored, and mined for agricultural intellectualization and precise decision making. By 2035, big data technology will enter its maturation stage, and provide comprehensive, accurate, and objective guidance for agricultural production, operation, management, and services. By then, agricultural production will be digitized, rural area governance will be transparent, peasant services will be customized, and the industry scale will be over RMB 200 billion.

3.4.3 Agricultural artificial intelligence technology

The new generation of artificial intelligence technology based on big data intelligence, context-aware computing, human-machine hybrid intelligence, swarm intelligence, and autonomous collaboration and decision-making will cover agricultural production, rural governance, and peasants' lives. By 2035, the market size will approach RMB 250 billion, agricultural production efficiency, resource utilization rate, and land output capacity will be multiplied, rural governance will be more efficient and transparent, and the life of peasants will be more convenient. After another 10−15 years, artificial intelligence will be fully applied in China in agricultural production, rural governance, and the life of peasants at various levels.

3.4.4 Agricultural robot technology

Artificial robot technologies, such as navigation, positioning, identification, operation, and relevant equipment will be gradually applied in agriculture. By 2035, the technology will enter its maturation stage, be applied at a large scale, and subvert the traditional industry. The market size will approach around RMB 300−500 billion. It will greatly emancipate labor productivity and increase labor efficiency. Agricultural robot technology is closely related to the development of industrial manufacturing and artificial intelligence technology. With further propulsion of rural urbanization, after another 10−15 years, China will become a leader in the field of agricultural robot technology in the world. At various stages of agricultural cultivation, harvest, plant protection, as well as in livestock, poultry, and aquaculture operations, agricultural robots can be applied at a large scale.

3.5 Major directions for disruptive technologies in non-traditional planting space utilization

(1) Researchers will develop high-efficiency, anti-clogging, water-salt regulating irrigation systems that target the root zone, investigate salt drainage in concealed conduits as wells as salt accumulation and blockage at the soil surface, screen salt drainage materials and optimize the structure and layout of salt draining concealed conduits, and strictly prevent secondary salinization of soils in areas with relatively shallow groundwater depth.

(2) Digitized agriculture will be developed: from soil moisture content monitoring to field fertilization and irrigation decision making; from crop pest monitoring and prevention to the determination of harvest time. With the help of sophisticated equipment, including communication networks, artificial intelligence, micro-robots, unmanned aerial vehicles (UAV), and sensors, the field of agriculture can be intellectualized and information sharing achieved. At the same time, information on decision-making and implementation processes can be reported to farmers in a real-time manner.

(3) Comprehensive agriculture-aquaculture systems will be adopted to accelerate secondary utilization of water resources. Thus, saline and alkaline areas away from the sea can be used for aquaculture. This system can help achieve intelligent administration and management of electrical equipment, such as aerators, batch feeders, water pumps, etc. [28]. Between 5‰ and 30‰ brackish water can be used for the cultivation of prawn, which subverts the typical prawn cultivation method reliant on aquaculture boxes in inland areas and additions of sea salt, an extra cost typically a function of the distance from the shoreline [29,30].

4 Development proposal of disruptive technology in the agricultural field

4.1 Accelerating the cultivation of innovative talent

For a long time, insufficient attention to agriculture and poor basic conditions in the field of agriculture have led to an overall shortage of high-level innovative talent in the field of agriculture. The quality of researchers needs to be improved, and more effort should be made to cultivate talent.

4.2 Establishment of special funds for basic research on disruptive technologies in the agricultural field

Disruptive technology is mainly derived from long-term accumulation of basic research. For many years, China has paid so much attention to the short-term benefits of technical research, but provided less attention to basic and cross-discipline research in the field of agriculture. It is necessary to establish long-term and stable research funds for long-term cultivation. In addition, it is also necessary to draw lessons from the organizational structure of the agricultural technology industry, and set up a batch of specialized teams with expertise on major strategic issues and long-term involvement in strategic technology research in the agricultural field, who can perform long-term innovative research on vital strategic issues in agricultural development.

4.3 Establishment of an innovative mechanism for business

It is necessary to establish an innovative mechanism for business that can promote technology research, development, implementation, and the more quick attainment of the industrial scale. It is necessary that there be adequate collaboration among government, businesses, and universities, so as to better stimulate the technological innovation ability of universities, and to ensure that businesses with the main interest and risk are willing to invest. In this process, a virtuous circle of industry−university−research institute cooperation can be established. We should not use administrative means to mandatorily assign tasks and assess progress, but rather should give full scope to the potential of technical services and market development to construct new methods of production, teaching, and research integration. It is necessary to establish a commercial technology application system as soon as possible, fully respect the social attributes of the free flow of talent, science and technology, capital, and germplasm. We should actively construct an environment with a market-oriented policy for the free flow and optimal allocation of resources, and establish the economic status of talent, science, and technology in the development of disruptive technology industries. Moreover, that policy which can protect and utilize talent and technology should be perfected in future.

4.4 Establishment of a policy system suitable for industrial development

Disruptive technology often leads to large-scale industrial change, investment, and commercial exploitation. New business models and emerging industries are often not suitable for existing industrial policies. For disruptive technology-driven industrial development, we need to provide a relaxed development environment and give priority to promoting industrial development that solves problems. Due to the large investment, high uncertainty, and high failure rate that is an inherent part of disruptive technology development, it is difficult to achieve substantial results with just short-term and centralized research. There are also many challenges in the application and promotion of disruptive technology in the later stage. It is, therefore, necessary to establish a long-term research initiative, and gradually establish a system that ties the market with the relevant laws and regulations.

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