2021 CAAS ANNUAL REPORT

Compiled by the Department of International Cooperation of CAAS

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Editorial Board of CAAS Annual Report 2021

2021

Message from the President

In 2021, CAAS had a good start in implementing the "14th Five-Year-Plan" for National Economic and Social Development. Focusing on strengthening national strategic, scientific and technological force and fulfilling the country's needs, CAAS made resolute efforts to ensure food supply, deliver solutions to major scientific issues and open up new situations. CAAS formulated and issued its own Development Plan during the "14th Five-Year-Plan Period (2021-25)" and formed a list of major tasks. CAAS launched the scientific and technological programs in improving seeds and farmland quality, established the biosecurity research center, and promoted the shift of research focus from agricultural sciences to a mix of agricultural sciences, rural economics and rural revitalization. By 2021, the full implementation period of the Agricultural Science and Technology Innovation Program (ASTIP) has been successfully accomplished.

CAAS, as China's premier national team in agricultural research, made a series of achievements in 2021, i.e. substantial breakthroughs in scientific and technological innovation, enhanced support to rural revitalization, increasing returns in research achievement transformation, refined talent structure, continuous improvement in postgraduate education, upgrading research facilities, stronger supportive capacity, and greater global influence. All of these reflected the Academy's commitment and devotion to building China's agricultural sci-tech strength and promoting rural revitalization to a higher level.

In 2021, CAAS experts led 393 national science and technology projects, among which 32 were National Key Research and Development Programs, up to one third of the national total in agricultural sector; 1 National Major Science and Technology Project, namely on "new generation of AI", was approved; 353 projects were funded by National Natural Science Foundation of China, including 28 key projects, notably, the "crop germplasm innovation and application" project was the first comprehensive key project the Academy undertook; 7 projects were funded by National Social Science Fund of China, and 2 out of 7 were major projects.

CAAS scientists published more than 6,700 papers in 2021, among which 6 were published in *Nature*, *Science*, and *Cell*. Major scientific discoveries were made in four basic research projects. Several key technologies achieved breakthroughs: the Institute of Plant Protection improved technology of inspection and control against the fall armyworm, which was recommended to the international community by FAO; the Institute of Urban Agriculture and the China National Rice Research Institute jointly achieved a major breakthrough allowing dwarf rice to be harvested in 63 days in the plant factory; Harbin Veterinary Research Institute completed the second phase clinical trial and production safety test for transgenic organisms of African Swine Fever gene deletion vaccine.

The total revenue from the achievements transformation of CAAS in 2021 was up to 1.3 billion RMB, and the revenue of 7 intellectual property transfers exceeded 10 million RMB each. Prof. Hou Shuisheng and Prof. Zhou Wei were elected Academicians of the Chinese Academy of Engineering. The new National Crop Gene Bank was built and put into trial operation. Lanzhou Veterinary Research Institute constructed the largest high-level laboratory facility cluster for animal biosecurity in China.

CAAS actively participated in international innovation initiatives and actions, such as engaging in 3 technical consultation groups at the UN Food Systems Summit. The International Science & Technology Innovation Program (CAASTIP) was steadily implemented, expanding cooperation with Harvard, Oxford, Heidelberg and other first-class universities, and employing high-level foreign experts. CAAS continued to expand collaborative research projects with international partners with additional funding of more than 65 million RMB. International cooperation made greater contribution to the Academy's research and innovation and helped to build a bigger circle of friends around the world.

All those accomplishments cannot be achieved without kind assistance and generous support from our friends and peers. CAAS people will keep our aspirations and openness unchanged, and are looking forward to more exchanges and cooperation with all partners. We would love to embrace a bright new chapter in the great course of rural revitalization and agricultural modernization in China.

Prof. Wu Kongming
CAAS President

Commitment

As a national-level agricultural research institution, CAAS is an academic institution for comprehensive agricultural scientific research and is responsible for providing strategic advisory services for agriculture and agricultural science and technology. It functions as the major technological force in the country's agriculture and rural development.

In response to the call from the CPC Central Committee and State Council's policies on rural development and agricultural research, CAAS has been steadfast in its mission and positioning as China's national agricultural research team. Focusing on the frontier of world agricultural science and technology, major demand from the country, construction of modern agriculture as well as the people's life and health, CAAS is striding towards building the world first-class research institute with world first-class research disciplines. It is dedicated to addressing major science and technology issues in agriculture and rural development that are nonprofit, fundamental, vital, strategic and forward-looking and leading agricultural research forces nationwide to sustainably improve innovation capacities and realize technological progress, therefore making pivotal contributions to the overall leap of China's agricultural science and technology, ensure food security and empower the development of agriculture and the rural economy.

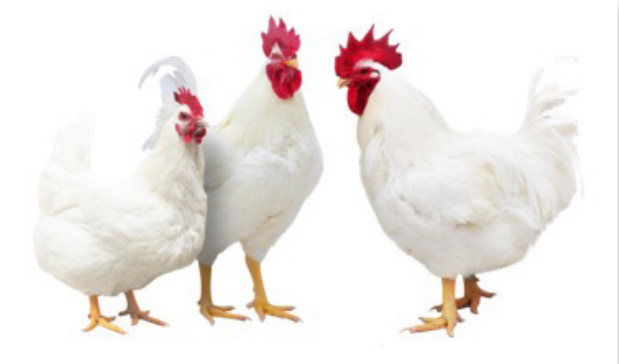
CONTENTS

Significant Progress

Development Achievements

S&T further supported overall rural revitalization

Selective breeding benefits the revitalization of the seed industry. "Guangming No.2" White Feather Broiler poultry has broken the long-term monopoly from overseas suppliers. The total area of 11 new cultivars of grain, cotton and oil crops, directed by CAAS, ranked among the top 10 in the country. "Zhongmai 895", a wheat cultivar, has been promoted to 51 million mu(1mu≈667m^2) accumulatively. Its filling rate and heat resistance ranked tops among the main varieties planted in the Huanghuai wheat growing region. "Zhongdou 63", a t soybean cultivar, has set a new record high for soybean harvests in South China. "Zhongyouza 19", a rapeseed cultivar, has reached the world's leading level of oil content breeding. "Zhonggan 21" has become a major summer vegetable brand. The trial planting of transgenic soybeans and maize achieved significant progress. **"The seven lands" coordinated project has supported land protection and quality improvement.** Important progress has been made in tackling key problems in black soil root system improvement, organic fertilizers effectiveness in preventing and controlling red soil acidification, application of nitrogen fertilizer in paddy soil, and protection and utilization of saline soil found along seashores. The technical model of "mind the skies, research online and manage the fields " fully guarantees the monitoring of high standard farmland. **New inputs were made to support stable agricultural production and supply.** Three technology integration models were selected as



▲ A new variety of White Feather Broiler named "Guangming No.2"

▲ High-quality cabbage cultivar named "Zhonggan 21"

▲ The wheat cultivar named "Zhongmai 895" with high filling rate and heat resistance

▲ The rapeseed cultivar named "Zhongyouza 19" with high production and high oil content

▲ 104 experts from CAAS went to provide technical services for rush harvest and rush planting in provinces hit by extreme weather

key national technologies. Three experts of CAAS were selected as national advanced individuals in grain production. More than 70 experts from 14 institutes under CAAS went to hard-hit areas after a major storm in Henan province to provide technical assistance. In order to ensure smooth development during the "Three Autumn" production campaign, more than 100 experts from 17 institutes went to 69 disaster-hit counties in five provinces to provide technical services for planting and harvesting.**Significant impacts were produced in supporting rural revitalization.** CAAS has promoted its new "field school" model to help agriculture with science and technology. The "Huachuan case" won the silver award among the "Top 10 Cases" for national Party building innovation achievements. The Academy assisted Wuyuan and Shouguang to be selected as the leading counties in the modernization of agricultural science and technology in China. **Supports to rural environmental governance were widely praised.** A Green Paper of "Report on China's Development of Rural Residents Environment" was released. Self-developed toilet improvement products and technical models were affirmed by the leaders of the State Council and promoted for application in 26 provinces. **Influence on supporting national decision making was further enhanced.** Up to 47 strategic advisory reports were approved by Party and State leaders, 28 of which were approved by the members of Standing Committee of the Central Committee. 8 documents were directly submitted to the central office for the first time, and 15 special reports were submitted to ministry-level leaders. 4 think tank reports, including "Agricultural Outlook""Agricultural Industry Development""Agricultural Green Development" and "Frontier Focuses and Competitiveness of Agricultural Science and Technology", were successively released.

▲ 74 experts of CAAS went to disaster-stricken areas to provide technical guidance

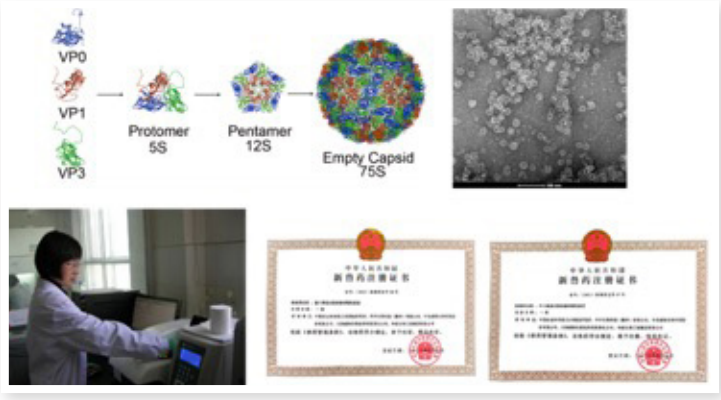
▲ Various types of field classes were held in 2021

Significant progress was made in scientific and technological innovation

The establishment of national science and technology projects enjoys good momentum. CAAS took the lead in undertaking 393 national science and technology projects. Among them, 32 were key research and development projects, and the number of projects in agricultural fields accounts for one third of the total. One was selected as a major special annual project for "New Generation Artificial Intelligence". CAAS had 353 programs of the National Natural Science Foundation of China in 2021, including 28 major programs. The basic science center program of "Crop Germplasm Innovation and Creation" of CAAS was the first comprehensive major program to be approved. There are seven social science fund projects, including two major projects. **A series of major original scientific discoveries have been made.** More than 6,700 scientific papers were published including 6 published in *Nature*, *Science*, and *Cell*. Basic research and applied fundamental research capabilities continued to improve. The Institute of Vegetables revealed the process by which Bemisia tabaci (tobacco whiteflies) harms more than 600 plants. The Biogas Research Institute discovered a new carbon metabolism process related to methanogens. The Institute of Genomics cultivated the first generation of highly homozygous diploid inbred lines and conceptual hybrid combinations. The Institute of Cotton revealed the genomic basis of geographic differentiation and fiber quality improvement of cultivated upland cotton. **Several breakthroughs were made in key technologies.** CAAS won 58 provincial and ministerial-level awards. The Institute of Plant Protection improved control of the fall armyworm, which was recommended to the world by FAO. The Institute of Urban Agriculture and the China National Rice Research Institute achieved a major breakthrough allowing dwarf rice to be harvested in 63 days. Four class-I new veterinary drugs developed by three institutes under the Academy have helped filled the domestic gap. Harbin Veterinary Research Institute completed second phase clinical trials and production safety tests for transgenic organisms of African swine fever gene deletion vaccine. Lanzhou Veterinary Research Institute successfully completed the subunit vaccine laboratory research.

▲ Bemisia tabaci are harmful to a large number of plants

▲ Diploid potato seeds vs. potato seed tubers



▲ Development of foot-and-mouth disease type O vaccine for pigs and cattle

Deep integration of industry and research

Cooperation with local governments has been strengthened. CAAS has cooperated with the Suzhou government to promote construction and development of East China Agricultural Science and Technology Center. It has reached agreements with the cities of Zibo and Huludao to jointly build new R&D institutions. CAAS has built new strategic cooperation relationships with more than 10 local governments. **Cooperation with science enterprises and industries has been further expanded.** Income from monetized achievements by CAAS exceeded 1.3 billion RMB in 2021, setting a new record. The transfer price of 7 intellectual property rights exceeded 10 million RMB per each, and the transfer price of "Zhongyouza 39" set a record high for a single rapeseed variety. CAAS has cooperated with leading enterprises such as China National Agricultural Development Group Co and Da Bei Nong Group to establish awards for innovation and outstanding talent in the industry. Together with China Mobile, which enjoys information technology advantages, CAAS built a public platform for intelligent breeding. The Academy established a science and enterprise consortium with more than 100 well-known enterprises such as COFCO, Syngenta and Beijing Capital Agribusiness and Foods Group. **The construction of innovation alliances continued to advance.** It took the lead in organizing nearly 1,000 units and more than 20,000 scientific and technical personnel to carry out collaborative research and built 11 alliance entities in total. "Union of Excellent Workers" for the dairy alliance is an oft-used phrase.

▲ CAAS signed an agreement with the municipal government of Zibo to jointly build the Digital Agriculture and Rural Areas Research Institute

Structure and quality of talents team optimized

High-level talent pool has been expanded. Prof. Hou Shuisheng and Prof. Zhou Wei were elected Academicians of the Chinese Academy of Engineering. Up to 29 talented individuals were selected into the national talent plan, and 37 high-level experts were introduced. The Academy had 43 new agricultural talented staff, which made the total number of such staff stand at 373. **CAAS further strengthened the building of a team of high-quality professional managerial staff.** The Academy improved the related mechanism and training system, and trained the managerial staff to improve their professional ability and strategic vision. The age structure of the management team has been greatly optimized. **The quantity and quality of the postdoctoral team rose.** The number of people on the postdoctoral team in CAAS exceeded 700, ranking tops among agricultural universities and research institutions. Postdoctoral fellows were awarded 52 youth programs and six general programs from the National Natural Science Foundation of China, and the number of youth programs accounted for 36 percent of the total in the Academy. **The level of postgraduate degree holders continued to increase.** CAAS applied for the Hainan special program, strengthened joint education and continued to expand enrollment scale. In 2021, CAAS recruited 1,813 graduate students, up 9 percent year-on-year. Among them, the number of students from "Double First-Class" universities accounted for 35 percent of the total. Altogether 1,413 people were awarded degrees, up 13 percent year-on-year. The Rural Revitalization College and Nanfan College were established. The school's operating conditions continued to improve.

▲ National High Containment Facilities for Animal Disease Control and Prevention

Platform conditions reached a new level

Construction of major scientific research facilities progressed smoothly. The new National Crop Gene Bank of China was completed and put into trial operation. Lanzhou Veterinary Research Institute built the largest animal biosscurity high-level laboratory facility cluster in China. Construction of the Northern Rice Center was essentially completed. The main structure of the overseas center was finished. The southern breeding phenotype facilities launched construction. Livestock and poultry bank projects as well as a seed industry innovation center were approved. The supportive ability was greatly improved. The Academy obtained special support from Hainan for the first time and also signed an agreement with Changping district in Beijing to acquire construction rights for 350,000 square meters. The scientific research platform was continuously strengthened. 4 national engineering centers, including crop molecular breeding, passed examinations given by higher authorities. National field stations in Shouyang and Dali received building approvals. The excellent rate of sharing facilities and instrumentation at the Academy reached 83.9 percent. The basic long-term observation network was further improved. More than 400 agricultural scientific research institutions nationwide were organized to carry out long-term positioning monitoring related to soil quality, habitat environment, germplasm resources, biological disaster prevention and control.

▲ The National Crop Gene Bank of China

▲ National Field Scientific Observation and Research Station of Agricultural Ecosystem in Dali, Yunnan Province

International communication and cooperation maintained a good trend

CAAS actively engaged in diplomatic activities. The Academy participated in the UN Food Summit and technical consultations in three fields, and hosted the "National Food Security and Sustainable Development Dialogue" and the sub forum on "Reducing Food Loss in Production". CAAS provided technical support for agricultural negotiations of *the UN Framework Convention on Climate Change.* CAAS remained engaged with global innovative resources. The International Science & Technology Innovation Program has been steadily implemented, expanding cooperation with Harvard, Oxford, Heidelberg and other first-class universities, and employing high-level foreign experts. The "China-Uruguay Soybean Joint Laboratory" was selected to the construction list of national "Belt and Road" joint

▲ CAAS hosted the "National Food Security and Sustainable Development Dialogue"

▲ The operational monitoring indicator system of the Academy

laboratories. CAAS expanded funding channels for international cooperation projects, and increased funding by more than 65 million RMB. CAAS continued the building of an international talent team. Altogether 88 overseas study fund projects were approved, and 30 high-level talented individuals were introduced to the Academy to engage in medium and long-term research work. 310 experts were stationed in international mechanisms and journals, with global influence continuing to increase.

The management mechanism continuously optimized

The Academy made progress in decentralizing power and improving services. CAAS explored ways to decentralize the right to evaluate senior professional titles, gradually expanded the funding approval authority to chief scientists of innovation teams, simplified financial procedures, so as to provide more convenience to scientific researchers. CAAS reformed the employment system for all staff. The Academy explored the pre-employment and long-term employment mechanism to upgrade the human resources structure. Full cost accounting reform was conducted. The Academy established a full cost accounting system and optimized the allocation of scientific research resources, which improved efficiency. CAAS established an institutional operational monitoring system. It closely followed its operation and development status, prevented risks and supervised implementation of the work. CAAS improved the level of standardized management. The Academy formulated and published management articles and a series of rules and regulations. It built a legal working system. It also paid close attention to regular epidemic prevention and control protocols, and maintained zero infections. A joint working mechanism was established with public security, communities and institutions, to ensure the standardized disposal of scientific research waste and hazardous laboratory chemical management and to maintain the safety of the Academy.

The 14th Five-Year Development Plan of Chinese Academy of Agricultural Sciences (2021-2025)

1. Missions and Goals

1.1 Missions

As the **national team and strategic force for agricultural research**, Chinese Academy of Agricultural Sciences (CAAS) takes the primary responsibility for the development of core agricultural technologies. During the 14th Five-Year Plan and subsequent periods, CAAS will continue to serve as "four centers" and a think tank that provide scientific and technological support for China's transition from a large agricultural country to an agricultural powerhouse.

As the **national agricultural science and technology innovation center**, CAAS is dedicated to providing scientific and technological solutions to strategic and fundamental issues in China's agricultural and rural development—issues involving public good, demanding a systemic approach, and requiring future-oriented research, in order to consolidate the country's foundation for an agricultural and technological powerhouse.

As the **national agricultural technology transfer center**, CAAS is committed to the transfer, commercialization, maturation, iteration and integration of agricultural technology in support of rural revitalization and agricultural and rural modernization.

As the **national agricultural talent center**, CAAS regards talents as the primary resource and gives priority to the development of talent. It aims to become the national center of strategic agricultural talent and an international center of agricultural scientists.

As the **national agricultural science and technology cooperation center**, CAAS is open to domestic and international cooperation, active in the international governance of agricultural technology, and integrated in the global agricultural innovation network. It serves as a strategic force for agricultural cooperation and exchange home and abroad.

As the **national think tank for agriculture**, CAAS has pooled a large number of strategic scientists and launched the national alliance for agricultural think tanks to provide consultation and recommendations for decision-making in agricultural and rural development, policy initiatives and scientific and technological progress.

1.2 Goals

By 2025, the agricultural innovation system of the Chinese Academy of Agricultural Sciences will be basically completed. The system will have rational planning, strong capabilities, capacity for targeted innovation, and an optimized ecology, serving as the strategic force supporting national strategies for rural revitalization, agricultural development, and advancing science and technology.

2. Development Plans and Priorities

2.1 Disciplinary Planning

Emerging and frontier disciplines. Guided by new growth points of modern agriculture and the trend of research, CAAS will catalyze and foster a number of new and frontier disciplines.

Traditional disciplines that support agriculture, rural development and farmers. Guided by the strategies of rural revitalization and agricultural and rural modernization, CAAS will expand research on agriculture, rural communities, and farmers to support rural development.

Disciplinary crossing and blending. Guided by key issues in agricultural science and technology, CAAS will promote innovation through disciplinary integration and build an innovation chain comprising basic research, technology development, product creation and commercialization.

2.2 Task Planning

Breakthroughs in basic and cutting-edge research. Focusing on basic and cutting-edge issues, CAAS will emphasize theoretical and methodological innovations by proposing new ideas, making new discoveries, and developing new technologies.

Inventing core technologies. Focusing on core technologies, CAAS will achieve major breakthroughs through proprietary research.

Providing integrated solutions. CAAS will work for technological integration along the industrial chain to solve complex regional problems and support the initiatives of building modern agriculture demonstration zones and rural revitalization demonstration counties.

Reinforcing nutrition and health research. Resources will be pooled to cultivate high-quality and high-yield cash crops, develop technologies on the storage, transportation, deep processing, and quality and safety assurance of agricultural products, and improve their nutritional quality.

Strengthening strategic research. Focusing on strategic, urgent, hot, difficult, and key issues, CAAS will organize academy-wide macro-strategic research to produce major research results with significant social influence.

2.3 Platform Planning

2.3.1 Planning for key scientific facilities. CAAS will plan for the initial approval and construction of state key laboratories.

2.3.2 Improving the three-tier platforms for research, innovation and application at the national, ministerial and CAAS levels.

2.3.3 Building the basic observation network for agriculture, rural communities and farmers to meet the long-term and basic needs of research and consolidate the basic network for research, industrial development and decision-making.

2.3.4 Enhancing platforms for international cooperation. CAAS will build and upgrade its international cooperation platforms and develop long-term cooperation mechanisms to share resources and strengths.

3. Major Tasks and Initiatives

3.1 Enhancing capabilities for independent innovation and fostering major achievements

CAAS will fully implement the Mission List system and launch the upgraded version of the Agricultural Science and Technology Innovation Program (ASTIP). CAAS will strengthen original basic research, nurture new, frontier and cross-cutting technologies, consolidate fundamental research, promote all-round rural revitalization, and increase the number of major breakthroughs.

3.2 Improving capabilities for commercialization and supporting rural revitalization

CAAS will build a team and a research institute for synergy among innovation, creation and entrepreneurship. It will strengthen the demonstration and replication of integrated green, high-yield and high-efficiency technological solutions and improve the capacity for the commercialization of research achievements.

3.3 Strengthening human resources development and building an innovators center

CAAS will build a talent echelon along four vertical lines—strategic scientists, leading scientists, young scientists, and postdoctoral/graduate students, and foster a team of talent with complex skills and capabilities for technological transfer and commercialization. Meanwhile, another four teams with horizonal functions will be developed, respectively for scientific research, management, supporting services and commercialization.

3.4 Building first-class facilities and conditions and laying a foundation for leapfrog development

CAAS will build national key facilities and consolidate its strengths in platforms for crop research, plant protection and animal farming. It will upgrade its laboratories and improve the structure and conditions of experimental and demonstration facilities (observation and experimental stations, plant resource nurseries, and livestock conservancies). It will build high-speed internet connections between research units, a Big Data center for agricultural research, and a new-generation digital collaborative innovation platform.

3.5 Domestic and international cooperation to gather strengths for innovation-based development

CAAS will shift from supply-driven to demand driven research. It will strengthen cooperation with local governments to boost local industries. It will deepen cooperation with top universities and research institutes in China to build collaborative innovation centers. It will promote high-level cooperation with international partners. CAAS will advance the implementation of the CAAS International Science and Technology Innovation Program (CAASTIP) and actively participate in international programs initiated by other countries. It will foster a talent team with a global vision and expertise on research and management, international cooperation and technology transfer, and attract high-caliber overseas talent. CAAS will actively participate in the international governance of agricultural science and technology.

3.6 Deepening institutional reform to build first-class research institutes

CAAS will improve the systems and mechanisms for innovation. The role of the Academic Committee will be enhanced to improve participation in decision-making. CAAS will explore a joint research mechanism for major tasks comprising of innovation teams selected on the basis of competition. It will optimize the human resource development system, including the training, use, incentive and competition mechanisms, so that every person will be placed in an appropriate place and given the opportunity to develop themselves, reach their potential, and achieve excellence.

3.7 Forging a high-end agricultural think tank and improving the capacity to support policymaking

The think tank system will be optimized to build an open network for collaborative research. CAAS will establish

a performance evaluation indicators system and evaluation methods driven by tasks at the academy, institute and team levels and encouraging innovation as a think tank. It will promote brand building and improve academic exchange platforms such as the Agricultural Economics Observation and CAAS Seminar Series for greater academic influence.

4. Programs for international cooperation

During the 14th Five-Year Plan period, CAAS will plan for and promote agricultural innovation from a global perspective. It will work to fully integrate into the global innovation network, actively participate in the global governance of science and technology, and strive to build win-win partnerships. It will strive to become a broad and open forum for global agricultural cooperation. The following five programs will be implemented:

4.1 The Talent for Internationalization Program (TIP) and the International Talent Program (ITP)

TIP will be implemented to support Chinese experts from different fields going abroad for mid- to long-term cooperative research or as visiting scholars at world-class universities and research institutions. It will also support qualified graduate students for study in those places. The training of "agricultural diplomats" and similar personnel to be dispatched overseas will be strengthened and outstanding experts will be recommended to work in Chinese embassies and international organizations abroad. ITP will be implemented to invite top international experts active in research for exchanges in China. High-level foreign experts from well-known foreign research institutions, universities or businesses will also be invited under this program for key research projects in China.

4.2 The International Science and Technology Innovation Program (CAASTIP)

International resources will be identified to match the CAASTIP research tasks. More international partners will be encouraged to participate in the on-going program projects and incubate major collaborative results in frontier and key technologies to contribute to the solution of global agricultural challenges. In basic research and key technological areas, projects with the potential of breakthroughs will be explored to form project reservoirs and build CAASTIP into a brand for sustainable collaborative innovation in agriculture.

4.3 The "Belt and Road" Agricultural Innovation and Application Program (BRAIAP)

CAAS will collaborate with BRI (the Belt and Road Initiative) countries in agricultural research, extension and demonstration and as a think tank in support of the overall agricultural cooperation with these countries. Research for innovation and integration of key technologies will be conducted for crop breeding, high efficiency cultivation, agricultural machineries and equipment, and value-added processing to develop technological models and products for green agriculture. CAAS will work with BRI countries in research on monitoring, early warning and prevention and control technologies for plant and animal diseases. Key research results and products will be generated to help build mechanisms for biosecurity cooperation and ensure agricultural biosecurity.

4.4 International Partnership for Innovation Program (IPPIP)

CAAC will upgrade the operation of existing international joint laboratories to achieve sustainable development and provide stronger support to collaborative innovation. Priority will be given to joint laboratories at the CAAS level and international reference laboratories and to the incorporation of excellent international joint laboratories at the CAAS level into national platforms for international agricultural cooperation. CAAS will advance the construction of overseas laboratories in key partner countries and send permanent staff there to deepen the level of cooperation. CAAS will advance the construction of Shenzhen International Agricultural Food Science Center and Shenzhen International Food Valley to enhance international cooperation in the fields of future agriculture, food nutrition and health.

4.5 Research on Overseas Agricultural Science and Technology Strategies and "Big Data" Program

CAAS will build a comprehensive think tank platform for research on the outlook for global agricultural science and technology, international agricultural innovation policies, and strategies on international cooperation and development, and provide recommendations and support on China's international cooperation policy. CAAS will build the "Big Data" Platform for International Agricultural Science and Technology and organize a team of data scientists with a global vision to lead CAAS's research and innovation toward the Fourth Paradigm—data-intensive scientific discovery.

Science and Technology Innovation

- National Science and Technology Awards
- Major Research Achievements
- Major Scientific Discoveries

National Science and Technology Awards

Large-scale identification, improvement, and utilization of elite maize germplasm (the second prize of the National Science and Technology Progress Awards of China)

Prof. Wang Tianyu carried out the field identification of elite maize germplasm for disease resistance and drought resistance

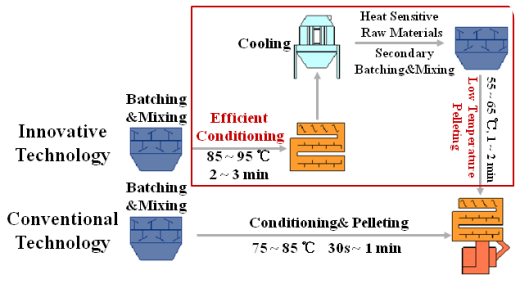
The research team led by Prof. Wang Tianyu at the Institute of Crop Sciences of CAAS studied the epidemic occurrence of northern leaf blight, southern leaf blight, sheath blight, and stalk rot in the main maize production areas of China, clarified the response characteristics of maize growth and development to drought stress, and tackled the difficulties of low accurate evaluation of disease and drought resistance by innovating precise identification techniques. They performed the dissection of the major-effect QTL related to disease resistance, drought resistance, and yield, developed new techniques for heterotic classification, and established a highly efficient technology system for maize germplasm improvement. The research team constructed the Ecological-Breeding Model (EBM) for maize by combining the directional testcross and directional selection.22 new hybrid varieties have been developed, of which 18 showed outstanding disease resistance, eight revealed excellent drought resistance, 17 exceeded the control yield by more than 8% in the regional test of maize, and three were selected as the controls in the regional test. The new hybrid varieties developed by the research team have been planted 12.67 million ha. Moreover, using the elite germplasm released by this team, other organizations have developed at least 94 new hybrid varieties, planted 25.33 million ha, and achieved significant economic, social, and ecological benefits.

Breeding and application of Zhongjiazao 17 and series super-high-yield early-season indica rice varieties for special purposes (the second prize of the National Science and Technology Progress Awards of China)

Breeding of good quality, high yield, and high fertilizer use efficiency (super efficiency) *indica* rice cultivars in the middle and lower Yangtze River region, China

The research team led by Hu Peisong at China National Rice Research Institute of CAAS has focused on the breeding and application of super-high-yield early-season indica rice varieties for special purposes in the middle and lower reaches of the Yangtze River, China. They aim to solve three outstanding technical difficulties: rotten seedlings caused by low temperature in the seedling stage, the bottleneck for high yield in a short growth period, and poor rice quality caused by high temperature during the maturation stage. Their study has proposed the theory and method of super-high-yield early-season rice breeding for special purposes, created many new germplasms for super-high-yield early-season indica rice breeding, and developed a high-efficiency and accurate identification and selection technology system. Meanwhile, eight new super-high-yield early-season rice varieties have been cultivated for rice noodle processing. The representative variety Zhongjiazao 17 shows excellent processing quality in making rice noodles. It was recommended as the primary extension cultivar by the Ministry of Agriculture from 2010 to 2016. As a result, its annual planting areas ranked first in China's southern rice region from 2013 to 2017. It is the only early-season rice variety that has been applied over 66.7×103 ha in a single year since 1991, covering about 20% of the early-season indica rice area in the middle and lower reaches of the Yangtze River. Their research achievement has brought enormous social and economic benefits.

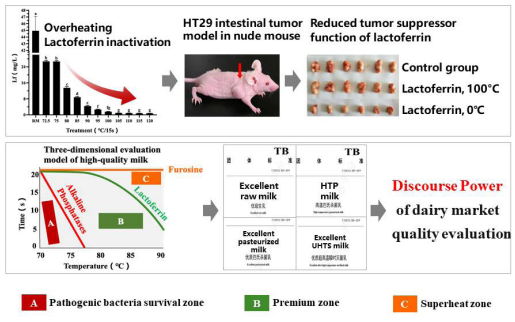
Creation and application of key technologies for quality and safety control of livestock and poultry feed (the second prize of the National Science and Technology Progress Awards of China)



Innovation technology of high-efficiency conditioning and low-temperature pelleting feed production

The research team led by Qin Yuchang at the Institute of Animal Sciences of CAAS has made many breakthroughs in key technologies, such as the detection of illegal additives and toxic & harmful substances in feed, the quality and safety control during the feed processing process, and the establishment of feed processing traceability system. These breakthroughs construct a whole industry chain feed quality and safety control technology system of "detection control-processing guarantee-system management". The achievements obtained 12 invention patents and eight software copyrights, led to the formulation or revision of 10 national standards and five industrial standards, were published in 289 papers (including 88 SCI/EI papers) and six books, and were awarded three first prizes such as Shennong China Agricultural Science and Technology Award. The project has been promoted and applied in more than 1,000 feed mills and breeding enterprises in the country and created a cumulative economic benefit of 8.057 billion RMB, leading the progress and development of feed quality and safety control technology and ensuring the quality and safety of livestock products.

Key technologies for safety control and quality improvement of milk and dairy products (the second prize of the National Science and Technology Progress Awards of China)



Key technologies for quality improvement of milk and dairy products

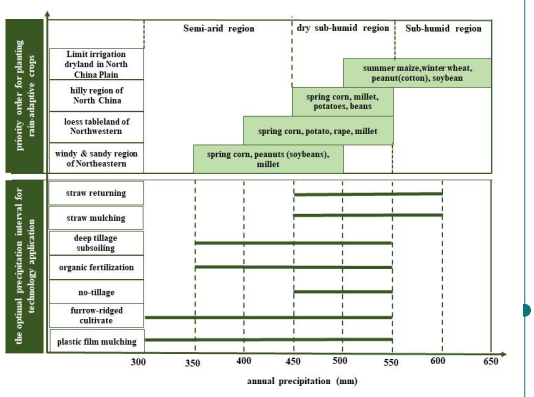
China's dairy industry faced severe safety and quality challenges in past decades: the absence of essential data for risk assessment, weak safety control technology, and backward quality improvement techniques. The Milk Research Team at the Institute of Animal Sciences of CAAS developed the "Quality and Safety Risk Assessment for Milk and Dairy products" database, which reveals the types of major risk factors in the dairy production chain. The team also developed technical specifications for safety control in the whole production process, whose application has significantly improved the safety level of raw milk nationwide. In addition, the team formulated the first international reconstituted milk identification standard, which has become a potent tool to supervise the illegal use of reconstituted milk in the dairy industry and protect consumers' rights. Moreover, the team employed green and low-carbon technology for milk processing. These technology systems lead the domestic dairy industry to transform and upgrade from focusing on safety to pursuing high quality. Their achievements won four first prizes of provincial and ministerial scientific and technological progress awards, one grand prize and one first prize of the Great Wall Food Safety Science and Technology Awards, enacted 30 national, industry, and group standards, and obtained 18 invention patents. Nineteen core technologies have been applied as the leading promoted technologies by the Ministry of Agriculture and Rural Affairs of China. The demonstration enterprises produced 482,500 tons of high-quality pasteurized dairy products in 2019, accounting for 90% of large-scale manufacturers' total pasteurized dairy products in China.

Development and application of novel veterinary drugs for preventing and treating high-incidence diseases of dairy cows (the second prize of the National Science and Technology Progress Awards of China)

Prof. Li Xiubo

With 20 years of continuous effort, Prof. Li Xiubo's research team at the Feed Research Institute of CAAS has established the world's largest pathogenic bacteria database for dairy cows, determined the pathogenic genera and distribution patterns of high-incidence pathogens such as mastitis and endometritis in dairy cows, and discovered a series of novel pharmaceutical targets for dairy cow diseases. The team innovated critical drug development and manufacturing technologies, reaching a leading level internationally. They have developed a series of safe and efficient new veterinary drugs, which has contributed to "full coverage" for the industry chain of dairy farming. Both the application and industrialization rates of the new veterinary drugs have achieved 100%. They have formulated 25 national standards for veterinary drugs, published 128 peer-reviewed research papers, and received 16 patent authorizations. Their research outputs have been promoted and applied in provinces (or autonomous regions) such as Heilongjiang and Inner Mongolia, with products exported to Germany, Japan, Brazil, and other countries. In the past three years, the research benefited 12.6 million cattle, trained more than 520,000 technical personnel for the industry, and generated a total economic benefit of 3.26 billion RMB. They have made fundamental contributions to China's dairy industry's healthy and sustainable development.

Drought-resistant and rain-adaptive planting technologies and their applications for dryland agriculture in northern China (the second prize of the National Science and Technology Progress Awards of China)



Crop planting priority and technical rainfall suitability for drought-resistant and rain-adaptive planting in dryland of North China

The research team led by Mei Xurong at the Institute of Environment and Sustainable Development for Agriculture of CAAS has been conducting synergic and innovative research for over 16 years. In view of the issues related to frequent drought and variable climate, excessive soil and water use, and decline in production stability in China's northern dryland, the research has revealed the changing dynamics of crop water supply and demand, and for the first time, determined the technical suitability and crop priorities of drought-resistant and rain-adaptive planting in the northern dryland. It has also determined the mechanisms of increasing field water holding capacity by soil carbon enhancement, reducing soil evaporation by surface mulching, and improving crop-producing efficiency by canopy shaping. These mechanisms contributed to establishing the theory and method of Soil-Surface-Canopy synergic control for drought-resistant and rain-adaptive planting. All the above research findings were integrated to develop the leading technologies, corresponding accessories, and technical standards for drought-resistant and rain-adaptive planting in main dryland areas in northern China. From 2017 to 2019, such integrated technologies were successfully implemented and applied on over 7.7 million ha in three main dryland areas in northern China, increasing grain production by 4.59 million tons, raising output value by 8.65 billion RMB, and saving 1.2 billion cubic meters of irrigation water. The research has significant economic, social, and ecological benefits. The research outputs provide an essential scientific basis and critical technical support for implementing the national dryland agricultural planning and dryland water-saving agriculture demonstration.

Key Technology for efficient utilization of nutrient resources of major food crops (the second prize of the National Science and Technology Progress Awards of China)

Field trials and demonstration of efficient fertilization of rice

The research team led by Zhou Wei at the Institute of Agricultural Resources and Regional Planning of CAAS aimed to reduce chemical fertilizer application and increase fertilizer use efficiency for the main food crops such as corn, wheat, and rice. The research team has established a new fertilizer recommendation approach based on yield response and agronomic efficiency by analyzing the nutrient demand characteristics. They have innovated key technologies for efficiently using organic fertilizer, straw, and other nutrient resources, created new fertilizer products, and integrated technical models for reducing fertilizer and increasing efficiency for main food crops. These innovations have constructed a comprehensive theoretical and technical system for efficiently using main food crops' nutrient resources, significantly improving the efficiency of nutrient resources, crop yield, and overall benefits. The research results have been applied to 5.327 million ha of corn, wheat, and rice in the past three years. The application has increased grain yield by 5.332 billion kg, reduced the application of chemical fertilizer nitrogen and phosphorus nutrients by 413,200 tons, increased income and saving by 12.286 billion RMB, and increased net income by 10.803 billion RMB. The research has provided necessary scientific and technological support for the National Zero Growth Action of Chemical Fertilizer Use.

Major Research Achievements

▲ Zhongmai 895 pilot field

▲ Zhongmai 895 with excellent tolerance to high temperatures

▲ Zhongmai 895 with excellent noodle quality

Zhongmai 895 enhances wheat production in the Yellow and Huai Valley, China (Prof. He Zhonghu's team at the Institute of Crop Sciences of CAAS)

Zhongmai 895, developed by the Institute of Crop Sciences and Cotton Research Institute of CAAS, is characterized by a high and stable yield of 11,730 kg/ha, excellent tolerance to high temperatures, and resistance to diseases. Its total sowing acreage has reached 3.4 million ha. It also shows short stature and outstanding lodging resistance, top performance in grain-filling rate and tolerance to high temperatures, outstanding production under reduced irrigations and late sowing environments, and excellent noodle and steamed bread qualities. Zhongmai 895 has served as a core parent in breeding programs, and six cultivars, including Zhongmai 30, have been released. It significantly contributes to wheat production and food security in the southern part of Yellow and Huai Valleys, China, facing the challenge of climate change.

▲ Broadcasting of tiny granules by UAV to control fall armyworm

▲ Prof. Wang Zhenying investigated fall armyworm infestation on corn

Technological upgradation of fall armyworm control drives the innovative progress of pest management (Prof. Wang Zhenying's team at the Institute of Plant Protection of CAAS)

Since first detected in China in January 2019, fall armyworm has spread across 27 provinces and infested more than 1.30 million ha of corn. As the occurrence and management of fall armyworm remain unclear in China, the team led by Prof. Wang Zhenying developed a new real-time system to monitor fall armyworm population dynamics based on the accurate clarification of the biology and occurrence of this pest. They developed novel bioinsecticides, seed treatments, tiny granules, and UAV spraying technology. These integrative technologies represent a milestone in fall armyworm management, boosting significant efficacy in fall armyworm control. This management strategy has been applied on a large scale in agricultural practice nationwide and recommended by FAO for fall armyworm control. It was also entitled as one of the ten piloting techniques of the Ministry of Agriculture and Rural Affairs of China in 2021.

▲ G033A products

▲ Control of *Spodoptera frugiperda* by Bt genetically engineered strain G033A in the field (Nanning, Guangxi)

Creating new efficient biological pesticides and leading the new direction of domestic pesticide development (Prof. Zhang Jie's team at the Institute of Plant Protection of CAAS)

The research team led by Prof. Zhang Jie independently developed the biopesticide *Bacillus thuringiensis* engineering bacteria G033A. This biopesticide solves the problem that no available efficient green pesticides can control flea beetle and important invasive pests, such as fall armyworm, potato beetle, and tomato leaf miner. It is the first genetically engineered microbial pesticide with independent intellectual property rights in China, breaking the monopoly of foreign countries. It showed high activity against important Coleopteran and Lepidopteran pests, and the field control efficacy was more than 85%. The genetically engineered bacteria G033A has been applied to 80,000 ha in 16 provinces and autonomous regions such as Guangdong and Guangxi, effectively saving labor and pesticide costs. The G033A leads the new direction of microbial pesticide development in China. It won the first prize in the 14th China Pesticide Industry Association Technology Innovation Award.

▲ Large-scale demonstration and promotion of Zhonggan 21

▲ World's first discovered cabbage dominant genic male sterile material "79-399-3"

◀ Zhonggan 21: Early-matured, high-quality spring cabbage cultivar

Zhonggan 21, a flagship brand of "Plateau Summer Vegetable" (Academician Fang Zhiyuan's team at the Cabbage Research Group of CAAS).

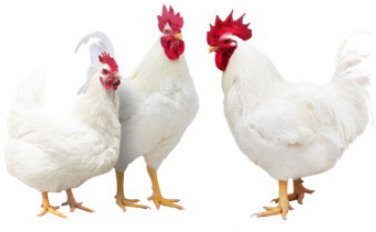
Zhonggan 21 is an early-matured spring cabbage cultivar derived from the world's first discovered cabbage dominant genic male sterile line. It has been voted the primary popularized cultivar for two consecutive years by the Ministry of Agriculture and Rural Affairs of China. Zhonggan 21 is round in head shape, green in color, fresh in taste, and tolerant to cracking, with high uniformity, yield, and quality. The cumulative planting area of Zhonggan 21 has reached 667 thousand ha across the country. It is the primary popularized cultivar in the open field during spring and the plateau area during summer in Hebei, Henan, Shandong, Shanxi, Gansu, Shaanxi, Liaoning, and Inner Mongolia, accounting for over 70% of the total cabbage planting area. Zhonggan 21 has contributed significantly to poverty alleviation and rural revitalization and won the second prize of the National Science and Technology Progress Awards of China.

▲ Breast muscle *in vivo* measurement with ultrasound technology

▲ Inspection at the breeder hatching site

Guangming 2 marks that China has independently developed white-feather broiler breeds (Prof. Wen Jie's team at the Institute of Animal Sciences of CAAS)

After ten years of cooperation between research institutions and enterprises, the government certified a new variety of the white-feather broiler, Guangming 2. New technologies, such as genomic selection, ultrasound determination, and meat quality and disease resistance selections, have improved the genetic progress of economic traits. These technologies save 2–3 years for the significant production performance of Guangming 2 to reach the same level as international varieties. Guangming 2 completed a pilot test in Guangdong and Shandong provinces. It showed that the new variety has a fast growth rate and high feed conversion rate, which can replace similar international varieties. Guangming 2 marks the 0 to 1 breakthrough in the independent domestic breeding of white-feather broiler breeds.



▲ Guangming 2 white-feather broiler

"Ruminant enteric methane reduction technology" contributes to carbon reduction and production efficiency improvement of livestock (Ruminant Feed Innovation Team at the Institute of Feed Research of CAAS)

Enteric methane emissions from ruminants account for 25% of agricultural greenhouse gas emissions. The research team improved the microecological balance of ruminants and reduced enteric methane emissions by manipulating dietary nutrition composition, changing dietary forage proportion, optimizing dietary feed resources, and enhancing nutrient digestibility *via* supplementation of probiotics, enzyme compounds, and plant extracts. Application of this technology can increase milk yield by 784 kg per year and reduce approximately 681 kg of CO2 emissions, which represents social and environmental benefits.

Monitoring methane emission of dairy cows

An accurate understanding of the pig industry facilitates the country's macro decision-making (Dr. Wang Zuli's team at the Institute of Agricultural Economics and Development of CAAS)

Dr. Wang Zuli' team pays close attention to the changing situation of pig production capacity and the development trend of major animal epidemics throughout the country. They accurately assessed the pig supply and demand and the industry development trends based on extensive data analysis combined with monitoring and early warning technology. They provide essential information support and policy recommendations for stable pig production and supply and the prevention and control of significant animal epidemics, which strongly supports the policy-making and decision-making in the pig industry.

Dr. Wang Zuli

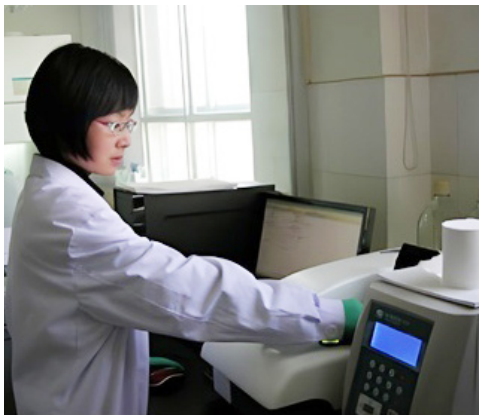
The historical change law of the recent five round "Pig Cycle" and its internal driving logic

The breeding of Zhongyouza 19 indicated that the biological breeding of high oil content in China entered the world's leading ranks (Prof. Wang Xinfa's team at the Oil Crops Research Institute of CAAS)

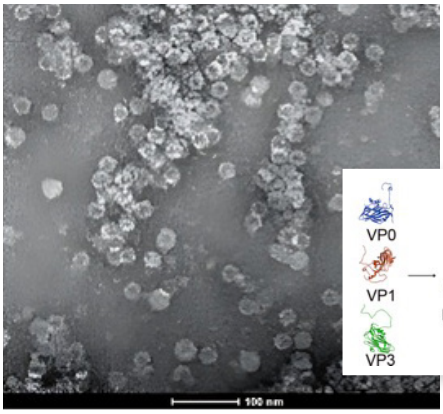
The representative hybrid Zhongyouza 19, breaking through the contradiction in simultaneously achieving high oil, high yield, and multiple resistance, achieved an average oil content of 50.09%. It is the first winter-type rapeseed variety with a high oil content of up to 50%, high yield, and multiple resistances, and it is suitable for mechanized harvesting. In 2020, the accumulated demonstration and extension area of Zhongyouza 19 in the Yangtze River basin, China, exceeded 200,000 ha, ranking the top three in China's winter rapeseed promotion area. Under physical pressing, the average oil production increased by 100.6%, and the income per hectare increased by 3,649.8 RMB. It has successfully created many sets of green and efficient production patterns widely used in the Yangtze River basin, which effectively supports the overall efficiency improvement of the rapeseed industry and ensures the self-sufficiency rate of China's edible oil.

Prof. Wang Xinfa

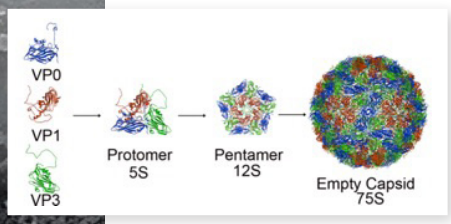
The large area demonstration of Zhongyouza 19 at the immature period



▲ Prof. Guo Huichen



▲ Electron microscope picture of VLPs

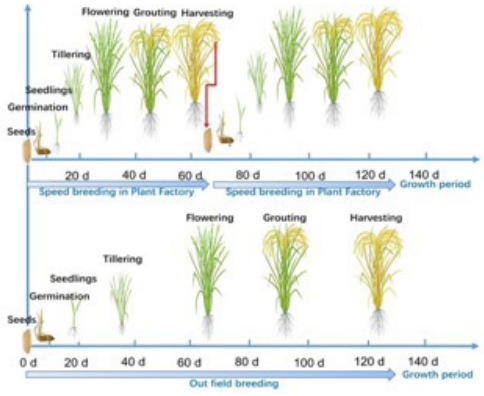


▲ Mechanism diagram

A key step of foot-and-mouth disease virus-like particle vaccine in industrialization (Prof. Guo Huichen's team at the Lanzhou Veterinary Research Institute of CAAS)

Guo Huichen's team has managed to express the same level of various viral capsid proteins in a soluble way simultaneously, thus breaking through the technical barrier of assembling intact virus-like particles (VLPs) in the liquid environment in vitro. This innovation has changed the traditional antigen preparation method that requires live viruses to produce inactivated foot-and-mouth disease (FMD) vaccines. It also has changed the antigen attributes of traditional vaccines. Their research opens a new era of safe and efficient genetic engineering vaccines for FMD. The FMD type O VLPs vaccines they developed for swine and bovine, respectively, have won two national first-class new veterinary drug registration certificates and the Chinese patent excellence award. The commercialization revenue of these two VLPs vaccines has exceeded 30 million RMB, opening up a new direction for the research and development of prevention and control products in major animal epidemic diseases.

▲ Rice breeding accelerator of plant factory



▲ Growth period of rice generation-adding breeding

A breakthrough in crop breeding methods: The key technology of rice speed breeding under plant factory environment (Prof. Yang Qichang's team at the Institute of Urban Agriculture of CAAS)

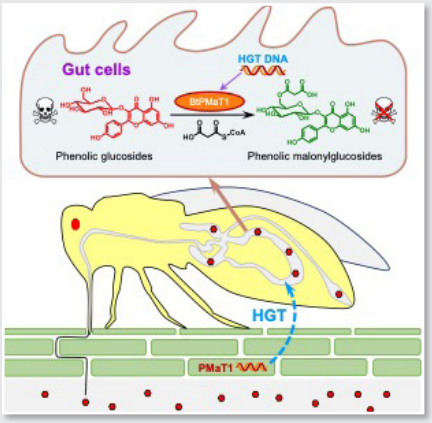
To solve the central problem of the long breeding time of rice and other crops, Prof. Yang Qichang's research team takes the lead in finding out the environmental and biological characteristics of shortening the rice growth cycle. They have created dynamic co-regulation technologies of environment & nutrition for rice growth at different stages and established a technical method to significantly shorten the rice growth period. In the plant factory condition, a breakthrough has been achieved in rice speed breeding: the generation time of dwarf rice is halved, and the dwarf rice can be harvested at around 63 days. This technology can significantly improve rice breeding efficiency by adding 5–6 generations per year, thereby greatly accelerating the breeding speed of new varieties. This breakthrough provides a new technical approach to vitalize the seed industry and guarantee national food security.

Major Scientific Discoveries

Whitefly hijacks a plant detoxification gene that neutralizes plant toxins

(Institute of Vegetables and Flowers;
first author: Xia Jixing; corresponding author: Zhang Youjun)
(Cell, IF 41.584, ranking 2/295)

The whitefly Bemisia tabaci, one of the most important agricultural pests worldwide, can attack more than 600 host plants. We found that, through an exceptional horizontal gene transfer event, the whitefly has acquired the plant-derived phenolic glucoside malonyltransferase gene *BtPMaT1*. This gene enables whiteflies to neutralize phenolic glucosides, which widely exist in host plants of whitefly such as tomato. Silencing *BtPMaT1* by genetically transforming tomato plants to produce small interfering RNAs impairs the whiteflies' detoxification ability. Our study provided the first empirical evidence for the horizontal transfer of functional plant-derived genes to insects. These findings reveal how insects develop resistance to plant defenses by horizontal gene transfer, open up a new perspective for the adaptive evolution of insects, and provide a new idea for precise and eco-friendly whitefly management.

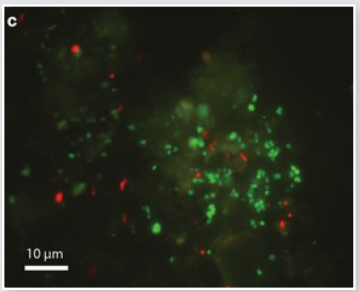


▲ Plant-derived horizontal transfer gene *BtPMaT1* empowers the whitefly to neutralize plant phenolic glycosides

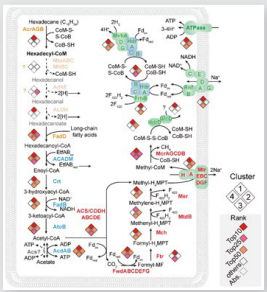
Non-syntrophic methanogenic hydrocarbon degradation by an archaeal species

(Biogas Institute of Ministry of Agriculture and Rural Affairs; .
first author: Zhou Zhuo; corresponding author: Cheng Lei)
(Nature, IF 49.962, ranking 1/72)

Traditionally, methanogenic degradation of complex organic matter requires the syntrophic metabolism between bacteria and archaea. The study used stable-carbon isotope-labeled culture, metagenome, and metatranscriptome sequencing and high-resolution mass spectrometry analysis to confirm that a novel single methanogenic archaeal species (Candidatus Methanoliparum) could directly complete the process of long-chain alkyl hydrocarbons degradation to methane production through β-oxidation and Wood Ljungdahl and methanogenesis pathways. Thus, the fifth methanogenic pathway (alkyltrophic methanogenesis) is proposed. Our research expanded the knowledge of the biogeochemical carbon cycle and provided a theoretical basis for developing carbon emission reduction technologies and underground biogas projects.



▲ CARD-FISH (green, Candidatus Methanoliparum; red, bacteria)



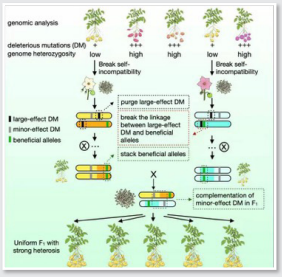
▲ Methanogenesis pathway of n-hexadecane degradation by single archaea

Genome design of hybrid potato

(Agricultural Genomics Institute at Shenzhen;
first author: Zhang Chunzhi; corresponding author: Huang Sanwen)
(Cell, IF 41.584, ranking 2/295)

Reinventing potato from a clonally propagated tetraploid into a diploid seed crop is an essential innovation in agriculture. Due to the numerous deleterious mutations hidden in the potato genome, developing highly homozygous inbred lines is still a big challenge. This research group constructed the pipeline of genome design of hybrid potato breeding, including the percentage of genome homozygosity and the number of deleterious mutations in the starting material, the number of segregation distortions in the S1 population, the haplotype information to infer the break of tight linkage between beneficial and deleterious alleles, and the genome complementarity of the parental lines. They employed genome design to develop a generation of pure and fertile potato lines and, thereby, the uniform, vigorous F1 hybrids. This study transforms potato breeding from a slow, non-accumulative mode into a fast-iterative one, thereby potentiating a broad spectrum of benefits to farmers and consumers.

▲ Comparison of potato tuber and seeds

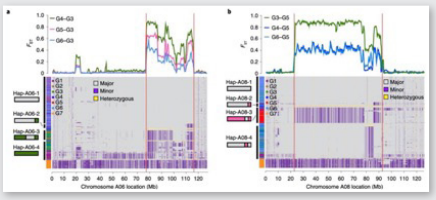


▲ Schematic diagram of genome design for hybrid potato breeding

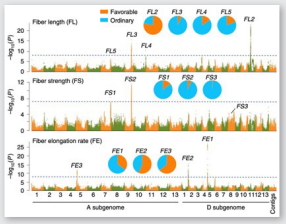
The genomic basis of geographic differentiation and fiber improvement in cultivated cotton

(Institute of Cotton Research; first author: He Shoupu; corresponding author: Du Xiongming)
(Nature Genetics, IF 38.331, ranking 2/325)

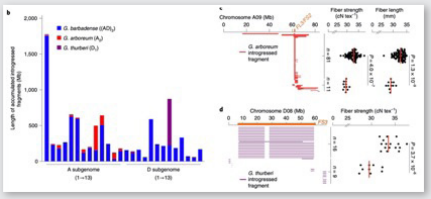
Large-scaled genomic variation investigations for germplasm are critical for understanding the formation and evolution of favorable traits in crops. This study demonstrated that two extensive chromosomal inversions derived from landraces were the essential causes for subpopulation divergence in the Upland cotton (cultivars) population via analyzing approximately 3,000 *Gossypium hirsutum* accessions. Moreover, genomic analyses also confirmed that the introgressed genomic fragments from diploid cotton were the key factor in improving fiber quality. This study provides insight into adaptation evolution and the theoretical basis for cotton fiber improvement.



▲ Extensive inversions of two chromosomes caused population divergence



▲ The major loci for fiber quality of Upland cotton



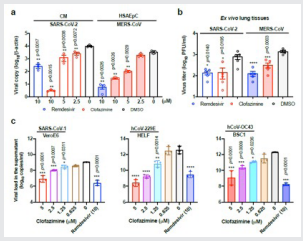
▲ The fiber quality improvement effect for introgressed fragments derived from diploid cotton

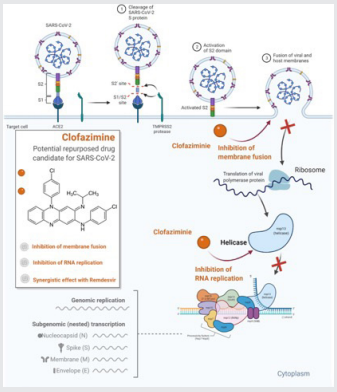
Clofazimine broadly inhibits coronaviruses including SARS-CoV-2

(Harbin Veterinary Research Institute, co-first author: Yin Xin)
(Nature, IF 49.962, ranking 1/72)

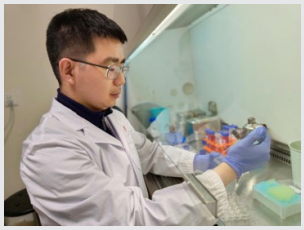
In this study, Yin and his colleagues found that clofazimine possesses broad antiviral activities against coronaviruses, including SARS-CoV-2. They demonstrated that clofazimine inhibits cell fusion mediated by the viral spike glycoprotein, as well as the activity of the viral helicase. Prophylactic or therapeutic administration of clofazimine in a hamster model of SARS-CoV-2 pathogenesis led to reduced viral loads in the lung and viral shedding in faeces and alleviated the inflammation associated with the viral infection. Combinations of clofazimine and remdesivir exhibited antiviral synergy *in vitro* and *in vivo* and restricted viral shedding from the upper respiratory tract. The study provided evidence that clofazimine may have a role in controlling the current pandemic of COVID-19, and possibly more importantly, in dealing with coronavirus diseases that may emerge in the future.

Clofazimine broadly inhibits coronavirus infection





The mechanism by which clofazimine inhibits coronavirus infection

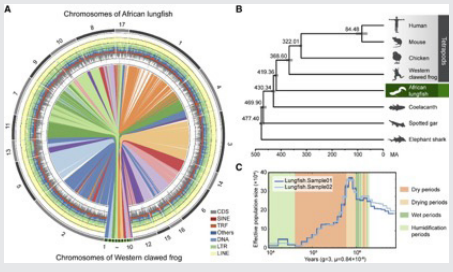


Yin Xin

African lungfish genome sheds light on the vertebrate water-to-land transition

(Agricultural Genomics Institute at Shenzhen; co-first author: Ruan Jue)
(Cell, IF 41.584, ranking 2/295)

Lungfish have the largest known genome of vertebrates. Scientists have failed to assemble it successfully for a long time. Therefore, the research on the transition of vertebrates from aquatic to terrestrial habitats missed a critical link. In a previous study, only 34.5 Gb of genome sequence was obtained from Australian lungfish, and the extremely low core gene completeness (67%) hindered the in-depth research in lungfish. In this study, we completed the analysis of 1.5 TB of third-generation data in three days by using an independently developed third-generation sequencing and assembly algorithm and obtained 39.1 Gb of genome sequence data. The core gene completeness is as high as 95%. Thus, the genome of African lungfish, which is the most difficult to assemble, was analyzed at high quality. Lungfish is known as a "living fossil"; the analysis of the genomic data revealed a three-step scenario for the water-to-land evolution. This achievement signifies that China has reached the international top level in giant genome assembly.



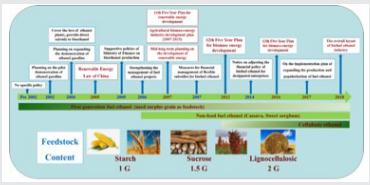
Chromosome-level genome assembly and evolutionary history of the African lungfish

Large memory computer operation site

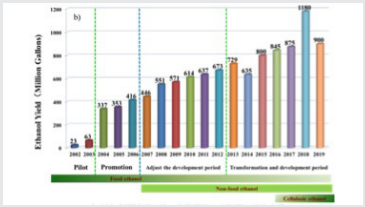
An insight to pretreatment, enzyme adsorption and enzymatic hydrolysis of lignocellulosic biomass: Experimental and modeling studies

(Institute of Environment and Sustainable Development in Agriculture; first author: Zhang Haiyan; corresponding author: Dong Hongmin)
(Renewable & Sustainable Energy Reviews, IF 14.982, ranking 1/44)

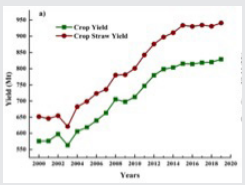
Currently, the fuel ethanol industry in China is in a critical period of transforming from the first-generation (1G) to the second-generation (2G). In this research, issues on the policy system, financial subsidy, industry layout, and historic yield of the fuel ethanol industry in China are comprehensively summarized and comparatively analyzed. Based on the correlation between the annual yield of crops and straws, a simple calculation is established to estimate the quantity of China's straw resources. This study presents a path to accelerating the valorization of straw resources on an industrial scale by addressing critical factors to straw utilization, such as the stable supply of straw feedstock and the technical development in pretreatment, hydrolysis and saccharification, strain breeding and screening, and fermentation. This research is significant to guide the straw resource utilization, transformation and upgrading of the fuel ethanol industry, and achievement of carbon neutrality.

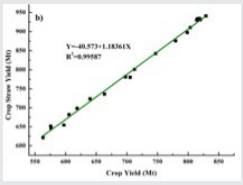


▲ Evolution of fuel ethanol policy in China since 2002



▲ Development periods of the fuel ethanol industry and historic ethanol yield in China since 2002



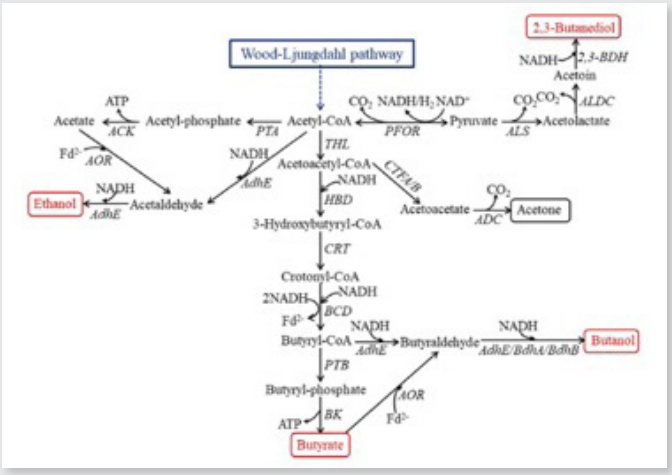


▲ A simple calculation to estimate the quantity of China's straw resource based on the correlation between the annual yield of crops and straws

Engineering acetogens for biofuel production: From cellular biology to process improvement

(Institute of Feed Research; corresponding author: Dong Lifeng)
(Renewable & Sustainable Energy Reviews, IF 14.982, ranking 1/44)

Increasing environmental concerns regarding fossil fuels and potential future supply constraints have driven the exploration of alternative fuel resources. The natural fermentation products by anaerobic acetogens can synthesize fuels and chemicals cleanly and sustainably. Cellular biology that enables syngas fermentation by using these versatile microorganisms contributes substantially to design strategies for acetogen cell engineering and to optimize these technologies to an industrially attractive production level. The potential to utilize metabolic engineering to improve the spectrum of acetogen products helps develop acetogens as efficient syngas fermentation biocatalysts for biofuel production in large-scale industrial processes.

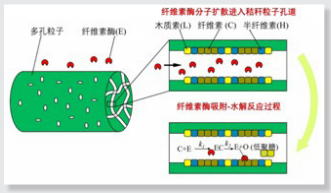


▲ Potential native biofuel products from acetogens

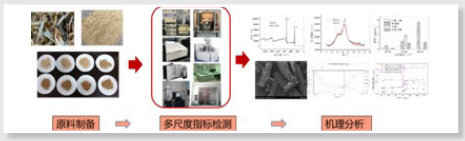
Current status and future prospective of bio-ethanol industry in China

(Biogas Institute of the Ministry of Agriculture and Rural Affairs; first author: Wu Bo; corresponding author: He Mingxiong)
(Renewable and Sustainable Energy Reviews, IF 14.982, ranking 1/44)

Enzymatic hydrolysis of lignocellulosic biomass is an attractive method for sustainable cellulosic ethanol production. Given the complex lignin-cellulose-hemicellulose network of lignocellulosic biomass, enzymatic hydrolysis is a complicated heterogeneous catalytic process. This work is the first to comprehensively analyze the research progress of enzymatic hydrolysis (including pretreatment, enzyme adsorption, and enzymatic hydrolysis) using both experimental and theoretical model evidence. The mechanism and the main influencing factors of the hydrolysis process were revealed. The appropriate method and suitable reaction conditions of enzymatic hydrolysis were proposed. This work also analyzed the relationship between experimental and modeling studies, which supports optimizing the hydrolysis parameters and advancing enzymatic hydrolysis development in industrial applications.



▲ Flow diagram of cellulosic ethanol production



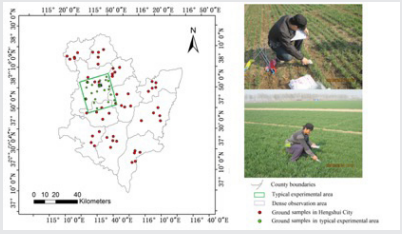
▲ Pretreatment and multi-scale characterization of lignocellulose and mechanism analysis

◀ Schematic diagram of the enzymatic hydrolysis process of lignocellulosic biomass

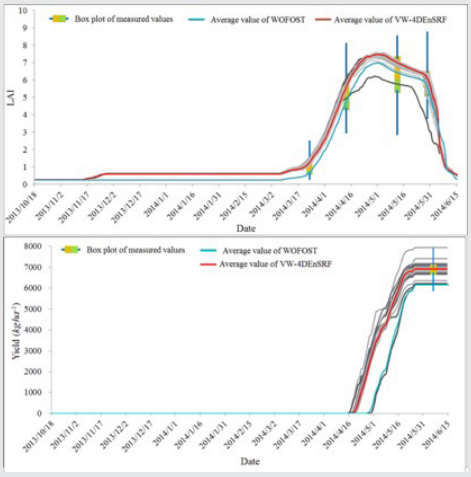
Regional winter wheat yield estimation based on the WOFOST model and a novel VW-4DEnSRF assimilation algorithm

(Institute of Agricultural Resources and Regional Planning; first author: Wu Shangrong; corresponding author: Chen Zhongxin)
(Remote Sensing of Environment, IF 10.164, ranking 1/29)

In order to improve the accuracy of regional crop yield estimation based on data assimilation, this study proposed a novel EnSRF assimilation algorithm based on a variable time window and four-dimensional extension (VW-4DEnSRF) and constructed a new crop yield estimation system based on crop growth model and VW-4DEnSRF algorithm. This study conducted the quantitative simulation and yield estimation of regional winter wheat, which proved the feasibility and effectiveness of the proposed algorithm of the large-area crop yield simulation. The proposal of the new assimilation algorithm provides a new feasible method for large-area crop yield estimation, which is of great significance for ensuring national food security.



▲ Ground sampling and data collection



▲ Simulated results of dynamic change of leaf area index and yield of winter wheat by VW-4DEnSRF

Strategic Programs

- Agricultural Science and Technology Innovation Program (ASTIP)
- Rural Revitalization and Poverty Alleviation through Science and Technology
- National Agricultural Science and Technology Innovation Alliance
- Integration and Demonstration of High Yield and High Efficiency Technology
- Talent Project
- Think Tank Construction

Agricultural Science and Technology Innovation Program (ASTIP)

In 2021, CAAS evaluated ASTIP implementation and summarized achievements over the past five years. Based on the evaluation results, all the work has achieved remarkable results.

First, CAAS has explored a new path for the reform and development of national agricultural scientific research institutions. Focusing on the mission of "serving the major scientific and technological needs of the industry and leaping to the top of the world's agricultural science and technology echelon", the Academy has provided long-term and stable support for public welfare, fundamental and strategic scientific research, clearer responsibilities and more focused goals and tasks. CAAS has established the employment mechanism of assigning posts according to needs, hiring people according to posts, and opening up competition and mobility of human resources, so as to improve the management prowess of the Academy to a new paradigm. Through the reform of the performance evaluation mechanism decided by significant output and the distribution mechanism decided by excellent performance, the enthusiasm of scientific and technological personnel for innovation has been motivated, and the innovation vitality has been greatly enhanced.

Second, CAAS has built an innovative model that conforms to the laws of modern agricultural scientific research. A "three-level disciplinary system" consisting of nine disciplinary clusters — 57 discipline fields — more than 300 key directions, has been established, stabilizing the related direction of the Academy. More than 300 scientific research teams composed of chief experts, research backbones and research assistants have been established, forming a stable and organic agricultural scientific and technological innovation team that meets the needs of modern agricultural scientific and technological innovation. CAAS has deployed a tri-level innovation task encompassing a modality focused on academies, institutes and scientific research teams, and established an innovation task system focusing on the primary needs of the country.

Third, CAAS promoted agricultural scientific and technological innovation to make new breakthroughs. With the support of the innovation projects, the innovation level and efficiency of the Academy have been greatly improved, and major scientific and technological achievements continue to emerge. The Academy has made many international original scientific discoveries in rice genomics, vegetable genomics, genomics technology and other fields. CAAS has made breakthroughs in a number of core key technologies in wheat hybridization, soil resource protection, intelligent livestock breeding, etc. The Academy created a batch of internationally leading new crop and livestock varieties such as high-quality, heat-resistant and high-yield wheat "Zhongmai 895", yellow feather broiler and white feather broiler. CAAS has carried out major national emergency-level research on such agricultural matters of concern as African swine fever and the fall armyworm, making significant contributions to ensuring the supply of live pigs and crops.

Fourth, CAAS started an enhanced strategy of leveraging resources to carry out collaborative research. Driven

▲ Performance evaluation meeting for the comprehensive promotion period of ASTIP

Focusing on "four aspects", a series of major results have been achieved

- Achieved series of global-leading important theoretical discoveries
- Made series of breakthroughs in key core technologies to boost agricultural and rural development
- Created batch of key products that lead modern agricultural development
- ssued series of major consulting reports on overall agricultural development

Overall results: Innovation ability clearly enhanced

by successful innovative projects, the Academy, together with international institutions and major national scientific research forces, launched and implemented major international agricultural science programs such as functional crop genomics and smart agriculture. It organized and carried out coordinated research on key programs between the Academy and local governments, having promoted provinces including Shandong, Guangxi and Fujian to launch provincial agricultural science and technology innovation projects. It took the lead in organizing 300 scientific research institutions and nearly 1,000 enterprises to establish nearly 100 innovation alliances to carry out collaborative innovation. The Academy organized and carried out coordinated innovation actions of green output and efficiency gains in grains and vegetables, and jointly promoted technological innovation and integrated demonstration events with the scientific research force of the Academy and local governments. Together with the Chinese Academy of Engineering, CAAS established the Chinese Agricultural Development and Strategy Research Institute to strengthen strategic consulting capacity. The synergy of national agricultural science and technological forces in collaborative innovation has been significantly enhanced, and the pattern of collaborative innovation has initially taken shape.

The innovation projects have played the role of innovative engine and incubator, explored a new path for agricultural science and technology drivers, and established a new model for China's agricultural science and technology innovation, which have made a solid foundation to achieve leapfrog development, as well as better shoulder national missions in the agricultural science and technology sectors.

Rural Revitalization and Poverty Alleviation through Science and Technology

Based on the experience in the construction of four demonstration counties for rural revitalization, namely Donghai in Jiangsu province, Wuyuan in Jiangxi province, Lankao in Henan province, and Qionglai in Sichuan province, CAAS promoted the smooth transition from a demonstration county for poverty alleviation through science and technology to a demonstration county for rural revitalization in Lintan in Gansu province, Huachuan in Heilongjiang province, Fuping in Hebei province and Ziyang in Shaanxi province. The Academy launched the construction of three demonstration counties, namely Xinxiang in Henan province, Qiyang in Hunan province, and Wuyishan in Fujian province. It organized and promoted the construction of Wuyuan in Jiangxi province and Shouguang in Shandong province to be selected as leading counties in the modernization of agricultural science and technology under the Ministry of Agriculture and Rural Affairs. CAAS has taken steps to provide scientific and technological assistance to two counties, namely Zhouqu in Gansu province and Taijiang in Guizhou province. Based on the rallying cry: "Where the main battlefield of modern agriculture is, that's where the CAAS experts are", experts were sent to participate on the frontlines of rural revitalization. By doing so, there evolved a number of technologies on display, as well as a group of technical talent with knowledge of agriculture and love for rural areas and farming. CAAS has created a new model of field school to help farmers, which has become the strategic brand of the Academy in serving the development of agriculture, rural areas and farmers in the new era. It has also won the silver award of "Top 10 cases" of the central and State-owned departments' innovative Party work achievements, providing the CAAS wisdom and serving as a model for overall national rural revitalization.

▲ Training in Huachuan (Institute of Crop Sciences)

▲ Rape Seed Industry Workshop in Wuyuan (Oil Crops Research Institute)

▲ Demonstration County in Wuyishan (China National Rice Institute)

▲ Livestock Breeding in Lintan (Lanzhou Institute of Husbandry and Pharmaceutical Sciences)

▲ Rice Field in Qiyang (Institute of Agricultural Resources and Regional Planning)

National Agricultural Science and Technology Innovation Alliance

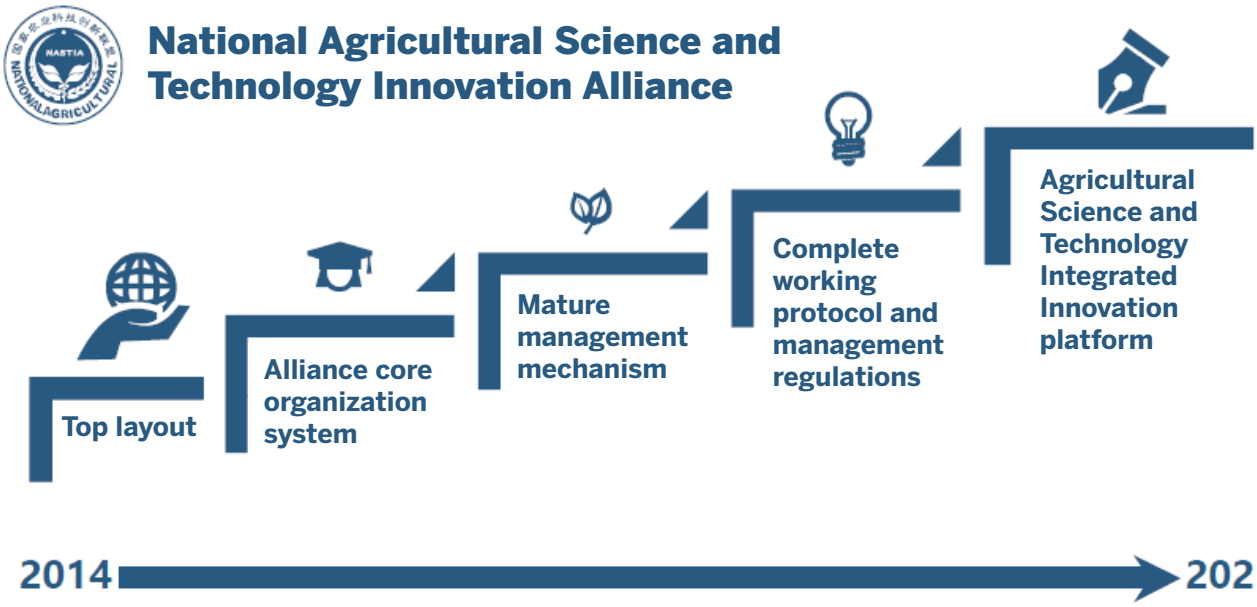
With a focus on quality, the environment and effectiveness, the National Agricultural Science and Technology Innovation Alliance convened about 1,000 teams and around 20,000 experts from over 3,000 units to carry out 1,046 sets of integrated technologies, formed 1,348 standards and published 487 standards, with a total of some 2.46 billion RMB in funding. With an existing 2,442 demonstration bases, 1,013 demonstration bases were newly built. More than 2,974 training courses were offered, with 940,000 people trained and a total of 1,104 on-site meetings held. The alliance got approval instructions from the Ministry-level eight times. The work of the alliance supported and contributed to the implementation of the strategy of rural revitalization, and the promotion of the innovative development of modern agriculture.

The management mechanism was further improved to standardize the operation of the alliance. The alliance formulated the Measures for Administration on the Construction and Operation of the National Agricultural Science and Technology Innovation Alliance. The alliance made the related mechanism pursuant to the signing agreements, major event alterations, and the third-party evaluation of the alliance. At the same time, a third-party evaluation was carried out over 12 sub-alliances eligible for assessment under the framework of the alliance. Nine recognized alliances, including two model alliances, were announced. One was suggested to rectify its problems and two alliances were recommended to be withdrawn from the alliance.

The layout of the alliance was improved and key tasks were promoted. The alliance established three industrial alliances focusing on standardization of traditional Chinese medicine, mountain agriculture and agricultural product processing. Based on the alliance, key tasks such as rural environmental governance in cold and dry lands and standards establishment of high quality cotton were carried out. Among them, the rural environmental management alliance participated in organizing the on-site meeting of the National Rural Toilet Revolution, displaying the relevant products, technical models and innovative achievements in recent years, which was highly praised by Vice-Premier Hu Chunhua.

The mechanism innovation continued to build a benchmarking alliance. Through the implementation of the mechanism of "substantiation" and other modalities, the alliance has established 20 substantiation operating institutions and created 20 benchmark alliance models, which has promoted the deep integration of scientific research and teaching units and enterprises, led to the emergence of a large number of scientific and technological achievements, and formed a number of examples of mechanism innovation.

The website of the alliance was revised to enhance its media influence. The new version of the alliance website includes seven first-level columns and 23 second-level columns, which can enrich the digital media influence of the alliance, improve the communication and interaction of the alliance with audiences, and create a public platform for the alliance.



Integration and Demonstration of High Yield and High Efficiency Technology

To meet the technical needs of high-quality development of regional agriculture, CAAS adhered to the principle of "increasing both yield and efficiency, germinating good seeds and methods, integrating agricultural machinery and techniques, and coordinating production and ecology" and advanced 15 research and demonstration programs along the entire industrial chain's key technology application, including oilseed rape, potatoes, cotton, vegetables, tea, melons and fruits and other agricultural commodities, as well as dairy cattle, sheep, hogs, ducks, etc. A total of 138 high-yield and efficient technology integration demonstration bases have been established, covering a total demonstration area of 930,000 mu and radiating across an area of 2.37 million mu, with 14.96 million head of livestock and poultry. The average cost per mu has been reduced by 30 percent. Consumption of water, fertilizer and pesticides fell by 30 percent, 20 percent and 25 percent, respectively. Some 184 advanced and practical technologies from home and abroad were integrated, and 60 sets of comprehensive technical models were formed for different regional ecological conditions. These efforts supported stable food production and supply. Three integrated projects, including cotton, grapes and hogs, were selected into the the major technology promoted by the Ministry of Agriculture and Rural Affairs in 2021. An experimental station model about pears in Ningling was reported by State media Xinhua News Agency and other media platforms.

▲ Dairy cattle demonstration project (Institute of Animal Sciences)

◀ Field school of sheep breeding demonstration project (Lanzhou Institute of Husbandry and Pharmaceutical Sciences)

▲ Potato demonstration project (Institute of Vegetables and Flowers)

▲ Xinjiang cotton demonstration project (Institute of Cotton Research)

Talent Project

Talent Development Plan during 14th Five-Year Plan period (2020-25)

Focusing on the goal of building a talent center and innovation locus, and promoting high-level self-reliance in agricultural science and technology, the plan closely focuses on two major tasks: building a national agricultural science and technology strategic talent pool and deepening reform of the mechanism. The plans have achieved their preliminary goals. By 2025, the number of high-level talent will increase significantly, including 280 leading talent and 300 young talent. The innovation ability of the scientific research team will be significantly enhanced, and about 80 excellent teams will be established. The structure of the talent will be further optimized. The average age of leading talent in agricultural science and technology fell to around 51 years of age. The number of team leaders aged below 45 years old accounted for 20 percent, and the number of young talent aged under 40 years old accounted for 50 percent. CAAS will strive to cultivate 30 strategic scientists, 100 world-class leading talent, 100 top knotch teams and a large number of young talent by 2035, in order to build a globally significant talent center and innovation locus.

Special Supportive Policies for CAAS Outstanding Talent

CAAS has developed a set of policies to support outstanding agricultural talent both at home and abroad. The policies will assist with recruiting leading high-level talent, giving priority support to jointly promote and construct complete talent development, and cultivating systems to attract and cultivate high-end science and technology talent while encouraging innovation and creativity.

For full-time talent (including contract personnel) of scientific and technological experts who are mainly engaged in tangible project support and transformation, the "Implementation Plan of Special Support for Supporting Talent of the Chinese Academy of Agricultural Sciences" and the "Implementation Plan of Special Support for Transformative Talent of the Chinese Academy of Agricultural Sciences" were both issued. The selected candidates will be given a subsidy of about 100,000 RMB per person annually, and special support will be provided in the areas of capability improvement, career promotion, project support, talent recommendation and humanitarian care.

The special support policies are mainly extended to full-time science and technology professionals working in research posts at CAAS. These posts can be divided into three levels — top talent, leading talent and young talent. CAAS provides each group with research funds and annual subsidies.

CAAS released the Talent Development Plan during the 14th Five-Year-Plan Period, established a talent layout with scientific research talent as the main body, management talent as the guarantee, and supporting talent and transforming talent as the auxiliary. Meanwhile, the layout will take strategic scientists as the core, leading talent as the backbone, young talent as the support, and post-doctoral and graduate students as the backup. CAAS will implement the agricultural talent project and give priority support to the selection of outstanding talent at the Academy and institute levels.

By the end of 2021, CAAS had 356 CAAS Outstanding Talent, among whom 17 were top talent, 254 leading talent, 75 young talent, five supporting young talent and five transformative young talent.

Elite Young Scientists Program

The Elite Young Scientists Program is a high-intensity young science and technology talent introduction pro-

Top talents	Research funds: 2 million RMB (per person a year)	Annual subsidy: 500,000 RMB (per person a year)
Leading talents in Class A	Research funds: 1.5 million RMB (per person a year)	Annual subsidy: 300,000 RMB (per person a year)
Leading talents in Class B	Research funds: 1 million RMB (per person a year)	Annual subsidy: 250,000 RMB (per person a year)
Leading talents in Class C	Research funds: 800,000 RMB (per person a year)	Annual subsidy: 200,000 RMB (per person a year)
Young talents	Research funds: 600,000 RMB (per person a year)	Annual subsidy: 100,000 RMB (per person a year)

gram initiated by CAAS in 2013 that promotes high goals and standards. The plan was listed as one of China's first 55 key initiatives aimed at recruiting high-level overseas experts and specialists in 2014. It now consists of two projects — an introduction project and a cultivation project. It aims to attract both domestic and foreign high-level leading scientists and innovative talent in various disciplines who are under 40 years of age and have strong global perspectives.

Introduction of High-level Talent with Flexible Policies

In 2018, CAAS issued interim measures for the management of high-level talent introduction with flexible policies, providing support to such individuals in terms of staffing, project applications and research conditions.

It aims to widen talent introduction channels and implement more positive, open and effective staff introduction policies. The policies ultimately strive to attract more high-level Chinese and foreign agricultural elites to serve the cause of the development of modern agriculture.

Postdoctoral Work

CAAS' center for postdoctoral studies was established in 1991. It covers four academic fields: natural science, engineering, agronomy agriculture and management. It also includes mobile research centers for postdoctoral studies in veterinary medicine, animal husbandry, crop science, plant protection, agriculture and forestry management, agricultural resources as well as environmental, biological, horticultural, and agricultural engineering. By the end of 2021, 2,237 postdoctoral researchers have been enrolled, including 216 Chinese graduates from foreign universities and 104 foreign specialists. In 2021, CAAS enrolled 231 postdoctoral researchers (including seven foreigners), and there are currently 704 postdoctoral researchers, which ranked first among agricultural and forestry universities and scientific research institutions across the country.

▲ The Fifth Talent Working Conference of CAAS in 2021

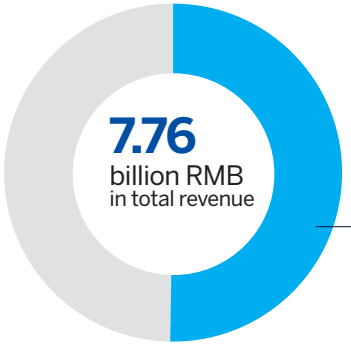
Think Tank Construction

The influence and popularity of the high-end agricultural science and technology think tank has continued to be strengthened and the Academy's consultancy ability is continuously on the rise. On May 25, 2021, CAAS, together with the International Food Policy Research Institute (IFPRI), hosted the China and Global Agricultural Policy Summit in Beijing and released *the China Agricultural Industrial Development Report (2021)* that looked both back and ahead to macroeconomic conditions in the agricultural industry at home and abroad from the perspective of the agriculture-food system. On July 28 in Beijing, *the China Agricultural Green Development Report (2020)* was released which objectively and authoritatively reflected the overall level, major actions and important progress of China's green agricultural development from 2019 to 2020. On Nov 19, CAAS hosted the 2021 China Agricultural and Rural Science and Technology Development Summit in Beijing, and released several reports, including *2021 Major Advances in China Agricultural Science* that published 10 basic scientific research achievements representing frontier research and major breakthrough progress in global agricultural science and technology. Another study, *the 2021 Global Agricultural Research Front*, published 54 global agricultural research theses regarding eight subjects. A third, *the 2021 Analysis on the Competitiveness of Global Scientific Papers and Patents*, showcased that China has become the country with the most published agricultural science and technology papers, and ranks second in terms of the competitiveness of agricultural patents. Lastly, *the 2021 Evaluation of Innovation Ability of China's Agriculture-related Enterprises* revealed that the innovation ability of listed agriculture-related enterprises in China was still at an insufficient level across the country. The summit attracted over 2.8 million people in terms of on-site and online participants. More than 20 official media outlets, such as Xinhua News Agency, People's Daily and CCTV, have issued a series of reports on the findings of the think tank. CAAS' social influence on the achievements of agricultural science and technology think tanks has greatly improved, which provides powerful reference for agricultural scientific and technological innovation and the implementation of rural revitalization strategies.

Support Capability

- Annual Budget
- Staff
- Integrated Coordination between Science and Agricultural Industry
- International Cooperation
- Major Scientific Research Layout
- Research Facilities Construction
- Intellectual Property
- Postgraduate Education

Annual Budget

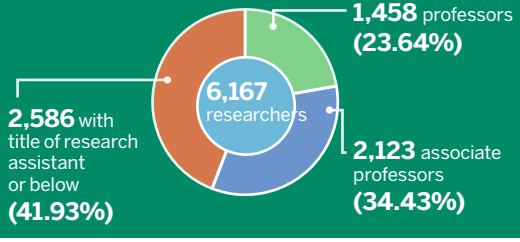


Staff

CAAS had 11,236 staff members by the end of 2021

6,849 permanent employees | **1,247** contract employees | **65** employees for the CAST Press

Among them, **1,618** are managerial staff **(23.62%)**; **6,167** are professors, including **1,522** people who also hold managerial posts **(90.04%)**, and **586** are technicians and logistics workers **(8.56%)**



Researchers

(Postgraduate degree holders account for **75.99%**)

3,263 hold doctorate degrees

Managerial staff

(Postgraduate degree holders account for **68.29%**)

574 hold doctorates degrees

531 hold master's degrees

813 are under 45 years old **(50.25%)**

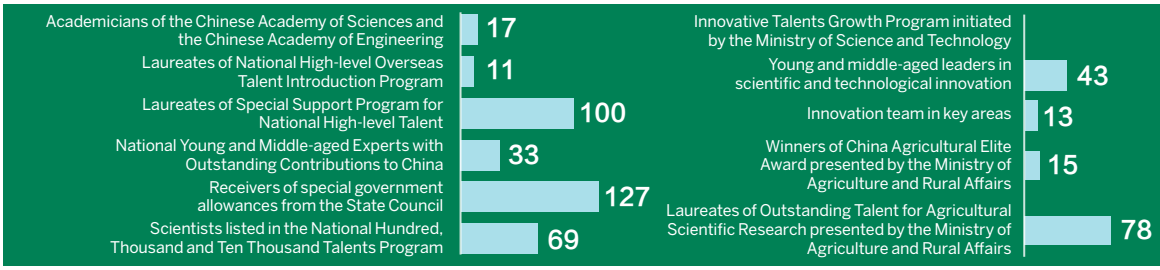
Technicians and logistics workers

122 technicians have college degrees and above, accounting for **20.82 %**)Uptiis pedis repelle ssediaepra

11 in first-class technical posts

132 in second-class technical posts

42 are under 45 years old **(7.17 %)**



Integrated Coordination between Science and Agricultural Industry

In order to accelerate the integrated development of CAAS and enterprises, and better serve rural revitalization and agricultural modernization, CAAS studied and drafted *the Work Plan for Integration Coordination between Science and Enterprises*. Through integrating resources, making use of each others' advantages, CAAS further promoted the establishment of a market-oriented, innovation system with cooperation between universities and enterprises, accelerated transformation of scientific and technological achievements, and promoted improvement of enterprise innovation capabilities. CAAS promoted the establishment of the consortium for integrated development between scientific research and enterprises and proposed the list of members, which has gathered together leading agricultural enterprises nationwide, and will improve the independent innovation level in agricultural science and technology in China. Under the leadership of CAAS leaders, a scientific process has been formed in terms of science and enterprise docking, agreement drafting, etc. Five open mechanisms of "germplasm resources, scientific research, intellectual property rights, scientific and technological talent, and innovation space" have been established, as well as a variety of cooperation modes such as "enterprises raising questions and the Academy providing answers". CAAS has signed strategic cooperation agreements with China National Agricultural Development Group Co Ltd, Da Bei Nong Group, China Rongtong, CNOOC, Shunxin Holdings, and other enterprises with a total contract value of 1.68 billion RMB. Among this, 100 million RMB was donated by

▲ Dr. Shao Genhuo from Da Bei Nong Group donated 100 million RMB to award outstanding innovation teams of the Academy

Dr. Shao Genhuo from Da Bei Nong Group to award the excellent innovation teams of the Academy. At the same time, CAAS has established close contact with companies including Alibaba Group, China Mobile Chengdu Research Institute, JD Group, CNOOC Refining and Chemical, and Tencent to promote strategic cooperation with enterprises. Institutes affiliated to CAAS actively established institute-level consortiums with enterprises, carrying out cooperation in technological development, intellectual property transfer and technical services, to better promote the transformation from the "research, learning, to production" mechanism to industrial production-led scientific research and innovation.

International Cooperation

CAAS adheres to the principle of mutual respect and win-win cooperation, actively participates in the global agricultural science and technology governance and contributes to the sustainable development of global food safety through open cooperation.

After intensive research and planning, the International Cooperation and Development Plan of CAAS during the 14th Five-Year-Plan period was officially released in 2021, which clearly outlined the objectives, key tasks and main measures for high-quality development of international cooperation over the next five years.

In 2021, CAAS signed 57 international cooperation agreements and memorandum of understanding with its foreign partners in different continents, including the second extension and amendment agreement with FAO to ensure wider cooperation between the two sides under the working framework and the first cooperation MOU with United Arab Emirates University, which has expanded the cooperation network between CAAS and the Middle East. In 2021, CAAS hosted 64 online international conferences and training courses, and participated in more than 230 online international conferences, which doubled the level seen the previous year. CAAS has jointly published more than 180 high-level papers with its international partners, with an increase of nearly 40 percent year-on-year. It was approved to engage in 88 overseas visiting and study projects via State funding.

Through online and offline communication and cooperation, the Academy maintained good relationship with global agricultural science and technology partners. More than 300 experts of CAAS work part-time in internationally renowned institutions and journals, contributing their professional expertise in relevant fields, which has promoted the innovative development of agricultural science and technology.

CAAS has actively participated in global food and agriculture management and shared China's experience in agricultural science and technological development. CAAS has participated in the work of organizing the Chinese side during the UN Food System Summit 2021. Experts of CAAS undertook the task of the summit advisory committee and technical consultation in three action tracks of the summit. The relevant work received a letter of thanks from United Nations Secretary-General Antonio Guterres. CAAS held successful the conference on "National Food Security and Sustainable Development Dialogue". CAAS prepared *the Report on the Sustainable Development Path of China's Food System*, and submitted it to the secretariat of the UN Food Summit to be shared openly, thus contributing Chinese wisdom and planning to the summit. CAAS held the sub-forum themed "Reducing food loss in production ", as the first phase of the International Conference on Food Loss Reduction in Jinan City, which significantly promoted exchanging ideas, policies and technologies on food saving and agricultural green development. CAAS participated in the FAO Global Action for Fall Armyworm Control, and introduced a Chinese pest control model and technical equipment to Asia and Africa, which have helped improve global food security.

CAAS pushed forward the 4 International Science & Technology Innovation Programs focusing on "molecular design breeding", "cross-border pest control", "smart agriculture", and "livestock and poultry waste utilization", and made new progress. CAAS expanded the relationship with high-level partners such as the University of Oxford in the United Kingdom, the University of Cambridge in the UK, Harvard University in the United States, and the University of California Davis in the US. The collaborative work in theoretical and practical research make greater efforts to achieve breakthroughs in key technologies, including 47 jointly published high-level papers, 21 authorized invention patents and 10 new plant variety rights, as well as a number of new technologies and methods.

CAAS promoted the construction of high-quality cooperation mechanisms and platforms to better play the role of resource integration. As the Co-Chair of the EU-China Task Force on Food Agricultural and Biotechnology, CAAS held the “CAAS and EU Agricultural Science and Technology Innovation Seminar” and the “10th Meeting of EU-China Task Force on Food Agricultural and Biotechnology”, identifying key cooperation areas such as comprehensive pest control, food nutrition management, and agricultural waste recycling to be integrated into the priority areas of the EU’s new round of science and innovation programme Horizon Europe 2021-2022.CAAS reached a consensus with FAO on an agreement to establish the innovation center and promoted the establishment of the "China-Israel Modern Agricultural Innovation Cooperation Center" and "China-Africa Agricultural Science and Technology Innovation Alliance", so as to build sustainable cooperation platforms for the demonstration and exchanges of modern agricultural technologies. CAAS organized a series of academic activities such as the "China-South Korea-Japan Smart Agriculture Seminar" "CAAS-CSIRO Cooperation Seminar" "China-France Agricultural Science and Technology Cooperation Seminar" "China-Denmark One Health Seminar", and "China-UAE Agricultural Science and Technology Cooperation Seminar". Chinese and foreign experts carried out deep exchanges and discussions around smart agriculture, crop breeding, animal and plant disease prevention and control and other fields, in order to explore development paths for ensuring food security and human health through innovation.

▲ The 13th Annual Meeting of the Steering Committee of the MARA-CABI Joint Laboratory was held at CAAS

▲ CAAS and the United Arab Emirates University (UAEU) jointly hosted the "China-UAE Agricultural Science and Technology Cooperation Seminar" and signed the first MOU

▲ CAAS and the Embassy of the Kingdom of Denmark to China jointly held the "Sino-Danish Side Event for the World Food Summit"

Major Scientific Research Layout

Major science and technology facilities built

▲ The National Crop Gene Bank of China

The National Crop Gene Bank of China is the top research and protection center for crop germplasm resources , which can safely copies1.5 million pieces of crop germplasm resources and meet the needs of national crop breeding, basic research, industrial development in the next 50 years.

Major science and technology facilities under construction

▲ Design sketch of the Hainan National Crop Phenotype Research Facility at Sanya

The Hainan National Crop Phenotype Research Facility at Sanya is a pilot project to promote the construction of China's Silicon Valley of Agriculture and the National Tropical Agricultural Science Center. It is a major scientific and technological infrastructure project focusing on crop field environment and environmental phenotype identification in China, which will raise service ability and modern breeding level. After completion of construction of the facility, it can evaluate 3,400 environmental phenotypes, 4,600 field environmental phenotypes and create 10,000 genetic resources.

▲ Design sketch of Agricultural Genomics Research Center

Targeting national demand for food security, biological security and ecological security, the **Agricultural Genomics Research Center** Targeting solving major cutting-edge and technical problems in agricultural genomics and becoming a global powerhouse in the field of agricultural genomics research. The center will establish its international agricultural genome science research and development center, national sharing platform for agricultural genome technology, and international agricultural genome talent training center. The new agricultural genome data facility can achieve data storage capacity of 20 PB, a peak computing ability of 500 trillion times per second, and complete 100,000 agricultural biological resource genome analyses.

Design sketch of the Seed Industry Innovation Center

The Seed Industry Innovation Center is a comprehensive research platform and innovation locus for seed industry innovation in China. It will form a national seed industry science and technology strategic force to boost construction of a tropical agricultural science center and ensure science and technology resource supplies for Hainan Free Trade Zone. After completion of the project, 100 to 200 high-yield, high-quality and efficient green germplasm resources, 30 to 50 breakthrough breeding parents, 10 to 15 strategic new varieties with a promotional area of more than 10 million mu, 5 to 10 high-yield, high-quality and stress-resistant livestock and new poultry varieties (supporting lines) can be cultivated. It will also effectively improve water and fertilizer utilization efficiency, reduce pesticide consumption and ease environmental and resource pressure.

Design sketch of the North China Rice Research Center

The North China Rice Research Center has an extremely important strategic role. It will carry out the introduction, collection, identification, screening and Distinctness, Uniformity and Stability (DUS) determination of rice varieties in North China, create new rice germplasm resources, as well as collect and preserve 2,000 rice germplasm resources, in order to realize the continuous improvement of quality and efficiency of the rice industry in the north and ensure the long-term absolute food safety and security for the country.

New major science and technology facilities in operation

Design sketch of the National Livestock and Poultry Gene Bank

The National Livestock and Poultry Gene Bank will build a nation-level livestock and poultry germplasm resource conservation and utilization platform with the largest amount of livestock and poultry germplasm resources, the most complete varieties and systems in the world with the highest level of advancement and efficacy. It will create a "global bank" for strategic conservation of livestock and poultry germplasm resources, which can save 2,522 domestic and overseas livestock and poultry varieties, with a capacity of 33.25 million copies of ultra-low temperature preservation, covering all domestic varieties and about 25 percent of overseas varieties.

Research Facilities Construction

Major Scientific Research Platforms

CAAS has two major national scientific facilities, one national high-level biosecurity laboratory for animal disease prevention and control, six state key laboratories, one key state laboratory jointly built with provincial governments, 22 comprehensive key laboratories under the Ministry of Agriculture and Rural Affairs, 68 special key laboratories under the Ministry of Agriculture and Rural Affairs, 30 agro-products quality safety risk evaluation laboratories under the Ministry of Agriculture and Rural Affairs and 52 Academy-level key laboratories.

Major Technology Innovation Platforms

CAAS has five national engineering technology research centers, seven national engineering research centers, 22 national centers (sub-centers) for the improvement of crop varieties, 16 national agricultural industry technology research and development centers, and 32 Academy-level engineering technology research centers.

Major Basic Support Platforms

CAAS has six national science and technology resource sharing and service platforms, 12 national quality crop seed resource banks and 13 national nurseries for quality crop seed resources. The Academy boasts 520,000 accessions of crop germplasm resources under long-term preservation, which ranks second in the world. It also has seven national field stations for scientific observation and experiments, three national product quality supervision and inspection centers, 32 ministerial-level quality supervision and inspection test centers, five national agricultural testing reference laboratories, nine national reference and professional laboratories, two FAO reference centers and seven OIE reference laboratories. CAAS owns the National Agricultural Library, in which the collection of agricultural books and journals ranks tops in Asia and third globally.

▲ The National Agricultural Library of CAAS

Intellectual Property

CAAS strengthened top-level design and improved the leading capability of the intellectual property sector. *The Plan for Improving the Intellectual Property Transformation Capacity of CAAS* was issued to open up the whole chain of intellectual property creation, application, protection, management and services, and promote agricultural science and technology innovation to support rural revitalization and modern agricultural development. CAAS researched and formulated *the Naming Rules for New Animal and Plant Varieties of CAAS (Trial)*, and initiated the registration of institute-level certification trademark to strengthen brand building and enhance the influence of the Academy's scientific and technological achievements.

CAAS strengthened theoretical research and took full understanding of the Academy's situation on the intellectual property sector. The consulting report on Strengthening Intellectual Property Protection and Promoting Self-reliance of Agricultural Science and Technology was completed, as well as the Intellectual Property Analysis Report of CAAS in 2020, which provided an important foundation for macro decision making.

CAAS strengthened training guidance and improved management level. The Academy translated and published *the Best Practice Manual for Intellectual Property Management of Agriculture and Health Innovation*, held several training sessions on achievement transformation and intellectual property, and constantly consolidated the foundation of intellectual property professionals. The Academy guided the Institute of Grassland Research to finish the standardization of "Intellectual Property Management Standard for Scientific Research Organizations", which has promoted the whole process management of scientific research and innovative intellectual property of the Institute, and improved the standardized management level.

Award Ceremony of CAAS Achievements Transformation Awards 2021

Incentive measures were strengthened and pilot reforms were promoted. The Academy completed the review of achievements transformation award of CAAS in 2021 and the recommendation of China Patent Award. The Notice of the CAAS on Further Improving the Recognition and Reward Distribution of Cash Income from Scientific and Technological Achievements Transformation was issued. The pilot work of granting ownership or long-term use rights of scientific and technological achievements to scientific researchers was completed, which has created a good atmosphere for encouraging innovation and attaching more importance to transformation. In 2021, the number and proportion of high-quality invention patents by CAAS has continued to increase, with 1,431 domestic invention patents and 81 new crop and plant varieties. The income from intellectual property transformation reached 450 million RMB, accounting for 36.2 percent of CAAS' total income from achievements transformation.

Postgraduate Education

In 2021, the Graduate School of CAAS (GSCAAS), has strictly advanced the reform of graduate education and continued to improve educational quality, under the leadership of the political construction of the Party. It has officially printed and distributed the Development Plan for Postgraduate Education in the 14th Five-Year Plan Period of CAAS (2021-25). It organized and held the work conference on CAAS graduate education, and planned to promote the construction of universities. The "Hainan Special" graduate enrollment unit was approved. The first batch of students of Nanfan College officially started classes. CAAS revised and improved the evaluation index system of postgraduate education, as well as comprehensively promoted the construction of "first-class graduate school" and "first-class discipline". The development of postgraduate education reached a new level.

▲ Opening Ceremony of 2021 GSCAAS

◀ International students participated in the event of "Perception of China", organized by the China Scholarship Council

▶ International students participated in the event of "Perception of China", organized by the China Scholarship Council

CAAS recruited 1,813 graduate students in 2021: 1,233 students seeking academic master's degrees (1,204 full-time students, 22 part-time students, seven foreign students). 580 are PhD candidates (479 domestic students, 63 foreign students, and 37 students in Chinese-foreign cooperative education projects). In 2021, 5,877 students were studying in CAAS, with 3,516 seeking academic master's degrees and 2,361 PhD candidates. CAAS deepened the reform of the enrollment system, accepted 194 students who were exempted from tests and 23 students who would finish all the education from graduate study to PhD directly in CAAS. At present, there are 2,506 supervisors in GSCAAS, including 19 academicians of the Chinese Academy of Science and the Chinese Academy of Engineering, 956 supervisors for doctoral programs and 583 teachers. Teaching ability and course management level have been significantly improved by holding tutor training classes and online teacher training. CAAS launched the construction of characteristic core courses and biosecurity course system, organized 253 courses throughout the year, and 35 online video courses for students to learn independently. CAAS strengthened the construction of ideological and po-

litical theory courses and formed a long-term mechanism that the Party Secretary of the Academy teaches the first lesson of Politics, which can strengthen the education of socialist core values. In 2021, 1,413 degrees were awarded, including 329 PhD holders and 1,084 masters' degrees. 1,358 students graduated with an employment rate of 90.2 percent. CAAS actively served the cause of rural revitalization. It has completed 14 training programs, and has trained 489 person times on-site and more than 40,000 person times received online training. CAAS upgraded the online learning platform of "Internet plus+ Modern Agriculture", with new recorded courses including 11 agricultural courses and 40 media operation courses, which brought the total number of online courses to 122.

CAAS has been actively working for the national Belt and Road Initiative and the "going global" need of the agricultural industry. There are 437 international students (387 for doctoral degree, 44 for master's degree, seven visiting scholars) in GACAAS. They are from 54 countries around the world, of which 57 percent are from countries along the BRI. Checking the annual evaluation of Chinese government scholarships by the China Scholarship Council, GSCAAS garnered an excellent score of 95. 148 foreign students graduated in 2021, including 126 with PhDs and 22 with master's degrees. A total of 223 SCI papers (1.51 per student) were published by international graduates, with an average impact factor of 3.86 and the highest impact factor of 9.147 for an individual paper. Three international students won the Chinese Government's Scholarship for Outstanding International Students in China, and two alumni won the "Outstanding Achievement Award" jointly awarded by the Food and Agriculture Organization of the United Nations (FAO) and the International Atomic Energy Agency (IAEA). One graduate cofounded a company, which achieved a new breakthrough among international graduates to start their own businesses in China.

Some 228 students were enrolled in Chinese foreign cooperative education projects in GSCAAS in 2021. There were 19 graduates of the project. 104 papers have been published by those graduates as primary, initial authors, including 62 SCI papers, with 3.27 per capita. The highest impact factor of a single paper was 9.381. The second phase of the Sino-Dutch project was approved by the Ministry of Education and began to recruit students.

▲ GSCAAS Commencement Ceremony for foreign students

▲ Students from home and abroad participated in the 9th Beijing International Kite Festival

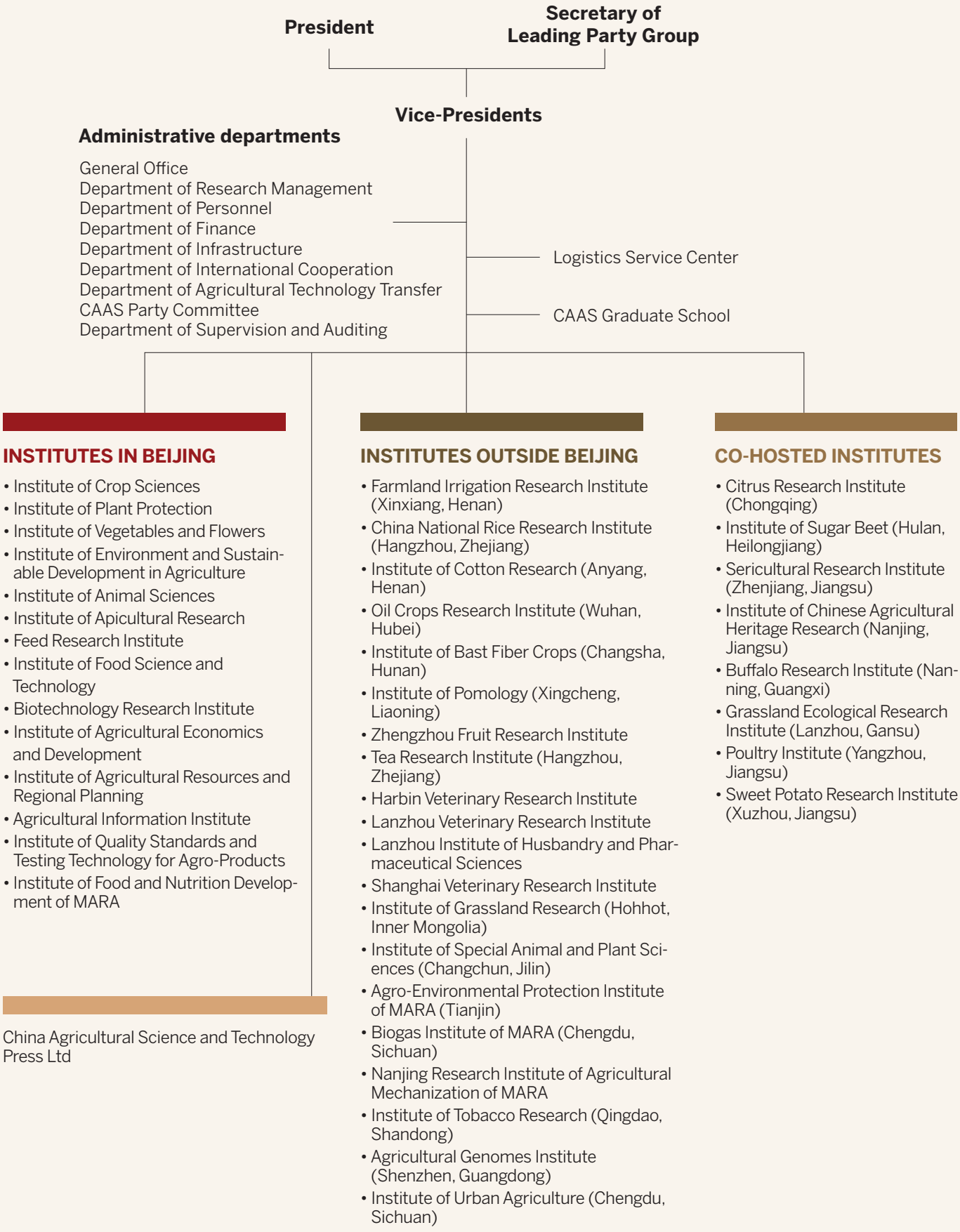
▲ Students won prizes in the competition of "100 Reasons to Love Beijing"

▲ 2021 Commencement Ceremony of GSCAAS

Appendix

- Organizational Structure of CAAS
- Key Laboratories and Centers

Organizational Structure of CAAS



Key Laboratories and Centers

Major National Facilities

No.	Facilities	Research	Institutes
1	National Key Facility for Crop Gene Resources and Genetic Improvement	New gene discovery and germplasm innovation; crop molecular breeding; crop functional genomics; plant proteomics; and crop bioinformatics.	Institute of Crop Sciences; Biotechnology Research Institute
2	National Center for Agricultural Biosafety Sciences	Significant agricultural and forestry diseases and insect pests; invasive alien species; and genetically modified organism biosafety for agriculture and forestry.	Institute of Plant Protection

Key National Laboratories

No.	Facilities	Research	Institutes
1	State Key Laboratory for Biology of Plant Diseases and Insect Pests	The mechanisms of calamities caused by important crop diseases and insect pests, monitoring and forecasting, and control technologies; the mechanisms of invasive alien species; functional genome for plant protection, and gene biosafety.	Institute of Plant Protection
2	State Key Laboratory of Animal Nutrition	Nutritional requirements and metabolic regulation; feed safety and evaluation; animal nutrition and environment; animal nutrition and immunology; molecular nutrition and genetics.	Institute of Animal Sciences
3	State Key Laboratory of Rice Biology	Genetic basis of rice germplasm improvement and innovation; physiological and the biochemical mechanism of rice growth and development; interrelation studies between rice plants and environment, and rice molecular breeding.	China National Rice Research Institute
4	State Key Laboratory of Veterinary Biotechnology	Genetic engineering of animal pathogens, cell engineering, molecular biology, and other areas of basic research in veterinary medicine.	Harbin Veterinary Research Institute
5	State Key Laboratory of Veterinary Etiological Biology	Infection and pathogenesis; etiological ecology, immunity, early warning and prophylaxis of veterinary and major zoonotic diseases .	Lanzhou Veterinary Research Institute
6	State Key Laboratory of Cotton Biology	Cotton genomics and genetic diversity research; cotton quality biology and functional genes research; cotton fiber yield biology and genetic improvement research; and cotton stress biology and environment regulation research.	Institute of Cotton Research

International Reference Laboratories

No.	Facilities	Research	Institutes
1	FAO Reference Center of Animal Influenza	The Laboratory is in charge of the confirmative diagnosis of highly pathogenic avian influenza, animal influenza surveillance, development and update of vaccines and diagnostic reagents.	Harbin Veterinary Research Institute
2	FAO Reference Center of Biogas Technology Research and Training	Policy study and technology research in biogas-related sectors.	Biogas Institute of MARA
3	OIE Reference Laboratory for Equine Infectious Anemia	Research focused on epidemiology and immunology of Equine Infection Anemia. An equine infectious anemia virus vaccine model is used to study the mechanism of protective immunity for lentiviruses.	Harbin Veterinary Research Institute
4	OIE Twinning Laboratory for Equine Influenza	The laboratory is to carry out the research on the epidemiology, etiology, and diagnosis of Equine Influenza and development of a vaccine and diagnostic reagent.	Harbin Veterinary Research Institute
5	OIE Foot and Mouth Disease Reference Laboratory	Technical consultations and services, etiology studies, molecular epidemiology research and immunology research; R&D on techniques and products for FMD prevention and control.	Lanzhou Veterinary Research Institute
6	OIE Ovine Theileriosis Reference Laboratory	Pathogen identification, epidemiology, diagnosis, prevention and control of ovine theileriosis.	Lanzhou Veterinary Research Institute
7	OIE Reference Laboratory for Infectious Bursal Disease	Studies related to basic pathogen research, epidemiological studies and the prevention and control of the infectious bursal disease virus.	Harbin Veterinary Research Institute
8	OIE Reference Laboratory for Avian Influenza	In charge of the confirmative diagnosis of avian influenza, avian influenza surveillance, development and update of vaccines and diagnostic reagents.	Harbin Veterinary Research Institute
9	OIE Collaborating Center for Zoonoses of Asia-Pacific	Carries out research on the regional epidemiology, etiology, the mechanism of interspecies pathogen transmission, molecular mechanism of pathogenesis and immune mechanism.	Harbin Veterinary Research Institute

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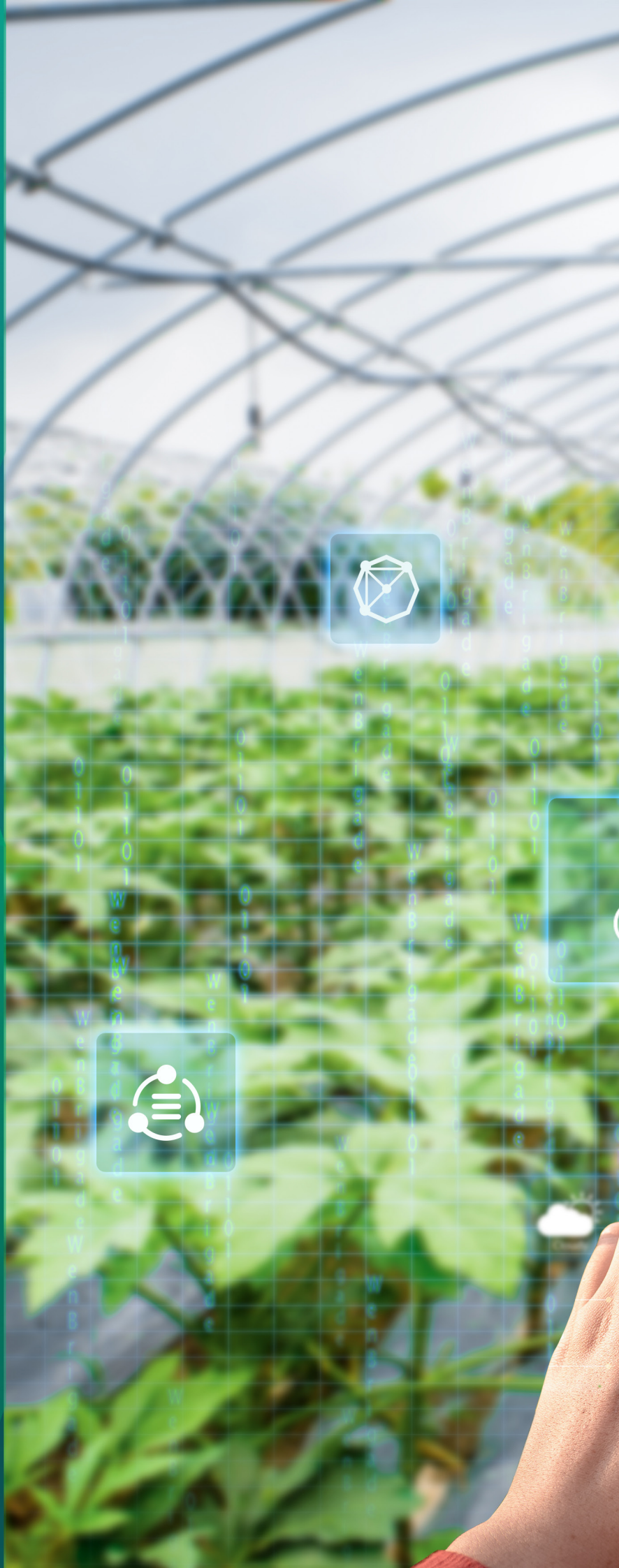

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