Produced by the *Science*/AAAS Custom Publishing Office

Agricultural innovations in China aid countries around the world

The Chinese Academy of Agricultural Sciences creates international teams of scientists and global collaborations to make farming more efficient, environmentally friendly, and beneficial to human health.

China produces more food than any other country in the world, but it also consumes more.[1] Even with increasing food production, Chinese Academy of Agricultural Sciences (CAAS) President Kongming Wu says: "China has to feed nearly 20% of the global population with 9% and 6% of the world's farmland and freshwater, respectively." On the other hand, he adds, "climate change, scarce land and water resources, biodiversity loss, together with volatility in global food prices, threaten sustainable food production."

Meeting these challenges is CAAS, a national comprehensive agricultural scientific research organization that promotes sustainable agriculture within and outside China, extending its research findings through technology exchange and cooperative research activities with domestic and international agricultural research institutions/universities and global non-governmental organizations.

CAAS, established in 1957 and headquartered in Beijing, oversees 34 affiliated research institutes across China. CAAS also incorporates a graduate school and a publishing house. Research and policy work at CAAS cover a broad range of topics, categorized in 11 major disciplinary clusters: Agricultural Basic and Frontier Research; Crop Science; Horticulture; Plant Protection; Agricultural Resources and Environment; Animal Science; Veterinary Medicine; Agricultural Microbiology; Agro-product Quality and Processing; Agricultural Equipment, Engineering and Information; and Agricultural Economics and Rural Development.

CAAS relies on innovation in ensuring national, regional, and global food security. "Thanks to new technologies and approaches such as biotechnology, digitalization, artificial intelligence, and nanotechnology, there are more options available to make agriculture more productive and water and land use more efficient, improve diet structure, and reduce waste and greenhouse gas emissions," says Wu.

Up to now, CAAS' efforts have reaped benefits. In 2022, according to Wu, agrotechnology accounted for 62.4% of the growth in China's agricultural output. "This impressive figure means that China has become one of the technologically advanced countries in the field of agriculture, yet it is still outshone by the more successful few countries," Wu explains.

Wu and his CAAS colleagues plan to reduce that gap and make China one of the global leaders in advanced agriculture.

Creating a scientific community

CAAS leverages research to modernize agriculture and improve the health of people and the environment. Addressing such a wide range of areas depends on a strong scientific community. CAAS consists of a very large group: more than 11,000 staff members including nearly 6,200 researchers.

In 2013, supported by government, CAAS launched the Agricultural Science and Technology Innovation Program (ASTIP). One of ASTIP's key functions is, according to Wu, "fueling agricultural and rural development through major research in China and globally."

To encourage innovative and inclusive research, CAAS has piloted new management mechanisms that reward excellence in performance and prioritize talent cultivation. The last decade have witnessed breakthroughs made by CAAS in basic research in agriculture, such as genomics, functional genomic analysis, and mechanisms of major diseases and pests as well as new grain crop varieties and new animal breeds with high commercial value. For future development, CAAS also cultivates the next generation of researchers.

The Graduate School of CAAS (GSCAAS) is one of the leading graduate schools in agricultural sciences, offering excellent postgraduate programs built upon CAAS research resources and preparing students with creative thinking and hands-on operations. By the end of 2022, there were over 5,640 students studying at GSCAAS. In addition, more than 700 students hailing from more than 50 countries were trained at GSCAAS through the international education program in the last 10 years, and that number is growing.

PHOTO: COURTESY OF CAAS

Engineering-enhanced varieties

CAAS scientists use a range of techniques to develop new plant and animal varieties. Here, the path to innovative technology begins with basic research. CAAS scientists can design crops that Wu says have "important breeding values, such as genes conferring heat tolerance, drought tolerance, high yield and disease resistance."

Peisong Hu, director general of the China National Rice Research Institute and an expert in genetic improvement of rice quality traits, notes: "We have bred several extra-early maturing rice varieties, such as Zhongjiazao 33, and heat-tolerant rice varieties." The extra-early maturing rice mature more quickly and produce more grain. The heat-tolerant rice varieties, Hu says, are not "stressed by short-period extreme high temperature, ensuring rice yield and food security against climate change."

CAAS scientists also work on advanced methods of improving animal production. For example, Peking duck—a Chinese delicacy known and loved around the world—is improved by Professor Shuisheng Hou's research at the Institute of Animal Science of CAAS.

The traditional forced feeding of Peking duck is contrary to animal welfare. Hou has been successfully changing this backward feeding method from the perspective of breeding. He's investigated everything to break the genetic antagonism among growth efficiency, disease resistance, and meat quality. Using genetic selection, Hou and his colleagues developed the free feeding "Z-type" Peking duck, an accomplishment benefiting diners worldwide.

Modernizing a traditional method

In the view of CAAS scientists, while emphasizing the bottom line of 120 million hectares of total farmland in China, the protection of farmland is not only a quantitative issue, but also need to be considered from the qualitative and ecological perspective. CAAS promotes sustainable farmland use and agricultural technology innovation to increase farmland productivity.

To enhance and simplify fertilization, Wei Zhou, Professor from the Institute of Agricultural Resources and Regional Planning of CAAS, and his colleagues developed the Nutrient Expert (NE^2) approach for making nutrient recommendations. Designed to be easy for all farmers to use, the NE^2 can be used without soil test. It is particularly beneficial to smallholders, and the method is focused on a simple "Four R" principle: apply fertilizer with "the right source at the right rate, right time, and right place," as he puts it.

"Farmers can use NE across different climate conditions and explore the potential for improving crop productivity and reducing the environmental footprint of cropping systems compared to current management practices," Zhou says. Field tests he conducted with colleagues showed that NE^2 improved rice yields by 4.4% and profits by 5.8%.[2]

Similarly, NE^2 produced 10%–20% less greenhouse gas than other practices.[2] "This approach could also help reduce greenhouse-gas emissions in other regions globally," says Zhou.

Managing invasive alien species

"Invasive alien species (IAS), especially harmful invasive species, are a major global challenge, and had serious impacts on sustainable agricultural development in China," says Wu. "Monitoring and early warning of invasive pests is a critical element in effective management." To this end, the research team at the Institute of Plant Protection of CAAS established a monitoring system of invasive and migratory pests, such as the fall armyworm, that can achieve early detection, accurate quantification, and timely data collection. Such precise monitoring and early-warning technology could provide valuable information about when to apply control measures to the most vulnerable areas.

"Crop diseases and pests are estimated to cause a 20%-40% of annual crop-yield loss," says Wu, adding that using chemical ecology, molecular biology, and genetic engineering, CAAS scientists produce precise and green measures of prevention and control against crop pests. For example, Bt crops—transgenic crops that contain a toxin produced by the bacterium *Bacillus thuringiensis* (Bt)—help to control important pests and reduce the need for chemical insecticides.

"The key to the prevention and control of fall armyworm and other pests is to build a system of green and sustainable control technologies," Wu explains. The impact of this work grows beyond agricultural fields to homes of people throughout China. Integrated management of fall armyworm in China has also been extended to Asian and African countries by the Food and Agriculture Organization of the United Nations as a success story.

Addressing infectious diseases

Besides of study on genetics, breeding, reproduction, and nutrition of animals, scientists at CAAS also play a key role in animal infectious disease control and safeguarding human public health.

When the new H7N9 influenza virus triggered multiple outbreaks in 2013, virologist Hualan Chen, director of the State Key Laboratory of Animal Disease Control and Prevention at Harbin Veterinary Research Institute of CAAS, and her team's work was put to the test. Her team found that the H7N9 virus, which infects humans, was hiding in chickens at live poultry markets, and they also characterized the highly infectious virus and revealed what made it so dangerous.

Guangming 2, a white-feather broiler breed developed by CAAS scientists

PHOTO: COURTESY OF CAAS

Despite efforts to control H7N9, the virus stubbornly persisted in poultry and mutated to highly pathogenic forms in 2017.[5] Then, Chen's team developed an elegant solution for the H7N9: a chicken vaccine. "The H5/H7 bivalent inactivated vaccine was produced by using two artificially generated vaccine seed viruses," Chen says. "The vaccine seed viruses are non-lethal in animals but replicate highly efficiently in chicken eggs and cells, which are used for the vaccine antigen production."

The use of this vaccine led to a 93.3% reduction in infections,[6] and according to Chen, "the vaccination of chickens successfully prevented or eliminated further human infection waves with H7N9 virus."

Sophisticated methods including next generation sequencing, bioengineering, and bioinformation technologies also facilitate CAAS to study and fight other important animal diseases. As one example, Wu notes, "we had solved highly refined three-dimensional structure for African swine fever virus. And also developed a promising gene-deleted live vaccine against African swine fever that has completed the clinical trials."

Reducing labor intensity by mechanization: Robot farmers

Wu said that in the past decade, the comprehensive mechanization rate of grain production in China increased from 57% in 2012 to over 72% in 2021. Agricultural mechanization not only reduces labor intensity, but also ensures stable and increasing grain production while reducing costs and improving efficiency.

CAAS scientists produced a variety of specialized agricultural machinery, such as for hilly areas, greenhouse facilities, multi-cropping cultivation, and preliminary processing of agro-products. They developed smarter agricultural machinery by applying aerospace remote sensing, aerial remote sensing, citrus and ground-based Internet of Things, and retrofit agricultural equipment to be more applicable to the diversified scenarios in agricultural and rural sectors.

For instance, the smart control system for orchard production can be widely used for fruits, such as apples, citrus, and pears. By utilizing integrated technologies, the system enables data diagnosis and analysis on the spot with just "one click." The in-field operational service platform can control smart field patrol robots, operation-monitoring robots, weeding robots, chemical spraying robots, fruit and vegetable harvesting robots, and irrigation pipelines for integrated application of water and fertilizer.

CAAS is implementing the "Smart Machinery Action," which aims to make the production equipment of major grain crops smarter and promote the R&D of machinery for major economic crops.

Enabling green and low-carbon production

Wu pointed out, besides the good practices on fertilization, CAAS scientists also constantly explore effective ways towards low-carbon agriculture, including promoting rural clean energy and reducing methane emissions of rice fields and carbon emissions of livestock and poultry. In 2023, CAAS released its first "Report on Low-Carbon Agricultural and Rural Development in China."

Meanwhile, CAAS developed green agricultural production technologies and products. Its scientists released China's first plant-immune protein biopesticide, "A'Tailing," and several low-cost, easily degradable, and slow-release fertilizers. A technology combing efficient and low-risk pesticides and efficient utilization of nutrients reduced more than 20% and 10%, respectively, of chemical pesticides and fertilizers. By using key technologies and equipment for efficient dryland farming and drought-resistant and adaptive water planting, the precipitation utilization efficiency in northern arid regions in China increased by 5 percentage points in average, 13,000 intensive farms and family farms are using innovative technologies for livestock and poultry manure recycling, and more than 30% of the wastewater was reduced from the source.

Reaching rural communities

Many CAAS programs focus on rural areas. "Small-scale agricultural households predominate in China, and a fully modernized operational structure has yet to be built," Wu says. "It is thus crucial to ramp up guidance and services to provide better seeds, farming practices, and technologies in key areas and critical stages of production for bumper harvests of ample grains and other essential agricultural products."

CAAS scientist scouting pests in the corn field

PHOTO: COURTESY OF CAAS

To help rural farmers consider new technologies and get trained in using them, a dozen of CAAS expert teams were established, working on the production of wheat, rice, corn, soybean, rapeseed, vegetable, and cotton, to provide effective support for the whole industrial chain of agricultural production and make it through the "last mile." "Over a thousand CAAS specialists immersed themselves in more than 300 counties and 100 cities in over 20 provinces only in 2022, offering technical guidance and services in the field," Wu says. Furthermore, CAAS pilots more than 20 demonstration projects in 20 industries for cost saving, high-efficiency, and high-yield, such as animal production, peanuts production, and living environment improvement. 167 bases were set up in major producing regions, where more than 200 sets of advanced technologies were extended to the field.

Working in China and beyond

Covering so much land and a range of crops takes teamwork. "Together with research institutions, universities with agricultural programs, and relevant enterprises, CAAS has played a leading role in setting up over 90 technical, industry-based, and region-specific national alliances for agricultural science and technology innovation," Wu notes. "Those alliances bring together stakeholders along industrial chains to jointly seek solutions for common production problems, such as groundwater overdraft in north China and soil loss in southwest karst areas."

CAAS programs are as wide-reaching as its participants. In 2019, for example, CAAS launched its International Science and Technology Innovation Program (CAASTIP). By working with scientific and technological resources and institutions from around the world, this program has already created new approaches to agriculture, such as using precise genome editing and whole-genome selection techniques in molecular-design breeding.

CAAS also participates in projects for south–south cooperation in which countries in the global south work together to make the most of advances in science and technology. For example, CAAS scientists played a part in the China–Argentina Biogas Development and Cooperation Center project, which drives sustainable development of this energy source in both countries.

CAAS has teamed up with the Bill & Melinda Gates Foundation and 58 other institutions to launch the Green Super Rice project. "The project has enabled smallholder farmers to increase rice yield by 20% in Africa and southeast Asia," Wu says.

Developing in the decades ahead

After six decades of work, CAAS is planning to make even more contribution to global food security, climate-change mitigation, and poverty reduction. Working with its partners, CAAS scientists will target six research areas: seeds, farmland, agricultural machinery, agricultural biosecurity, eco-friendly and low-carbon agriculture, and rural development. "Looking forward, CAAS will continue to set its sights on global frontiers, major national needs, modern agriculture, and the people's health and safety," Wu says.

To make those advances applicable and to support the rural revitalization, CAAS will send even more experts to the fields across China. "We plan to set up groups of industrial consultants with relative organizations, and be a team leader for technical assistance projects in 44 counties," says Wu.

Furthermore, CAAS is working with scientists around the world to develop G2P (Genome to Phenome - Deciphering Crop Genetic Resources), "an international mega-science project," in Wu's words. "The project is expected to facilitate global research on and equal access to plant genetic resources, make fresh contribution to global food security and nutrition."

In that sense, the future of CAAS reflects its past. The goals of tomorrow are a continuation of over half a century of work, but today that work is an international project with global reach.

References

1. D. Dou,, F. Li, L. Li. *Food Science and Nutrition*. 2023. **11**(3):1507–1520. https://doi.org/10.1002/fsn3.3190
2. J.J. Zhang *et al. Soil Fertility and Crop Nutrition*. 2018. **110**(2):696–706. https://doi.org/10.2134/agronj2017.05.0291
3. M. Xie, S.S. Hou, W. Huang. *Poultry Science*. 2006. **85**:743–746. https://doi.org/10.1093/ps/85.4.743
4. A. Zheng, A. *et al. Journal of Proteomics*. 2014. **98**:271–288. https://doi.org/10.1016/j.jprot.2013.12.021
5. J. Shi *et al. Cell Host Microbe*. **24**:558–568.e7. https://doi.org/10.1016%2Fj.chom.2018.08.006
6. X. Zeng *et al. 2018. Science China Life Sciences*. **61**:1465–1473. https://doi.org/10.1007/s11427-018-9420-1

Sponsored by

CHINESE ACADEMY OF AGRICULTURAL SCIENCES