Cultivating its research capabilities has helped Henan University grow in stature.

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A NORTHERN POWERHOUSE RISES THROUGH THE RANKS

HARD-HITTING RESEARCH ON TOPICS such as semiconductors, quantum dots, and nitrogen fixation in crops has been key to success at China's Henan University.

Henan University is one of China's rapidly rising research institutions. Based in the city of Kaifeng, in China's central north, it ranked 37th in China's top 50 rising institutions for research output in the *Nature Index 2023 China*.

Henan University has sharply increased its output of high-quality papers, while fostering the talent of local researchers who have made major discoveries with global impacts. Two of Henan's leading research areas are understanding crop biology to boost output, and the use of quantum dot technology to produce brighter, longer-lasting digital displays.

"Henan University is a university with multiple disciplines and a long history, allowing us to develop research teams with diverse disciplinary backgrounds," says biologist, Xuelu Wang, who leads a team studying legumes in the State Key Laboratory of Crop Stress Adaptation and Improvement.

He adds that the university's location in Henan province, with a population of around 100 million people, offers many opportunities to find high-quality students and faculty, and has helped its rapid ascent through the ranks.

FARMING FIXATION

Henan is also one of China's most important provinces for farming, making it is a great place to develop basic and applied agricultural research projects, says Wang, whose work focuses on molecular mechanisms underlying the symbiotic relationship between legume crops and nitrogen-fixing bacteria.

Nitrogen is a crucial for plant growth, but though it is abundant in the atmosphere, nitrogen needs to be converted into a form plants can use, such as ammonia. Sixty percent of nitrogen in land plants and animals arrives by way of bacteria that live in special root nodules of leguminous plants, such as soybeans. These bacteria convert or 'fix' nitrogen into ammonia.

How these rhizobia bacteria-hosting nodules formed wasn't well understood. But, in an important paper published in 2021[1], Wang and his team showed that both light signals, and the products of photosynthesis in the upper parts of plants, are necessary for the formation of these crucial root nodules. The research found that light triggered the production of two proteins, GmSTF3/4 and GmFT2, which travel from shoot to root to kickstart nodule formation.

"We found the molecular mechanisms through which light regulates legume-rhizobia symbiotic root nodule formation and nitrogen fixation," says Wang. "Through this mechanism, legumes can properly integrate above-ground light signals with underground rhizobia signals to initiate the symbiotic nodule formation."

The discovery holds promise for reducing human dependence on nitrogen fertilizers. For instance, the new findings could lead to ways to artificially control nitrogen fixation, including triggering it in non-leguminous plants.

In a subsequent study, Wang and his team further elucidated the molecular mechanisms for how plants sense cellular energy to regulate carbon redistribution for nitrogen fixation and other cellular activities, and how this is communicated via specific proteins[2]. "This discovery provides novel targets for designing legume crops with optimized carbon use for efficient nitrogen fixation and robust growth under various conditions," he explains.

Wang's team also ran a genome-wide association study (GWAS) of different cultivars of soybeans.[3] This led to the "discovery of a major co-evolutionary mechanism of legumes and rhizobia" giving researchers molecular tools to design leguminous crops that are highly efficient at fixing nitrogen.

"Our findings provide grounds for the molecular selection and design of soybean or other leguminous varieties with rhizobia to gain high-performance symbiotic nitrogen-fixation," adds Wang. That could reduce dependence on "fossil-fuel based nitrogen fertilizers, benefitting the development of sustainable agriculture."

Henan University's support is not limited to crop science. Materials scientist, Huaibin Shen of Henan's School of Materials and Engineering, says the university has given great support to his team working in the field of semiconductor research and quantum dots.

"We're seeing extremely rapid progress in displays globally," he explains. "And quantum dots have emerged as the leading technology in this field." In October 2023, the Nobel Prize for Chemistry was awarded to researchers in the US for work on quantum dots.

Quantum dots are particles of semiconductor consisting of a few dozen atoms. They promise more affordable and sustainable displays, and have already transformed television screens.

However, the inability of quantum-dot light-emitting diodes (QD-LEDs) to produce high brightness at low voltage has held the technology back.

Now, a team led by Shen — and co-worker, Fengjia Fan, at the University of Science and Technology of China in Hefei — is taking steps to overcome this issue. Today's QD-LED televisions use light from conventional LEDs to excite quantum dots. Directly passing a current through the dots would be more efficient and consume far less energy than liquid-crystal displays. But producing sufficiently bright and efficient QD-LEDs has been hard.

Currently, the generated heat reduces efficiency and accelerates reactions that make QD-LEDs degrade. "The biggest challenge for making QD-LED displays is how to fabricate stable QD-LEDs, especially for the blue colour," says Fan. "Decreasing the driving voltage and reducing heat will help."

Quantum dots can be fabricated using chemical reactions to form dots in solution. The dots are stabilized by coating with shells, and a layer of chemical ligands, to eliminate surface defects. However, this ligand colloid film has poor conductivity.

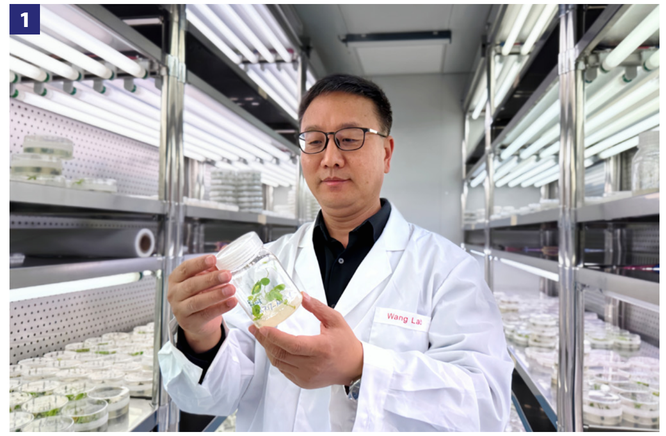
BRIGHTEST QD-LEDS

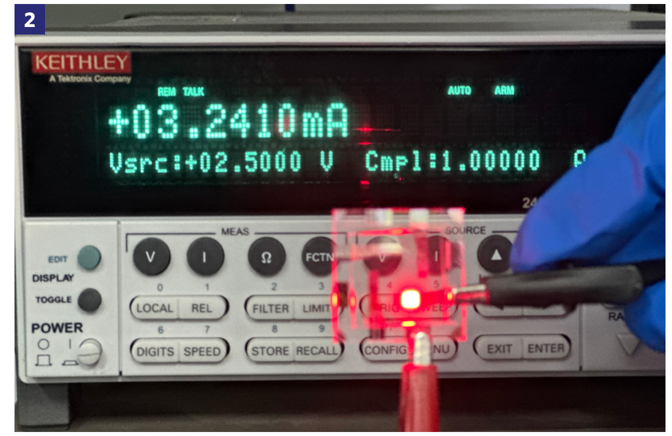
By introducing the selenium in both the core (cadmium selenide) and shell (zinc selenide) of QDs[4], Shen was able to stabilize the QD-LEDs, reducing the stress caused by lattice mismatch, reducing defects and increasing the photons emitted by each dot. This resulted in the brightest red, green, and blue QD-LEDs ever fabricated, and dramatically enhanced the lifespan of the dots.

In 2023, Shen and Fan took this discovery further, using selenium alloy to make dots with extremely thick shells[5]. These funnelled more electrons and holes into each quantum dot, resulting in brighter light and less heat at lower voltages.

When combined, Fan's and Shen's discoveries increased the power conversion efficiency of QD-LEDs from 18% to 23% and increased their lifespans almost five times. This, Shen says, puts mass-production and the arrival of QD-LEDs in millions of households within reach.

Research into QD-LEDs and crops may not seem related, but together they exemplify how Henan is helping scientists succeed — an approach that is fuelling the university's rapid ascent of both Chinese and international rankings. ■





▲ 1. The ability of soybeans to fix nitrogen can be improved by understanding the molecular mechanisms involved, says Xuelu Wang of Henan University.
2. Researchers test quantum dot technology in search of more affordable and sustainable displays.

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