VII. Agriculture

1 Engineering research hotspots and engineering research focus

1.1 Development trends of engineering research hotspots

The top 10 hotspots in agricultural engineering research are classified into two categories:

• *Hotspots involving in-depth traditional research.* They include "Conservation farming systems" in crop science, "Healthy growth of livestock and poultry" in agricultural bioengineering and veterinary medicine, "Vegetation diversity and classification" and "Soil fungal communities" in agricultural resource science, "Grazing and lactating dairy cows" in livestock science, and "Behavior among wild animals" in applied ecology.

• *Emerging research hotspots.* They include "Soil organic carbon mapping," "Reduction of methane emission," and "Soil moisture data assimilation" in agricultural resource science and "*In vitro* antibacterial activity" in animal medicine.

There are no revolutionary research hotspots in this category. The number of core papers supporting each hotspot is approximately 50, and the average citation frequency is approximately 30. Among hotspot papers, the proportion of consistently cited papers is less than 30%, with an average of approximately 16%. The number of papers cited in patents is relatively small, with an average of less than two (Table 1.1.1). In addition, the data indicate that the core papers in the top 10 research hotspots have been generally published around 2013. Among them, the overall number of core papers on "Healthy growth of livestock and poultry" and "Reduction of methane emissions" reveals an upward trend, whereas no clear pattern is found for the rest hotspots (Table 1.1.2).

Brief descriptions of all the top 10 hot engineering research topics are provided below.

1.1.1 Conservation farming systems

Conservation farming systems is a hotspot in crop science, which involves in-depth traditional research. It ensures crop yield and quality improvement based on considerations from the levels of soil, crop, and environmental stress. Techniques included in this hotspot are as follows:

(a) Conservation tillage technique: After harvest, the crop residues are crushed and left as ground cover. In the next season, cultivation is carried out without tillage to reduce mineralization, erosion, soil and water loss, and the chemical inputs, and to increase crop yields and agricultural income.

(b) Crop genetic improvement technique: The traditional breeding, cell engineering, chromosome engineering, transgenic techniques, and other methods are utilized

Table 1.1.1 Top 10 engineering research hotspots in agriculture

No.	Engineering research hotspots	Core papers	Citation frequency	Average citation frequency	Mean year	Proportion of consistently cited papers	Patent-cited publications
1	Conservation farming systems	44	1396	31.73	2013.11	29.5%	0
2	Soil organic carbon mapping	49	1328	27.10	2013.47	2.0%	0
3	Healthy growth of livestock and poultry	90	2251	25.01	2013.89	20.0%	1
4	*In vitro* antibacterial activity	46	1329	28.89	2014.24	21.7%	4
5	Vegetation diversity and classification	48	1614	33.63	2013.17	12.5%	2
6	Reduction of methane emission	48	872	18.17	2013.98	18.8%	1
7	Soil fungal communities	50	1637	32.74	2013.30	10.0%	2
8	Grazing and lactating dairy cows	49	1083	22.10	2013.02	14.3%	4
9	Soil moisture data assimilation	47	1385	29.47	2013.02	6.4%	2
10	Behavior among wild animals	46	1310	28.48	2013.43	23.9%	1

Table 1.1.2 Annual number of core papers belonging to each of the top 10 engineering research hotspots in agriculture

No.	Engineering research hotspots	2011	2012	2013	2014	2015	2016
1	Conservation farming systems	6	11	9	8	10	0
2	Soil organic carbon mapping	7	9	4	16	9	4
3	Healthy growth of livestock and poultry	11	9	7	27	24	12
4	*In vitro* antibacterial activity	4	4	4	8	17	9
5	Vegetation diversity and classification	9	12	6	11	3	7
6	Reduction of methane emission	2	6	3	18	18	1
7	Soil fungal communities	7	12	9	7	11	4
8	Grazing and lactating dairy cows	6	11	15	11	5	1
9	Soil moisture data assimilation	7	10	11	14	4	1
10	Behavior among wild animals	10	6	8	7	6	9

for the alteration, transfer, and recombination of crop genetic materials, to promote crop yield, and to improve quality.

(c) Environmental stress prevention technique: Biological environmental stress, such as pests and diseases, is an important factor restricting crop production. Most strategies for crop protection involve increasing the ability of crops to resist pests and pathogens or using chemicals. Non-biological environmental stress, such as drought, low temperature, high temperature, and wind damage, will lead to the decline in crop yield and quality.

1.1.2 Soil organic carbon mapping

This is an emerging research hotspot in agricultural science. Soil organic matter (SOM) refers to the collection of humus, animal and plant residues, and microbiome formed by microbial action The carbon in SOM is referred to as soil organic carbon (SOC). SOC content is the balance between the input of organic matter (e.g., biological debris) into the soil and the loss of organic matter mainly caused by microbial decomposition. SOC content and distribution are important factors in the soil classification system. In the soil classification system of the USA, there are many diagnostic horizons, all of which involve organic carbon content and distribution. The isohumic property is utilized in the Chinese system of soil classification; i.e., the ratio of the SOC content at 0–20 and 0–100 cm is used as a classification index. SOC is an important component of the terrestrial ecosystem carbon pool and has a profound impact on the physical, chemical, and biological properties of the soil.

1.1.3 Healthy growth of livestock and poultry

This is a hotspot in agricultural bioengineering and veterinary medicine involving in-depth traditional research. Healthy growth refers to creating a suitable environment for livestock and poultry, providing adequate feed, protecting the health of livestock and poultry, reducing disease incidences, ensuring the product quality and safety, decreasing pollution, achieving ecological balance, and reflecting a high degree of unity of the economical, ecological, and social benefits of modern animal husbandry. Healthy growth mainly focuses on the health of livestock and poultry, product safety, and environmental protection. It can ensure product safety by effective regulation of the production process.

1.1.4 *In vitro* antibacterial activity

This is an emerging research hotspot in animal medicine. Antibiotic activity refers to the ability of antibiotics to inhibit or kill pathogenic microorganisms, and it can be determined using *in vitro* antibacterial tests and *in vivo* experimental treatments. *In vitro* antibacterial experiments are important references for clinical medication. The minimum inhibitory concentration (MIC) is the minimum concentration that can inhibit the growth of bacteria in the culture medium. When the proportion of bacteria killed are used as assessment criteria, the concentration that can decrease the total number of viable bacteria by 99.0% or more than 99.5% is known as the minimum bactericidal concentration (MBC). In a batch of experiments, the MICs that can inhibit 50.0% or 90.0% of the test bacteria are known as MIC50 and MIC90, respectively. The bacteriostatic and bactericidal activities of antibiotics are relative, and some antibiotics show bacteriostatic activity at low concentrations, but bactericidal activity at high concentrations.

1.1.5 Vegetation diversity and classification

Vegetation diversity and classification, which is a hotspot in agricultural resource science, involves in-depth traditional research. Vegetation diversity includes species, habitat, nutritional, life cycle, and genetic diversity. Among them, species diversity is determined by the genetic diversity in different ecological environments. The complexity of gene expression in vegetation growth and development on the spatial and temporal scale determines the diversities of vegetable external morphology, physiological metabolism, and the DNA molecular level.

1.1.6 Reduction of methane emission

This is an emerging research hotspot in agricultural resource science. Methane is the hydrocarbon with the simplest structure. In recent years, a rapid growth in methane emissions has occurred, and its reduction is the key for avoiding the exacerbation of global warming. Several studies have indicated that anthropogenic methane emissions account for 60% of global methane emissions, and approximately one-third of anthropogenic methane emissions come from agricultural production. Rice cultivation and animal husbandry are its largest sources.

1.1.7 Soil fungal communities

This is a hotspot in agricultural resource science, involving in-depth traditional research. Soil fungi refer to the unicellular or multicellular branching filamentous eukaryotic organisms live in the soil. They use the soil as their habitat for completing all or a part of their life history. Fungal hyphae have the ability to decompose organic matter, have a lower soil pH requirement than actinomycetes and bacteria have, and they are the main decomposers of organic matter in acidic soils, particularly in forests.

1.1.8 Grazing and lactating dairy cows

This is a hotspot in animal husbandry science and involves in-depth traditional research. Milk production in cows used in the dairy industry can be improved by breeding programs. Cows have poor heat resistance and high requirements for grazing and feed management. Breeding high-quality beef cattle and high quality lactating dairy cows with high and stable yield is the only method of enhancing the development of this industry. The performance determination system of cows, i.e., dairy herd improvement (DHI), is the main method of determining the improvement of dairy herds.

1.1.9 Soil moisture data assimilation

This is an emerging research hotspot in agricultural resource science. Soil moisture is an important physical factor in land-air interaction affecting the surface evapotranspiration, runoff, surface albedo, surface emissivity, and surface heat and latent heat fluxes. Land surface data assimilation is based on land surface model and hydrological model. Different data assimilation algorithms are used for assimilating surface observation data as well as satellite and radar data, and optimizing the estimations of soil moisture, temperature, and surface energy flux on the surface and root zone.

1.1.10 Behavior among wild animals

Animal behavior is a hotspot in applied ecology that requires in-depth traditional research. The behaviors of wild animals are complex and diverse. According to the different behaviors displayed, they can be divided into foraging behavior, storage behavior, aggressive behavior (within the same species), defensive behavior (among species), territorial behavior, reproductive behavior, rhythmic behavior (migratory behavior), social behavior, directed behavior, and communication behaviors. All kinds of behavior are adaptive responses of wild animals to the complex environment. Based on their learning process, behaviors of wild animals can be divided into innate behavior and learned behavior.

1.2 Understanding of engineering research focus

1.2.1 Conservation farming systems

Conservation farming systems ensure crop yield and quality improvement based on comprehensive considerations from the levels of soil, crop, and environmental stress. It includes conservation tillage techniques, crop genetic improvement techniques, and environmental stress prevention techniques. A number of international funds have conducted long-term surveys on soil fertility status and studies on conservation farming systems in African countries, such as Zimbabwe. These studies have proposed new systematic methods for crop rotation, straw mulching, weed control, and pest management to ensure high and stable crop yields.

The major countries publishing the core papers are Zimbabwe, the Netherlands, France, Kenya, and Brazil (Table 1.2.1). The consistently cited papers are from Zimbabwe, Kenya, and the USA. Based on the distribution of research papers among institutions (Table 1.2.2), the papers are mainly published by the International Maize and Wheat Improvement Center (CIMMYT) in Mexico, Wageningen University in the Netherlands, and the French Agricultural Research Centre for International Development (CIRAD). The cooperation network diagram indicates that Zimbabwe, the Netherlands, France, Kenya, and Brazil have a close cross-citation relationship (Figure 1.2.1). For institutions, a close cooperation exists among CIMMYT in Mexico, Wageningen University in the Netherlands, and CIRAD (Figure 1.2.2). A wide range of international cooperations has formed among countries, regions, and institutions. In this focus, the countries or regions with a large proportion of cited papers are Zimbabwe, the Netherlands, and France (Table 1.2.3), and the major research institutions are CIMMYT, the CIRAD, and Wageningen University (Table 1.2.4). The paper titled "Communicating complexity: Integrated assessment of trade-offs concerning soil fertility management in African reproductive systems to support innovation and development", which was published in the journal *Agricultural Systems* on 2011, has been cited 78 times. This paper and two other highly cited papers published in *Field Crops* are examples of international collaborative research

Table 1.2.1 Major producing countries or regions of core papers on the engineering research focus "Conservation farming systems"

No.	Country/Region	Core papers	Proportion of core papers	Citation frequency	Proportion of citation frequency	Average citation frequency	Consistently cited papers	Patent-cited publications
1	Zimbabwe	30	68.18%	919	73.93%	30.63	6	0
2	The Netherlands	16	36.36%	562	45.21%	35.13	2	0
3	France	11	25.00%	322	25.91%	29.27	1	0
4	Kenya	10	22.73%	393	31.62%	39.30	4	0
5	Brazil	7	15.91%	197	15.85%	28.14	1	0
6	Ethiopia	7	15.91%	161	12.95%	23.00	2	0
7	Italy	5	11.36%	207	16.65%	41.40	2	0
8	USA	5	11.36%	146	11.75%	29.20	4	0
9	Mexico	5	11.36%	99	7.96%	19.80	1	0
10	Malawi	4	9.09%	196	15.77%	49.00	1	0

Table 1.2.2 Major producing institutions of core papers on the engineering research focus "Conservation farming systems"

No.	Institution	Core papers	Proportion of core papers	Citation frequency	Proportion of citation frequency	Average citation frequency	Consistently cited papers	Patent-cited publications
1	CIMMYT	25	56.82%	609	48.99%	24.36	7	0
2	Wageningen Univ	16	36.36%	562	45.21%	35.13	2	0
3	CIRAD	15	34.09%	478	38.46%	31.87	2	0
4	Int Ctr Trop Agr	10	22.73%	319	25.66%	31.90	2	0
5	Int Livestock Res Inst	8	18.18%	318	25.58%	39.75	2	0
6	Int Crops Res Inst Semi Arid Trop	7	15.91%	294	23.65%	42.00	0	0
7	Univ Zimbabwe	6	13.64%	212	17.06%	35.33	2	0
8	Embrapa Cerrados	5	11.36%	81	6.52%	16.20	1	0
9	Int Inst Trop Agr	3	6.82%	105	8.45%	35.00	0	0
10	Food & Agr Org United Nations	3	6.82%	73	5.87%	24.33	1	0

Note: CIMMYT stands for International Maize and Wheat Improvement Center in Mexico; CIRAD stands for French Agricultural Research Center for International Development.

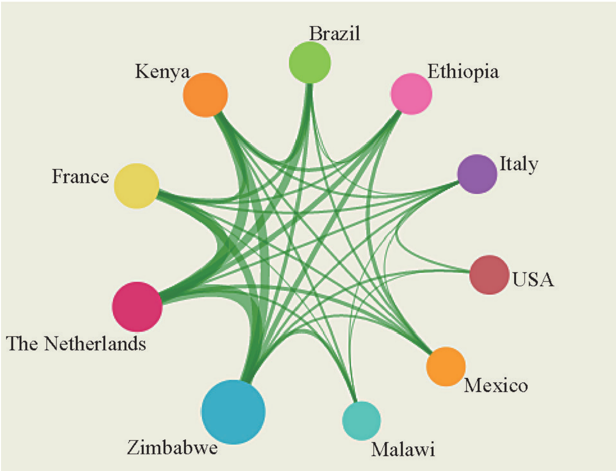

Figure 1.2.1 Collaboration network of the major producing countries or regions of core papers on the engineering research focus "Conservation farming system" [1]

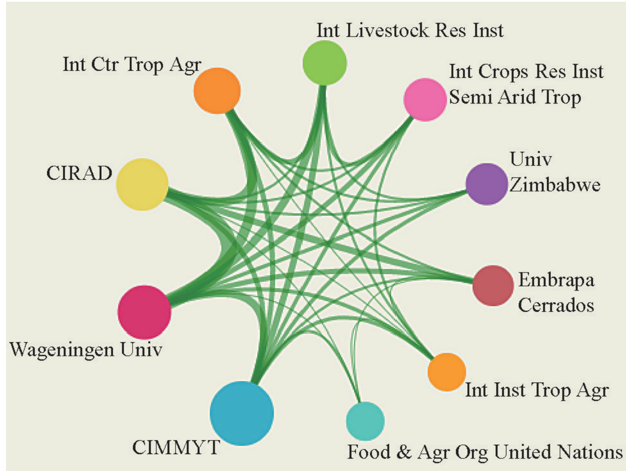

Figure 1.2.2 Collaboration network of the major producing institutions of core papers on the engineering research focus "Conservation farming system"

Table 1.2.3 Major producing countries or regions of core papers that are cited by core papers on the engineering research focus "Conservation farming systems"

No.	Country/Region	Number of core papers cited by core papers	Proportion	Mean year
1	Zimbabwe	23	19.66%	2013.13
2	The Netherlands	13	11.11%	2013.38
3	France	10	8.55%	2013.70
4	Kenya	8	6.84%	2013.25
5	Ethiopia	7	5.98%	2014.29
6	Brazil	6	5.13%	2013.83
7	Mexico	5	4.27%	2014.40
8	USA	4	3.42%	2013.50
9	Italy	3	2.56%	2013.00
10	Norway	3	2.56%	2013.33

at the University of Wageningen in the Netherlands. The contributions from China to this discipline are insufficient, with only a few core or consistently cited papers. The possible reasons may be that this discipline is regionally focused, the relevant researchers have mainly focused on the existing problems of agricultural development in China, and the number of relevant scientific studies in internationally relevant institutions is still low.

1.2.2 Soil organic carbon mapping

SOM refers to the collection of humus, plant and animal residues, and microbiome, and the carbon in SOM is referred to as SOC. SOC has a profound effect on the physical, chemical, and biological properties of the soil, and its content and distribution are important in the soil classification system. To date, seven global workshops on soil mapping have been held.

The USA, Australia, France, India, and Germany are the major countries publishing the core papers (Table 1.2.5), and the countries publishing consistently cited papers are the USA and Australia. The University of Sydney, the French National Institution for Agricultural Research (INRA), and the Louisiana State University are the main contributors of core papers (Table 1.2.6). The cooperation

[1] In the figure, the nodes refer to the countries or regions, the size of the nodes refers to number of papers, the connecting line between nodes refers to papers published based on research cooperation, and the thickness of the connecting line indicates the number of papers based on research cooperation. These are the same in full text.

Table 1.2.4 Major producing institutions of core papers that are cited by core papers on the engineering research focus “Conservation farming systems”

No.	Institution	Number of core papers cited by core papers	Proportion	Mean year
1	CIMMYT	20	14.60%	2013.65
2	CIRAD	13	9.49%	2013.54
3	Wageningen Univ	13	9.49%	2013.38
4	Int Ctr Trop Agr	8	5.84%	2013.50
5	Int Livestock Res Inst	6	4.38%	2013.67
6	Embrapa Cerrados	5	3.65%	2014.20
7	Univ Zimbabwe	4	2.92%	2012.75
8	Int Crops Res Inst Semi Arid Trop	4	2.92%	2012.75
9	Univ Life Sci	3	2.19%	2013.33
10	Int Inst Trop Agr	3	2.19%	2013.67

Table 1.2.5 Major producing countries or regions of core papers on the engineering research focus “Soil organic carbon mapping”

No.	Country/Region	Core papers	Proportion of core papers	Citation frequency	Proportion of citation frequency	Average citation frequency	Consistently cited papers	Patent-cited publications
1	USA	19	38.78%	466	39.86%	24.53	3	0
2	Australia	15	30.61%	314	26.86%	20.93	2	0
3	France	8	16.33%	239	20.44%	29.88	0	0
4	India	6	12.24%	114	9.75%	19.00	1	0
5	Germany	5	10.20%	209	17.88%	41.80	1	0
6	Italy	4	8.16%	89	7.61%	22.25	0	0
7	England	4	8.16%	72	6.16%	18.00	0	0
8	Belgium	4	8.16%	69	5.90%	17.25	1	0
9	China	4	8.16%	61	5.22%	15.25	0	0
10	Canada	3	6.12%	95	8.13%	31.67	1	0

Table 1.2.6 Major producing institutions of core papers on the engineering research focus “Soil organic carbon mapping”

No.	Institution	Core papers	Proportion of core papers	Citation frequency	Proportion of citation frequency	Average citation frequency	Consistently cited papers	Patent-cited publications
1	Univ Sydney	15	30.61%	314	26.86%	20.93	2	0
2	INRA	6	12.24%	178	15.23%	29.67	0	0
3	Louisiana State Univ	6	12.24%	131	11.21%	21.83	0	0
4	Ramakrishna Mission Vivekananda Univ	5	10.20%	88	7.53%	17.60	1	0
5	Texas Tech Univ	5	10.20%	80	6.84%	16.00	1	0
6	Inst Environm & Sustainabil	4	8.16%	89	7.61%	22.25	0	0
7	Joint Res Ctr	4	8.16%	89	7.61%	22.25	0	0
8	Catholic Univ Louvain	4	8.16%	69	5.90%	17.25	1	0
9	Tech Univ Munich	3	6.12%	106	9.07%	35.33	1	0
10	W Virginia Univ	3	6.12%	105	8.98%	35.00	0	0

Note: INRA stands for the French National Institution for Agricultural Research.

network diagram suggests that the USA plays a leading role among all the countries or regions (Figure 1.2.3) and works closely with India. Although the University of Sydney has produced the largest number of core papers, the cooperation among the universities in the USA is more extensive (Figure 1.2.4). Based on the cited core papers, the USA and Australia are dominant among all the countries or regions (Table 1.2.7), the University of Sydney being the most dominant institution (Table 1.2.8). China is among the top 10 countries in this research focus, but it is in a relatively backward state in terms of the number of core papers, average citation frequency, and consistently cited papers.

Among the 49 core papers in this focus, 33 have been published in *Geoderma*. The most cited paper, "Spatial distribution of soil organic carbon stocks in France," published in *Biogeosciences* by INRA, has been cited 75 times. It is based on a regional research project on SOC. "SoilGrids1km—Global soil information based on automated mapping," published later in *Plos One* in 2014, is a highly cited paper on digital mapping of SOC of different regions or different types.

1.2.3 Healthy growth of livestock and poultry

The key to healthy growth of livestock and poultry is to ensure their healthy growth during the nursing and production processes. Porcine epidemic diarrhea virus and avian brood parasites are two major threats to safe livestock and poultry products. The healthy growth of livestock and poultry can ensure product safety from the source.

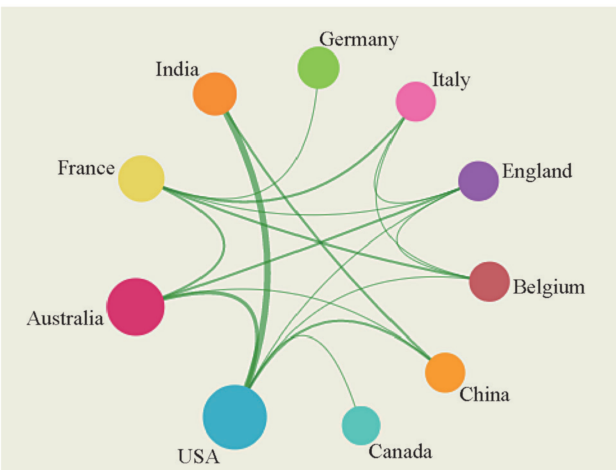

Figure 1.2.3 Collaboration network of the major producing countries or regions of core papers on the engineering research focus "Soil organic carbon mapping"

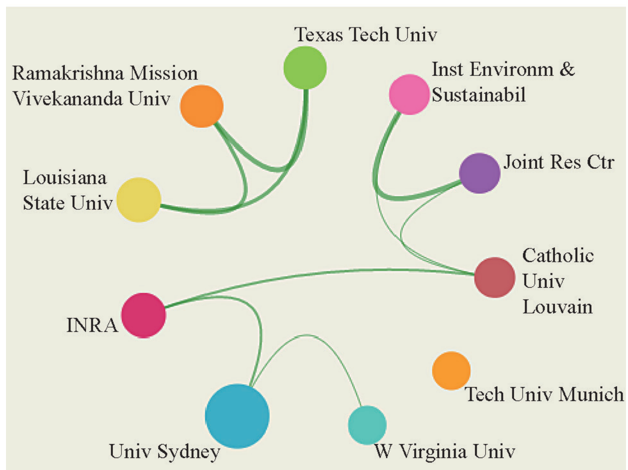

Figure 1.2.4 Collaboration network of the major producing institutions of core papers on the engineering research focus "Soil organic carbon mapping"

Table 1.2.7 Major producing countries or regions of core papers that are cited by core papers on the engineering research focus "Soil organic carbon mapping"

No.	Country/Region	Number of core papers cited by core papers	Proportion	Mean year
1	USA	14	19.44%	2014.07
2	Australia	13	18.06%	2014.31
3	France	6	8.33%	2013.33
4	India	5	6.94%	2014.20
5	England	4	5.56%	2014.00
6	Italy	4	5.56%	2014.75
7	Belgium	4	5.56%	2013.25
8	Egypt	3	4.17%	2014.00
9	China	3	4.17%	2014.67
10	Denmark	3	4.17%	2013.67

In terms of core paper publication by country or region, the USA produces the largest number of publications (Table 1.2.9), and the countries with consistently cited papers are the USA and the UK. The Iowa State University, the City University New York (CUNY), and Ohio State University are the dominant institutions (Table 1.2.10). The USA, Czech Republic, China, and Australia have a close cooperation (Figure 1.2.5). The Iowa State University has lesser number of cooperations, whereas the CUNY, Palacký University in Czech Republic, Hungarian Natural History Museum, and Hungarian Academy of Sciences have close cooperation (Figure 1.2.6). The top 3 countries producing the largest number of cited papers are the USA, China, and the Czech Republic (Table 1.2.11). Three universities in the USA—Ohio State University, Iowa State University, and CUNY—and the Palacký University in Czech Republic constitute the group of institutions with the highest number of cited core papers (Table 1.2.12). China is ranked third in the terms of the number of core papers on this research direction, but the total number of citation frequency is still at a low level. In terms of development potential, China has been ranked second for the number of cited core papers; although the publication of follow-up core papers can be expected, a core research institution has not yet been formed.

Table 1.2.8 Major producing institutions of core papers that are cited by core papers on the engineering research focus “Soil organic carbon mapping”

No.	Institution	Number of core papers cited by core papers	Proportion	Mean year
1	Univ Sydney	13	12.38%	2014.31
2	Louisiana State Univ	5	4.76%	2013.40
3	Ramakrishna Mission Vivekananda Univ	5	4.76%	2014.20
4	Texas Tech Univ	5	4.76%	2014.40
5	Inst Environm & Sustainabil	4	3.81%	2014.75
6	Joint Res Ctr	4	3.81%	2014.75
7	Catholic Univ Louvain	4	3.81%	2013.25
8	INRA	4	3.81%	2013.00
9	Univ Wisconsin	3	2.86%	2014.67
10	Aarhus Univ	3	2.86%	2013.67

Table 1.2.9 Major producing countries or regions of core papers on the engineering research focus “Healthy growth of livestock and poultry”

No.	Country/Region	Core papers	Proportion of core papers	Citation frequency	Proportion of citation frequency	Average citation frequency	Consistently cited papers	Patent-cited publications
1	USA	50	55.56%	1017	49.44%	20.34	6	0
2	Czech	14	15.56%	283	13.76%	20.21	1	0
3	China	13	14.44%	184	8.95%	14.15	1	0
4	England	12	13.33%	472	22.95%	39.33	4	0
5	Australia	11	12.22%	356	17.31%	32.36	1	0
6	Hungary	7	7.78%	163	7.92%	23.29	1	0
7	Scotland	5	5.56%	124	6.03%	24.80	1	0
8	New Zealand	5	5.56%	105	5.10%	21.00	0	0
9	France	5	5.56%	68	3.31%	13.60	0	0
10	Norway	4	4.44%	132	6.42%	33.00	0	0

Table 1.2.10 Major producing institutions of core papers on the engineering research focus “Healthy growth of livestock and poultry”

No.	Institution	Core papers	Proportion of core papers	Citation frequency	Proportion of citation frequency	Average citation frequency	Consistently cited papers	Patent-cited publications
1	Iowa State Univ	14	15.56%	473	22.99%	33.79	2	0
2	CUNY	14	15.56%	237	11.52%	16.93	2	0
3	Ohio State Univ	14	15.56%	193	9.38%	13.79	1	0
4	Palacky Univ	13	14.44%	265	12.88%	20.38	1	0
5	Univ Cambridge	9	10.00%	417	20.27%	46.33	3	0
6	Australian Natl Univ	6	6.67%	251	12.20%	41.83	1	0
7	Hungarian Nat Hist Museum	6	6.67%	133	6.47%	22.17	1	0
8	Univ Minnesota	6	6.67%	107	5.20%	17.83	0	0
9	Hungarian Acad Sci	5	5.56%	142	6.90%	28.40	1	0
10	Univ Edinburgh	5	5.56%	124	6.03%	24.80	1	0

Note: CUNY stands for the City University of New York.

Figure 1.2.5 Collaboration network of the major producing countries or regions of core papers on the engineering research focus “Healthy growth of livestock and poultry”

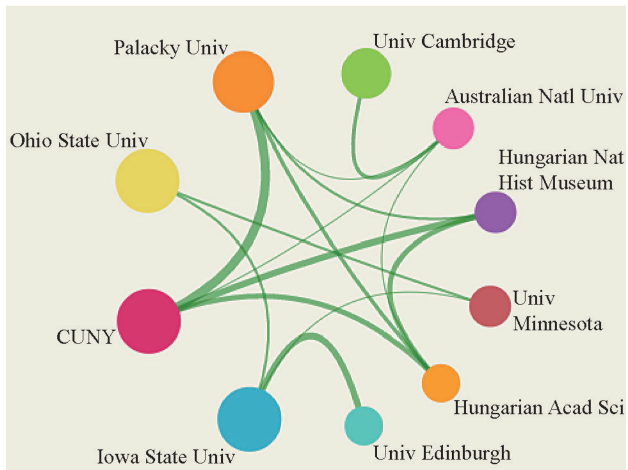

Figure 1.2.6 Collaboration network of the major producing institutions of core papers on the engineering research focus “Healthy growth of livestock and poultry”

Table 1.2.11 Major producing countries or regions of core papers that are cited by core papers on the engineering research focus “Healthy growth of livestock and poultry”

No.	Country/Region	Number of core papers cited by core papers	Proportion	Mean year
1	USA	45	33.09%	2014.56
2	China	13	9.56%	2014.77
3	Czech	12	8.82%	2013.42
4	Australia	9	6.62%	2012.67
5	England	8	5.88%	2012.13
6	Hungary	6	4.41%	2013.67
7	Scotland	5	3.68%	2014.20
8	France	4	2.94%	2014.50
9	New Zealand	4	2.94%	2013.50
10	Slovakia	4	2.94%	2012.75

Table 1.2.12 Major producing institutions of core papers that are cited by core papers on the engineering research focus "Healthy growth of livestock and poultry"

No.	Institution	Number of core papers cited by core papers	Proportion	Mean year
1	Ohio State Univ	13	6.57%	2015.23
2	Iowa State Univ	13	6.57%	2014.77
3	CUNY	13	6.57%	2013.54
4	Palacky Univ	11	5.56%	2013.36
5	Univ Minnesota	6	3.03%	2015.17
6	Hungarian Nat Hist Museum	5	2.53%	2014.00
7	Univ Cambridge	5	2.53%	2011.60
8	Univ Debrecen	5	2.53%	2014.00
9	Australian Natl Univ	5	2.53%	2012.00
10	Eotvos Lorand Univ	5	2.53%	2014.00

Based on supporting data, the researchers of Iowa State University studying porcine epidemic diarrhea virus published a paper titled "Emergence of porcine epidemic diarrhea virus in the USA: clinical signs, lesions, and viral genomic sequences" in 2013 in the *Journal of Veterinary Diagnostic Investigation*, which has been cited 158 times and shown a profound impact. In 2011, the researchers at the Palacký University in Czech Republic published "Constraints on host choice: why do parasitic birds have no exploit some common potential hosts?" in the *Journal of Animal Ecology*" and it is a representative research paper on avian brood parasites.

2 Engineering development hotspots and engineering development focus

2.1 Development trends of engineering development hotspots

The top 10 agricultural engineering development hotspots are classified into three categories.

• *Ground-breaking development hotspots*. They include "Precision irrigation" in agricultural engineering, "Animal stem cells" in veterinary medicine, and "New genetically modified varieties" in agricultural bioengineering.

• *Hotspots involving in-depth traditional research*. They include "Pesticide pollution and prevention" of plant protection, "Facility agriculture" and "Agricultural machinery improvement" of agricultural engineering, "Animal viral vaccine" in veterinary medicine, "Microbial fertilizer" in agricultural resource science, and "Biomass energy and materials" in forestry engineering.

• *Emerging development hotspots*. They include "Intelligent agricultural equipment" in agricultural engineering.

The hotspot "Agricultural machinery improvement" has produced a relatively high number of patents (> 600). However, the highest patent citation frequency is found in the hot topic "Animal stem cells" in veterinary medicine (up to 3651 times). The average citation frequency of all hotspots are approximately five times. Among them, the highest and the lowest average citation frequency of patents are in "Pesticide pollution and prevention" (approximately 10 times) and "New genetically modified species" (less than twice), respectively. The mean year (average publication year) of patents is mainly concentrated from 2012–2013 (Table 2.1.1). The number of patents in the hotspots "Pesticide pollution and prevention" and "New genetically modified varieties" in plant protection has shown a regular downward trend (Table 2.1.2).

Brief descriptions of the top 10 engineering development hotspots are as follows.

2.1.1 Intelligent agricultural equipment

This is a emerging development hotspots in agricultural engineering. Intelligent agricultural equipment combines the advanced manufacturing, information, and artificial intelligence technologies. It is an important tool for upgrading traditional agricultural machinery manufacturing with the aim of achieving intelligent automation of agricultural production processes. Moreover, it has become an important direction for the development of international high-end agricultural equipment manufacturing industry.

Table 2.1.1 Top 10 engineering development hotspots in agriculture

No.	Engineering development hotspots	Published patents	Citation frequency	Average citation frequency	Mean year
1	Intelligent agricultural equipment	142	685	4.82	2013.37
2	Precision irrigation	261	842	3.23	2013.37
3	Pesticide pollution and prevention	160	1481	9.26	2012.11
4	Facility agriculture	226	634	2.81	2012.99
5	Agricultural machinery improvement	606	1326	2.19	2013.49
6	Animal stem cells	473	3651	7.72	2012.26
7	Animal viral vaccine	264	1232	4.67	2012.29
8	Microbial fertilizer	315	1908	6.06	2012.59
9	New genetically modified varieties	105	154	1.47	2012.11
10	Biomass energy and materials	154	806	5.23	2012.75

Table 2.1.2 Annual number of core patents belonging to each of the top 10 engineering development hotspots in agriculture

No.	Engineering development hotspots	2011	2012	2013	2014	2015	2016
1	Intelligent agricultural equipment	23	19	27	34	33	6
2	Precision irrigation	32	52	44	71	45	17
3	Pesticide pollution and prevention	46	66	36	9	3	0
4	Facility agriculture	48	45	44	44	40	5
5	Agricultural machinery improvement	58	99	134	139	155	21
6	Animal stem cells	151	162	72	67	18	3
7	Animal viral vaccine	81	80	62	30	9	2
8	Microbial fertilizer	61	88	100	51	14	1
9	New genetically modified varieties	30	37	35	2	1	0
10	Biomass energy and materials	36	37	28	35	18	0

At present, the intelligent control of agricultural equipment focuses on the in-depth exploration of various sensors, communication systems, image processing, computer vision, and other information technologies, including the sensors used in vehicle steering control, the level control for the lifting and lowering of ground working parts of vehicles, and the electro-hydraulic control of vehicle position with pressure and depth. Furthermore, the focus includes the image sensor monitoring system for plant/crop characteristics, such as the maturity of fruits, vegetables, and other agricultural products in addition to equipment integrating image processing and visualizing sensing function (automatic visual monitoring system) for thinning out seedlings and weeding. Further, the focus includes the collaborative control of vision and image processing technology (e.g., stereoscopic vision system) on harvesters and transport trucks in a coordinated multi-machine system, the radio load control of harvester grain silos, the improvements in the grain push controllers with controllable pushing speed, the threshing mechanism combine harvester, and the performance of grain storage container. Intelligent agricultural equipment can meet the different levels of demand. They can be integrated with advanced technologies and information, including intelligent equipment, digital design and simulation systems, intelligent equipment testing platform, micro-electromechanical system agricultural sensors, agricultural robots, intelligent navigation control technology, the internet of things, big data, and cloud computing, and cloud service is the main direction of intelligent agricultural equipment research in the future.

2.1.2 Precision irrigation

This is a ground-breaking development hotspot in agricultural engineering. At present, water shortages have become the most important limiting factor in global agricultural production. In accordance with the crop growth needs, precision irrigation achieves the intelligent monitoring of water, fertilizer, gas, heat, light, and other crop growth factors, and uses water-saving irrigation facilities to provide the most appropriate amount of water supply to crops for achieving the optimal growth status. The application of precision irrigation can significantly improve the yield and quality of agricultural products, and contribute to achieving the water-saving, fertilizer-saving, labor-saving, high yield, and environmental protection goals. In the agricultural productions of Africa, the Middle East, Central Asia, and other arid and semi-arid areas, efficient use of water resources is the primary research topic. Based on the previous technical integration and the degree of mechanization, the performance of the irrigation controller in agricultural precision irrigation technology is more accurate (e.g., on-demand water input, which can be detected and controlled precisely), and the water-saving effect is more significant. E.g., an irrigation controller that automatically adjusts the progress of irrigation water according to the budget, the irrigation controller that automatically adjusts the water outflow according to the progress of irrigation and the irrigation system based on the theory of evapotranspiration (i.e., control of irrigation water outflow through the information transmitted by evapotranspiration units).

2.1.3 Pesticide pollution and prevention

Pesticide pollution and prevention is a hotspot in the discipline of plant protection, which involves in in-depth traditional research. Pesticide pollution refers to the excessive use of pesticides and improper selection of pesticide type and application time, which lead to excessive pesticide residues in agricultural products, thereby causing serious harm to human health. Some natural enemies (predators and parasites) of pests are killed, thereby disrupting the balance between pests and their natural enemies, and a rapid pest population growth. Meanwhile, the pollinating insects are killed, which affects the crop yield. Excessive pesticides enter the soil and water owing to rainfall, farmland percolation, and drainage, thereby damaging the ecosystem. The integrated prevention and control technology includes agricultural, biological, chemical, physical, and other methods of control. Low toxicity and biological control are the preferred research and development directions of plant protection.

2.1.4 Facility agriculture

Facility agriculture is a hotspot in agricultural engineering involving in-depth traditional research. Facility agriculture refers to a modern agricultural approach that uses engineering techniques for efficient production of animals and plants under a relatively controllable condition. Facility agriculture covers facility cultivation, facility breeding, facility-produced edible fungi, etc. Modern greenhouse and plant factory are two important areas of the research on facility agriculture intelligence. Compared with the modern greenhouse, a plant factory that can avoid the field production environment is a higher level of development of facility agriculture. Among them, the collection and monitoring of environmental and biological information, intelligent system control platform, biologically standardized and pipelined production management model, and the development of the quality traceability system of agricultural products based on the internet of things will be the core hotspots in future.

2.1.5 Agricultural machinery improvement

This is a hotspot in agricultural engineering involving in-depth traditional research. The focus includes the continuous improvement and manufacturing of advanced agricultural machinery and equipment, with the ultimate aim of improving agricultural production and management, and continuously enhancing the level of agricultural production technology, economic benefits, and ecological benefits. In addition, the comprehensive integration of the specialization, automation, information technology, and other core technologies of agricultural machinery is an important direction for development.

2.1.6 Animal stem cells

It is a disruptive development hotspot in veterinary medicine. Animal stem cells are cells with an ability of self-replication under certain conditions. They can differentiate into a variety of functional cells. According to their developmental stages, the stem cells are divided into embryonic stem cells and adult stem cells. According to their developmental potential, stem cells are divided into three categories: totipotent stem cells, pluripotent stem cells, and unipotent stem cells (monopotent stem cells). Stem cells are cells that are immature and not fully differentiated, possessing the potential to regenerate living organisms, various tissues, and organs. The animal models that have a close genetic relationship with human, such as cloned pigs, can grow organs and tissues suitable for humans, and cloned macaques can be used to test diabetes and other illnesses.

2.1.7 Animal viral vaccine

This is a hotspot belonging to the discipline of animal husbandry and involving in-depth traditional research. Vaccine refers to a biological agent that is used to inoculate living organisms, displays antigenicity, and is used to prevent and control the occurrence of infectious diseases. The types of viral vaccines include: (1) traditional vaccines, such as inactivated vaccines, attenuated live vaccines, and subunit vaccines, and (2) new viral vaccines, such as gene-deficient live vaccines, virus-like particles, nucleic acid vaccines, and live viral vectors. The new viruses that are constantly emerging pose a huge challenge for researchers to develop drugs or vaccines.

2.1.8 Microbial fertilizer

This is a hotspot in agricultural resource science involving in-depth traditional research. Microbial fertilizers refer to a type of biological products that use microbial activities for allowing crops to access a specific fertilizer. There are three categories: microbial agents, composite microbial fertilizer, and bioorganic fertilizer. They are used to inhibit the crop pests and diseases effectively or to provide nutrients and other growth-promoting substances to crops, to adjust and control the growth, enhance disease resistance, and increase the crop yield or crop quality. With the development of organic ecological agriculture, increasing attention will be paid to the use of microbial fertilizers.

2.1.9 New genetically modified varieties

This is a disruptive development hotspot in agricultural bioengineering. To obtain new genetically modified varieties, the useful target gene is isolated from donor organisms and introduced into the recipient animals and plants directly or through DNA recombination and genetic transformation. After screening, the genetically modified organism with a stable expression is obtained, and it can be produced by testing and selective breeding. In recent years, the genetic characteristics of organisms have been altered by processes such as gene knockout, and silence of genes to obtain the desired traits and breed new varieties. A large number of new cotton, corn, soybeans, and other crop varieties are reported from abroad; in addition, transgenic research on pigs, cattle, sheep, and other animals has been reported. The application of transgenic technology and the breeding of new varieties are the most popular and advanced research and development fields in the world.

2.1.10 Biomass energy and materials

This is a hotspot in forestry engineering involving in-depth traditional research. Biomass energy is the form of energy, in which the solar energy is stored as chemical energy, i.e., the biomass acts as the energy carrier. It is derived directly or indirectly from the photosynthesis of green plants and can be converted into conventional solid, liquid, and gaseous fuel. Biomass energy development technology is currently focusing on gasification, compressed fuel, combustion power generation, and the production of fuel ethanol and biodiesel. Among them, biomass gasification fuel and biomass compression molding techniques have matured from the traditional research content. In terms of combustion power generation, high-efficiency direct-fired power generation is considered the most viable way of biomass utilization and is an important future development direction. The current conversion efficiency in the production of fuel ethanol with forest waste as raw material is still low; this technique is still in the experimental stage, and the development of ethanol production technique using lignocellulose as raw material will be the focus of future research and development. The extraction of biodiesel from tree seeds with high oil content is still in the exploratory stage, and it is too early for industrial production. However, it is one of the key directions of future research and development.

2.2 Understanding of engineering development focus

2.2.1 Intelligent agricultural equipment

The focus of intelligent control technology for agricultural equipment is the in-depth explorations of various sensors, communication systems, image processing, computer vision, and other information technologies.

The countries or regions producing the core patents are China and the USA (Table 2.2.1). The number of core patents of China and the USA account for approximately 75%

Table 2.2.1 Major producing countries or regions of core patents on the engineering development focus "Intelligent agricultural equipment"

No.	Country/Region	Published patents	Proportion of published patents	Citation frequency	Proportion of citation frequency	Average citation frequency
1	China	107	75.35%	456	66.57%	4.26
2	USA	28	19.72%	210	30.66%	7.50
3	Korea	3	2.11%	14	2.04%	4.67
4	Canada	1	0.70%	3	0.44%	3.00
5	UK	1	0.70%	2	0.29%	2.00
6	Israel	1	0.70%	1	0.15%	1.00
7	Italy	1	0.70%	0	0%	0
8	New Zealand	1	0.70%	2	0.29%	2.00

Table 2.2.2 Major producing institutions of core patents on the engineering development focus "Intelligent agricultural equipment"

No.	Institution	Published patents	Proportion of published patents	Citation frequency	Proportion of citation frequency	Average citation frequency
1	Hunter Ind	5	3.52%	51	7.45%	10.20
2	Skydrop LLC	3	2.11%	5	0.73%	1.67
3	China Agric Univ	3	2.11%	18	2.63%	6.00
4	Kunming Univ Sci & Technol	3	2.11%	6	0.88%	2.00
5	Shandong Agric Univ	3	2.11%	8	1.17%	2.67
6	Valmont Ind Inc.	3	2.11%	7	1.02%	2.33
7	Beijing Res Cent Intelligent Equip Agric	2	1.41%	7	1.02%	3.50
8	Jiangsu Guanjia Water Conservancy Technology Co., Ltd.	2	1.41%	6	0.88%	3.00
9	Nat Diversified Sales Inc.	2	1.41%	9	1.31%	4.50
10	Rain Bird Corp	2	1.41%	24	3.50%	12.00

and less than 20%, respectively. However, the opposite situation is observed in the average citation frequency of core patents, with the USA and China accounting for 7.50 and 4.26, respectively. These findings indicate that the patents of the USA are low in a number, but influential. Hunter Ind. and Rain Bird Corp. in the USA, and China Agricultural University have a high core patent citation frequency and show a significant impact (Table 2.2.2). The USA and Canada have some cooperation, but no cooperation is observed among the top 10 research institutions (Figure 2.2.1 and Figure 2.2.2).

2.2.2 Precision irrigation

Owing to previous technical integration and the degree of mechanization, the performance of the irrigation

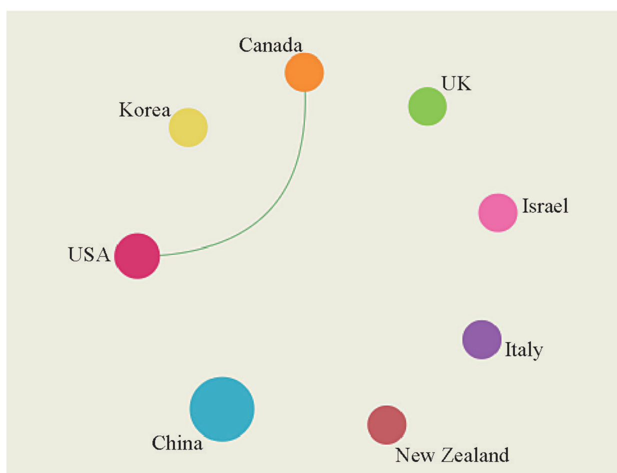

Figure 2.2.1 Collaboration network of the major producing countries or regions of core patents on the engineering development focus "Intelligent agricultural equipment"

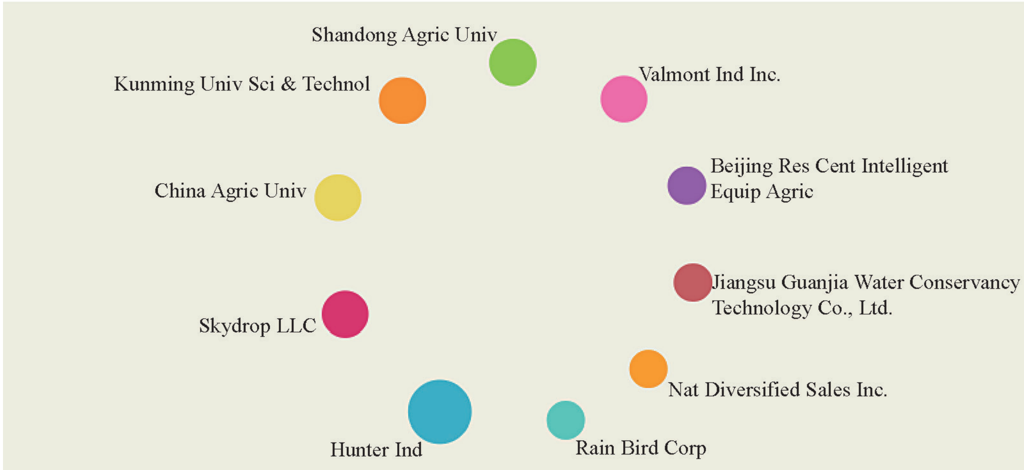

Figure 2.2.2 Collaboration network of the major producing institutions of core patents on the engineering development focus "Intelligent agricultural equipment"

controller in agricultural precision irrigation technology (e.g., on-demand water input is more accurate, and the water-saving effect is more significant. Examples include the irrigation controller that automatically adjusts the progress of irrigation water according to the budget, the irrigation controller that automatically adjusts the water outflow according to the progress of irrigation, and the irrigation system based on the theory of evapotranspiration (i.e., control of irrigation water outflow based on the information transmitted by evapotranspiration units).

In this research area, China has the highest number of core patents and is dominant (Table 2.2.3). Japan, Germany, and the USA have only a few patents, but a high average citation frequency. The average citation frequency of the Japanese patents is 4.79 times, whereas that of the Chinese patents is 3.17 times. The Nanjing Research Institution for Agricultural Mechanization (NRIAM) of the National Ministry of Agriculture and seven other Chinese institutions are among the top 10 organizations, and the other two organizations are a Japanese and an Austrian company (Table 2.2.4). Among the top 10 countries or regions, only Germany and Denmark have cooperation; among institutions, only Qingdao Agricultural University and a company in Qingdao (Qingdao Hongsheng Auto Fittings Co. Ltd.) have some cooperation (Figure 2.2.3 and Figure 2.2.4).

2.2.3 Pesticide pollution and prevention

The prevention and control techniques for pesticide

Table 2.2.3 Major producing countries or regions of core patents on the engineering development focus "Precision irrigation"

No.	Country/Region	Published patents	Proportion of published patents	Citation frequency	Proportion of citation frequency	Average citation frequency
1	China	208	79.69%	659	78.27%	3.17
2	Japan	19	7.28%	91	10.81%	4.79
3	Germany	6	2.30%	18	2.14%	3.00
4	USA	6	2.30%	22	2.61%	3.67
5	Korea	5	1.92%	10	1.19%	2.00
6	Austria	4	1.53%	10	1.19%	2.50
7	Russia	4	1.53%	5	0.59%	1.25
8	France	2	0.77%	7	0.83%	3.50
9	Belgium	1	0.38%	5	0.59%	5.00
10	Denmark	1	0.38%	2	0.24%	2.00

Table 2.2.4 Major producing institutions of core patents on the engineering development focus "Precision irrigation"

No.	Institution	Published patents	Proportion of published patents	Citation frequency	Proportion of citation frequency	Average citation frequency
1	Min Agric Nanjing Res Inst Agric Machinery	6	2.30%	18	2.14%	3.00
2	Qinghai Agric & Husbandry Machinery Mfg	6	2.30%	19	2.26%	3.17
3	Kubota Corp	5	1.92%	21	2.49%	4.20
4	Shandong Changlin Agric Equip Co., Ltd.	5	1.92%	19	2.26%	3.80
5	Qingdao Agric Univ	5	1.92%	11	1.31%	2.20
6	Alois Pöttinger Maschinenfabrik GmbH	4	1.53%	10	1.19%	2.50
7	Qingdao Hongsheng Auto Fittings Co., Ltd.	4	1.53%	21	2.49%	5.25
8	Henan Univ Sci & Technol	4	1.53%	13	1.54%	3.25
9	Chery Heavy Industry Co., Ltd.	3	1.15%	6	0.71%	2.00
10	Chongqing Standard Machinery Mfr Co., Ltd.	3	1.15%	6	0.71%	2.00

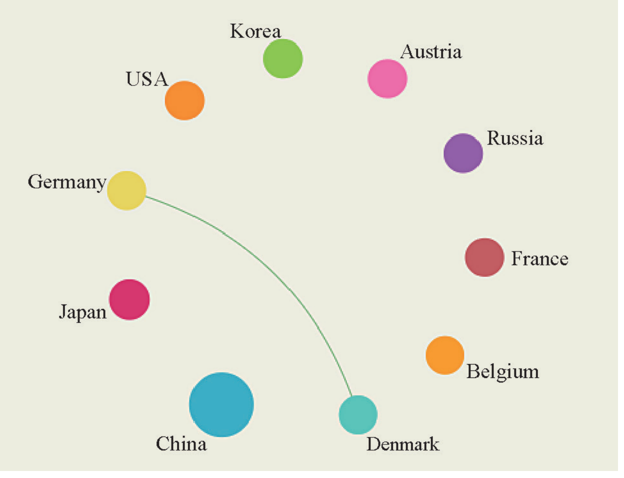

Figure 2.2.3 Collaboration network of the major producing countries or regions of core patents on the engineering development focus "Precision irrigation"

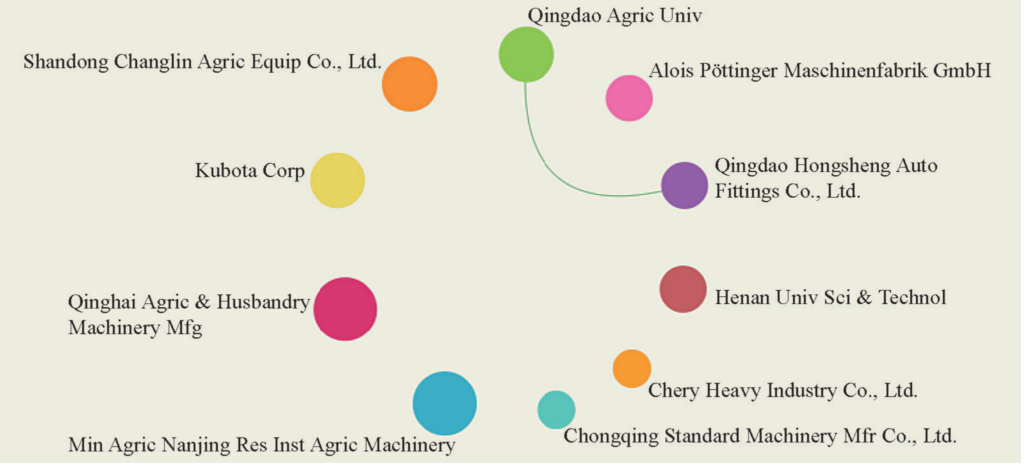

Figure 2.2.4 Collaboration network of the major producing institutions of core patents on the engineering development focus "Precision irrigation"

pollution include the following aspects: (1) Agricultural control—the use of crop rotation, selection of new pest and disease resistant varieties, and reasonable control of fertilizer and water to improve crop resistance to pests and diseases; (2) Biological control—the use of natural enemies for pest control, the use of insects, bacteria, animals and plants, and other organisms for weed control, and the use of biological pesticides for pest control; (3) Chemical control—the disease, insect, and weed forecasts, achieving timely control, and reasonable mix and alternate use of less-persistent pesticides; (4) Physical control—the use of mechanical or hand control, syrup and light trapping, manual weeding, mechanical weeding, etc. At present, the use of low toxicity and less-persistent pesticides is the dominant control technique.

The countries mainly producing the core patents on this focus are China, the USA, and Germany (Table 2.2.5). China has the largest proportion of published patents and has approximately the same average citation frequency as other countries have. Among the major organizations owning the core patents (Table 2.2.6), six institutions in Guangxi and Guangdong of China have a high number of patents, and one institution each from Germany, the USA, France, and Switzerland is among the top 10 organizations. The USA and France remain the main cooperating countries, and China mainly cooperates with Germany (Figure 2.2.5). However, there is no cooperation mechanism among the top 10 research institutions (Figure 2.2.6).

Table 2.2.5 Major producing countries or regions of core patents on the engineering development focus "Pesticide pollution and prevention"

No.	Country/Region	Published patents	Proportion of published patents	Citation frequency	Proportion of citation frequency	Average citation frequency
1	China	121	75.63%	1148	77.52%	9.49
2	USA	22	13.75%	177	11.95%	8.05
3	Germany	15	9.38%	153	10.33%	10.20
4	Switzerland	6	3.75%	60	4.05%	10.00
5	France	6	3.75%	46	3.11%	7.67
6	Canada	3	1.88%	24	1.62%	8.00
7	UK	3	1.88%	29	1.96%	9.67
8	Italy	2	1.25%	7	0.47%	3.50
9	Belgium	1	0.63%	6	0.41%	6.00
10	Finland	1	0.63%	12	0.81%	12.00

Table 2.2.6 Major producing institutions of core patents on the engineering development focus "Pesticide pollution and prevention"

No.	Institution	Published patents	Proportion of published patents	Citation frequency	Proportion of citation frequency	Average citation frequency
1	Guangxi Idyllic Biochemistry Co., Ltd.	20	12.50%	277	18.70%	13.85
2	BASF SE	13	8.13%	122	8.24%	9.38
3	Guangdong Zhongxun Agric Sci Co., Ltd.	7	4.38%	55	3.71%	7.86
4	Dow Agrosciences LLC	6	3.75%	57	3.85%	9.50
5	Nanning Defengfu Chem Co., Ltd.	5	3.13%	42	2.84%	8.40
6	HSP Crop Technology Co., Ltd.	4	2.50%	27	1.82%	6.75
7	Nantong Liannong Pesticide Preparation	4	2.50%	45	3.04%	11.25
8	Hebei Bojia Agric Co., Ltd.	3	1.88%	45	3.04%	15.00
9	Rhodia Operations	3	1.88%	12	0.81%	4.00
10	Syngenta Participations AG	3	1.88%	36	2.43%	12.00

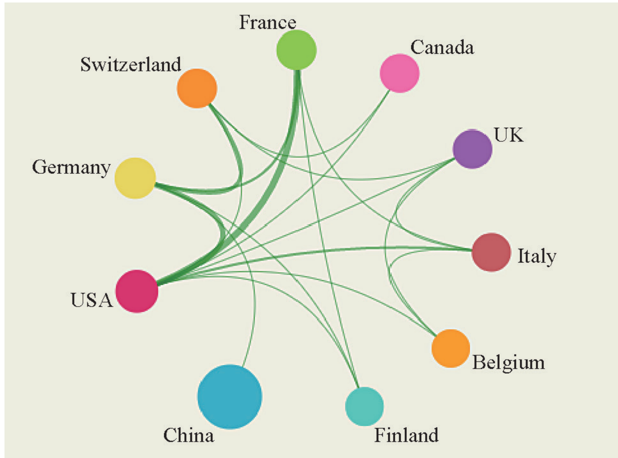

Figure 2.2.5 Collaboration network of the major producing countries or regions of core patents on the engineering development focus "Pesticide pollution and prevention"

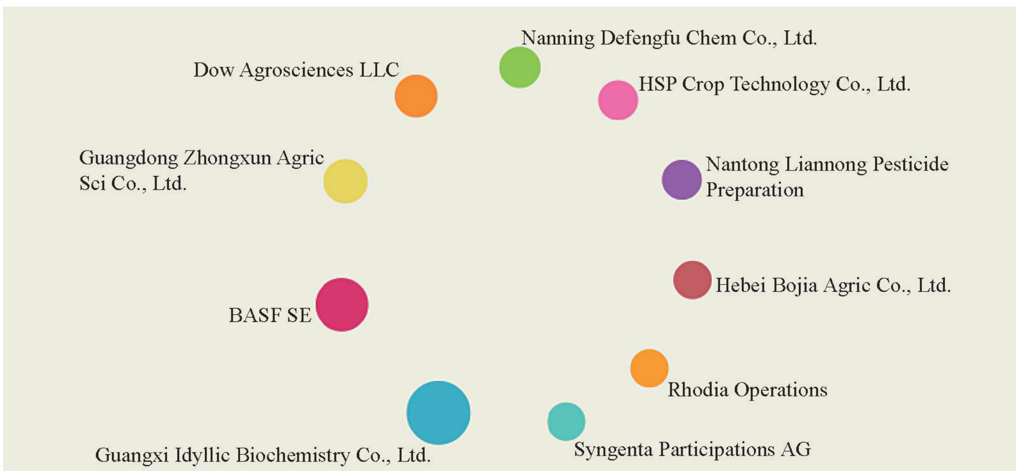

Figure 2.2.6 Collaboration network of the major producing institutions of core patents on the engineering development focus "Pesticide pollution and prevention"

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