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INFORMATION

GENOME EDITING: A GROUND BREAKING RESEARCH HAS BEEN RANKED TOP 10 ENGINEERING FRONTS FROM 2017 TO 2021

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'Global Engineering Fronts' is a report released by the Chinese Academy of Engineering (CAE) every year since 2017, which aims to assemble talents in the field of engineering science and technology to represent the global engineering research and development fronts by reviewing global papers, patents, and other data. The results are also expected to provide a reference for people on responding to global challenges and achieving sustainable development.

Currently, the world is facing major changes unseen in a century. The Corona Virus Disease 2019 (COVID) has aggravated the uncertainty of global development. The new round of scientific and technological revolution and industrial transformation continue to deepen and evolve. Engineering innovations are advancing in an interdisciplinary and integrated manner, and the engineering fronts continue to integrate with each other to achieve breakthroughs.

We, as members of the journal editorial board of *Frontiers of Agricultural Science and Engineering* (FASE), undertake related studies in the agricultural field of the 'Global Engineering Fronts' project in collaboration with Clarivate Analytics (Philadelphia, PA, USA)[1]. Analyzing the reports from 2017 to 2021[2], we found that genome editing, especially CRISPR/Cas9 editing, as a ground breaking research front has been consistently ranked among the top 10 engineering fronts in the agricultural field (Table 1). China and USA are the main contribution of papers in the engineering research front of genome editing techniques, e.g., CRISPR/Cas9 genome editing of agricultural organisms (Fig. 1). From the distribution of papers by research institution (Table 2), it can be seen that the Chinese Academy of Sciences (China) and University of

Table 1 Detailed information of genome editing rank in 2017–2021

Items	2017	2018	2019	2020	2021
Fronts type	Engineering development fronts	Engineering research fronts	Engineering research fronts	Engineering research fronts	Engineering development fronts
Full name	New genetically modified varieties	CRISPR/Cas9 genome editing in agricultural biotechnology	CRISPR/Cas9 genome editing of agricultural organisms	Precision animal and plant breeding by design	Gene editing and plant disease resistance
Rank	9	2	1	4	2
Citations	154	17,299	3261	8871	57

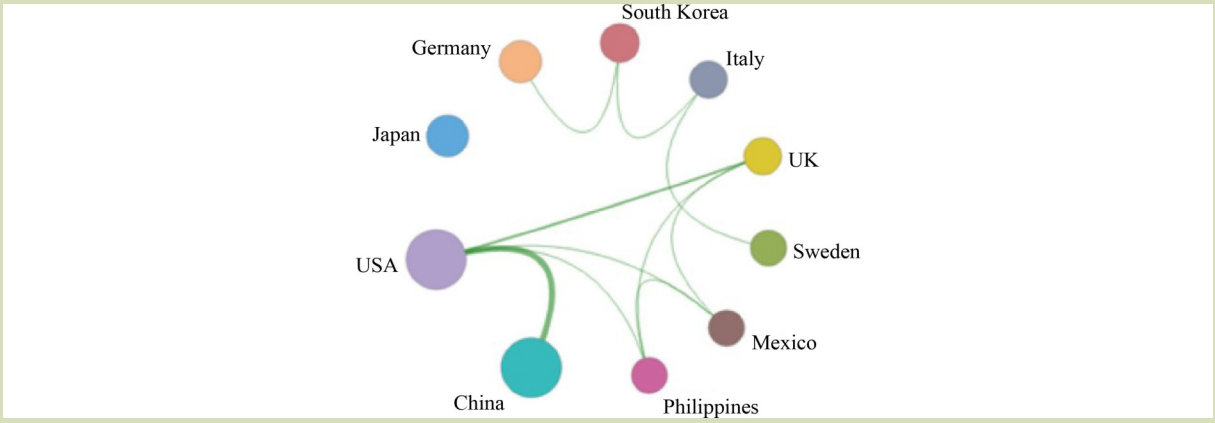

Fig. 1 Collaboration network among major countries or regions in the engineering research front of "CRISPR/Cas9" genome editing of agricultural organism in 2019.

Table 2 Institutions with the greatest output of core papers on "CRISPR/Cas9 genome editing of agricultural organisms" in 2019

No.	Institution	Core papers	Percentage of core papers (%)	Citations	Percentage of citations (%)	Citations per paper
1	University of Minnesota	7	16.67	486	14.90	69.43
2	Chinese Academy of Sciences	7	16.67	688	21.10	98.29
3	Karlsruhe Institute of Technology	4	9.52	395	12.11	98.75
4	Yokohama City University	4	9.52	116	3.56	29.00
5	Chinese Academy of Agricultural Sciences	4	9.52	176	5.40	44.00
6	Seoul National University	3	7.14	171	5.24	57.00
7	National Agriculture & Food Research Organization	3	7.14	77	2.36	25.67
8	University of Chinese Academy of Sciences	3	7.14	218	6.69	72.67
9	Institute for Basic Science of Korea	2	4.76	111	3.40	55.50
10	University of Science and Technology of China	2	4.76	195	5.98	97.50

Minnesota (USA) were ranked at the top with seven core articles each, and the number of citations was highest for papers published by the Chinese Academy of Sciences.

In addition to agriculture, we also found gene editing rank in the top 10 engineering fronts in the field of medicine and health, e.g., genetically engineered organ xenotransplantation technology[3].

Recent advances in genome editing techniques have substantially improved our ability to make precise changes in the genomes of eukaryotic cells. Programmable nucleases, particularly the CRISPR/Cas9 system, are already revolutionizing our ability to interrogate the function of the genome and can potentially be used clinically to correct or introduce genetic mutations to treat diseases that are refractory to traditional therapies. Genome engineering also has the capacity to endow xenogeneic tissues with down-modulating, anti-xenogeneic immune responses that can facilitate cross-species transplantation[4]. Pig-to-human organ transplantation provides an alternative for critical shortage of human organs worldwide. Genetically engineered pigs are promising donors for xenotransplantation as they show many anatomical and physiologiccal similarities to humans[5]. Research on xenotransplantation has been made a lot of progress, e.g., the latest study on "clinical-grade porcine kidney xenotransplant using a human decedent model"[6].

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