Research on Scientific Collaboration Social Network of Provincial Academy of Agricultural Sciences

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Abstract. A research was conducted on the co-authorship social network of Guangdong Academy of Agricultural Sciences by using bibliometrics and social network analysis (SNA), then statistics and analysis were conducted on the three statistic characteristics of scale-free network: average network path length, node degree distribution and condensed subsets. Results showed that Guangdong Academy of Agricultural Sciences had 3746 co-authorship network nodes and 9307 connection lines. The average network path was 12.81183 and network density was 0.00158670. For the total 3746 network nodes, the average degree was 2.96796583, among which the maximum was 80 and the minimum was 1. The connection distribution of collaboration network was uneven; a large number of nodes had few connections while a few nodes had most of connections in the network. The network was distributed to 597 condensed subsets, among which the largest condensed subset had 2156 nodes, accounting for 57.555% of the total nodes. There were 24 medium-sized subsets and the number of nodes was about 6 to 22. The co-authorship network was incompletely connected and the integral connection was fairly close. There were some closely connected groups in large sub-network and the integral co-authorship status was perfect. Different nodes of the co-authorship network were connected closely, among which the top 50 authors collaborated with other scientific research personnel frequently. Such kind of organization form of Guangdong Academy of Agricultural Sciences yet has great advantage in key agricultural science breakthroughs. It is reflected in those aspects: the forming mechanism of large-scale co-authorship network has close connection with the stability and durability of talents in this field, the breakthrough of key scientific projects can also lead to the formation of large-scale co-authorship network.

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Introduction

With the development and specialization of science, researchers need to collaborate to accomplish many scientific researches. On academy, it is reflected in frequent scientific research collaboration and science co-authorship. Researchers engaged in scientific research collaboration and science co-authorship are usually familiar with each other and collaborate to publish papers and establish a co-authorship publication network. This network can truly reflect the researchers' human network, also known as social network. Collaboration social network of scientific field is a complex scientific research collaboration network composed of different participants and they have extensive connection. In this network, network nodes represent researchers in scientific fields and network connection represents the relation of papers co-published by the researchers. The structure of collaboration social network of scientific field reflectes the network variables such as how the participants connect, connection degree and node distribution etc, which will influence the collaboration degree of researchers of scientific fields in the network and the development trend of network directly. In the past, bibliometrics were used to analyze the co-authorship relation. The disadvantage of such analysis was that the co-authorship relation was not explored as a whole and the underlying relation of some authors was ignored. Social network analysis was derived from sociology and has been developed as one of widely-used research methods nowadays. By using social network analysis (SNA) to explore the collaboration relation among authors, we can know the co-authorship status of some certain fields and scientific research range for strengthening collaboration.

Many foreign scholars have conducted empirical study on co-authorship network, however, such researches mainly focused on the natural sciences and authors usually collaborated in these fields. Scholars like Fuyuki Yoshikane made a comparison of co-authorship network between the filed of computer science research and the field of application research and modified the hits-algorithm to identify leaders and followers of the co-authorship network. Barabasi A L conducted a study on the evolution rules (with time variation) of co-authorship network and verified that: co-authorship network distribution was compliance with power law distribution, the clustering coefficient and average degree declined with time, proportion of maximally connected sub-graph of the whole network increased with time, new nodes preferred to establish connection with higher nodes. New-man M E J conducted a study on the inherence of co-authorship network in the fields of physics, biology and computer science and made a comparison and analysis of different networks. Scholars like Yasmin H made an introduction of the basic methods of social network analysis such as centrality analysis and cluster analysis and his research focused on the small group features formed by the cluster analysis of co-authorship network, which can be summarized as single type, consultant, enterprise and team and speculated the impacts of these small group features. In domestic, more researches were conducted to make empirical analysis on co-authorship network by SNA. Qinghua Zhu made a summary on the application status of SNA in the field of information science. He made an empirical analysis on the co-authorship social network of Journal of the China Society For Scientific and Technical Information, conducted the centrality analysis, cohesive subgroup analysis and core-remote structure analysis, evaluated the scholars' position in the co-authorship network, found the closely connected groups and figured out the number and organizations of the core authors in the co-authorship network. Bei Liu conducted a study on researchers' co-published network, co-word network, citation network and collaboration network of small groups in different periods. Aixian Jiang

conducted a research on the collaboration network of management science. However, majorities of researches were conducted to analyze co-authorship social network of some certain science and certain magazines, but less study was conducted on that of a certain organization.

Provincial academy of agricultural sciences plays an important role in scientific agricultural research in China. By coordinating the agricultural science and technology resources of the whole province and gathering the talents to strengthen regional collaborative innovation and development, the provincial agricultural research leader head the development of agricultural research of the province. Meanwhile, there are many research institutes in provincial academy of agricultural sciences, mainly including institutes of grain crops, vegetables, cash crops, plant protection, soil and fertilizer, animal husbandry and veterinary and agricultural economy etc. The integration of departments will help to integrate the interacting factors of those departments and gather them into a same task to achieve the effects of collaborative innovation that single innovation can not reach. In the meantime, provincial academy of agricultural sciences has research collaboration with office for agricultural research at local levels to extend the coverage of agricultural research in the whole province and puts agricultural research closer to frontline of agricultural production. However, no research on co-authorship network of specific research group has been conducted in domestic or abroad. Only Huili Wang conducted a study on the collaboration relation of professors of biological medicine of one provincial medical university. And Shanmin Ding conducted a research on the co-authorship relation of Institute of Chemistry of Tianjin Normal University. Therefore, it is necessary to make an analysis on the research collaboration network of provincial academy of agricultural sciences from the perspectives of network individuality attribute and integrity attribute to discover its connotation.

Materials and Methods

Data Collection

The scientific paper data including the papers and authors' information of Guangdong Academy of Agricultural Sciences from 2006 to 2015 were obtained through online search of China National Knowledge Infrastructure(CNKI), Wanfang Database, VIP database etc. by NoteExpress Software. A database was further established based on the collective data which were classified as thesis title, author, institution, publication date, journal and keywords, and such data were stored and handle by Excel.

Data Cleaning

There were some replication and inaccuracy in the raw data obtained by software, and such data would cause errors in the later analysis results. Therefore, it is necessary to clean the data. Softwares like NoteExpress and Excel were used to clean the data, and 5885 groups of basic data were obtained.

On the process of data cleaning, one of the key steps is to distinguish and deal with the duplicated authors. Considering the actual need of network analysis, we can reduce the statistical errors caused by duplicated names if we follow the methods below:

(1) Combine the author' name and organization to identify whether the synonymous author matches with the same person.

(2) There are different ways of expression on the organizations of some authors, it is needed to select and compare the key information of the organization to further identify synonymous author.

(3) One author may publish papers in various periods at different stages. The author at different stages may be identified as different ones if we put much emphasis on the combination of name and organization, which will also cause many problems during the process of statistics and analysis.

(4) In order to reduce the errors brought by the above mentioned methods, co-authorship network can be established to verify and revise the data. In the network, the shortest path of two synonymous authors with different institutions is 2, which represents that they ever collaborated with each other and can be considered as the same person. Repeatedly, some over-distinguished synonymous authors can be revised to improve the accuracy of the data.

Establishing Network

As the research focused on the co-authorship connection between authors, only related data of co-authors' were selected to establish co-authorship network. Totally, 5559 groups of effective data were selected. As the collected raw data were recorded in the form of "one paper to several authors", while the establishment of network was connected by taking authors as nodes. Such form needed to be transformed to the form of that authors collaborate in pairs in Excel table. Data stored in Excel table could not be entered into Pajek software and needed to be transformed into corresponding ".net" form through Excel2pajek software.

Results and Analysis

Network Characteristic Parameter

Average Path Length. Average path length refers to the average length of two random nodes. As the co-authorship network of provincial academy of agricultural sciences was an incompletely connected network and the average path length would be infinitely large if following general statistics. In order to avoid such situation, node pairs with no connected path would not be taken into account. However, the co-author network of provincial academy of agricultural sciences was usually part of agricultural research field and different nodes may have connections. Therefore, all nodes were analyzed in this research. Results showed that the longest path of co-authorship network of Guangdong Academy of Agricultural Sciences was 40 and the corresponding node was Xiaoman She and Xiaoqing Xue, which meant that these two people could be connected through 40 inter-linkages. For the whole network, there were 3746 nodes and the number of connection was up to 9307 (Figure1).

The average network path was 12.81183 and it meant that two random authors could set up co-authorship connection through a path of 12.81183 at the most. Compared to that of a certain subject or a certain college, the path of this network was longer. There were 15 research institutes (such as Rice Research Institute, Vegetable Research Institute etc.) under Guangdong Academy Agricultural of Sciences. The network scale became larger with the emergence of new subjects and engagement of new researchers, which further led to longer path.

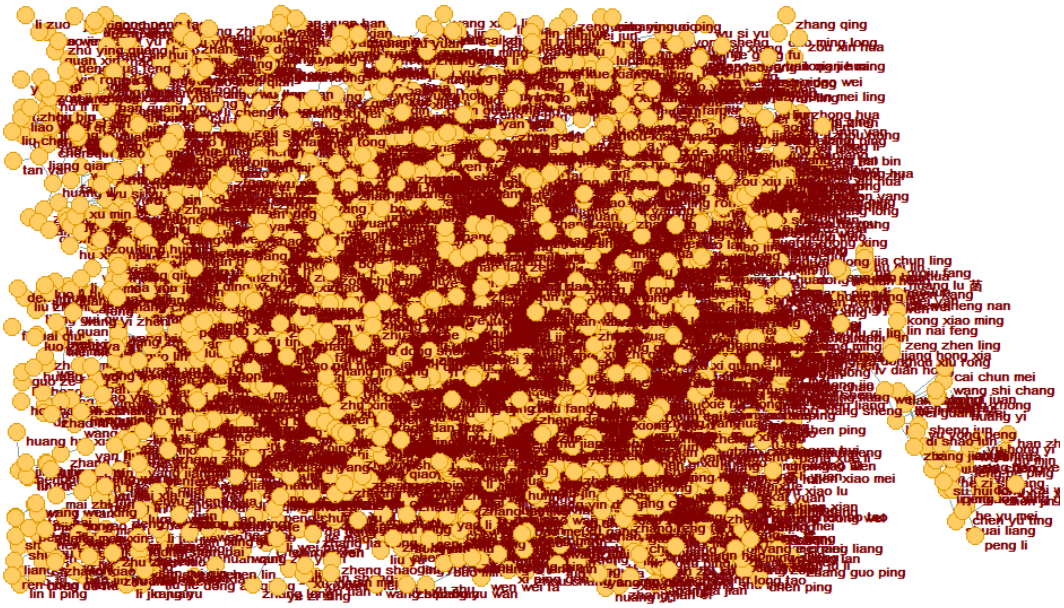

Figure 1. Co-authorship network of research personnel of Guangdong Academy Agricultural of Sciences

Network Density. Calculated by Pajek Software, the co-authorship network density of Guangdong Academy of Agricultural Sciences was 0.00158670. The network density was much lower compared to the largest density value (0.5) of actual network. Considering the larger scale of actual network involving collaboration connection of different organizations, the density was higher compared to ever-researched data (Mengwei 0.0002323), which showed that the network density of Guangdong Academy of Agricultural Sciences was higher and the collaboration of nodes was relatively close. In actual network, a person has limited ability and time to maintain certain relations and the person will stop establishing new relation if he gives more and gains less, especially for large-scale network.

Degree Distribution. In undirected network, degree describes the number of edges connected to specified nodes and this number reflects the importance of this node from one certain respect and is one of canonical measure of node centrality. The results showed that for the 3746 nodes in the whole network, the average degree of co-authorship network of Guangdong Academy of Agricultural Sciences was 2.9679658 (Maximum: 80, minimum: 1). From figure 2, it was showed that the connection distribution of the collaboration network was uneven, a large number of nodes had few connections, while a few nodes had most of connections in the network.

Analysis on Condensed Subsets. If classified based on condensed subset, the network was distributed to 597 condensed subsets (Figure 3), among which the largest condensed subset has 2156 nodes, accounting for 57.555% of the total nodes. There are 24 medium-sized subsets and the number of nodes was about 6 to 22 (Figure 4).

Results showed that the co-authorship network was incompletely connected and the integral connection was fairly close. There were some closely connected groups in large sub-network and the integral co-authorship status was perfect. Results (Figure 4) showed that the medium-sized condensed subsets had the nodes representing the staff ever worked for Guangdong Academy of Agricultural Sciences and they still collaborated closely with the Academy after they left the original organizations. In addition, there were 572 small-sized networks in the co-authorship network and most of them were composted of 3 to 5 nodes. The formation of such small-sized networks

was mainly because: First, the research area was special and small stable groups were formed. The core node of the small-sized network was Yu Chen and he was engaged in the research of rice genomics with Fen Chen, Jiangping Song and Dujuan Li. The research field was self-contained and the research group was relatively stable. Second, the research members worked for several organizations and Guangdong Academy of Agricultural Sciences was one of the organizations they worked for. As shown in Figure 7, the group of Huilong Su was not only the staff of Veterinary Research Institute of Guangdong Academy of Agricultural Sciences but also the staff of Veterinary College of South China Agricultural University. Third, some new administrative personnel needed to publish papers based on professional title and did not establish close connection with other research personnel.

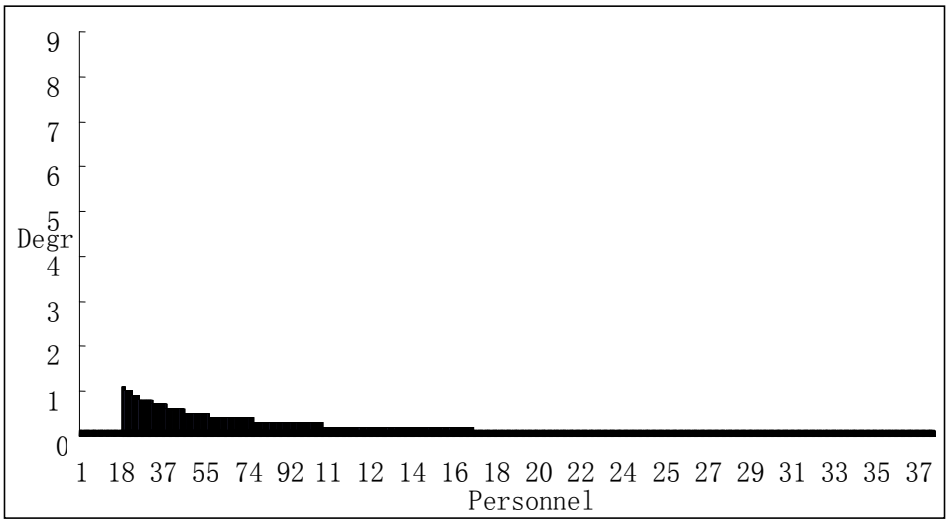

Figure 2. Distribution of nodes

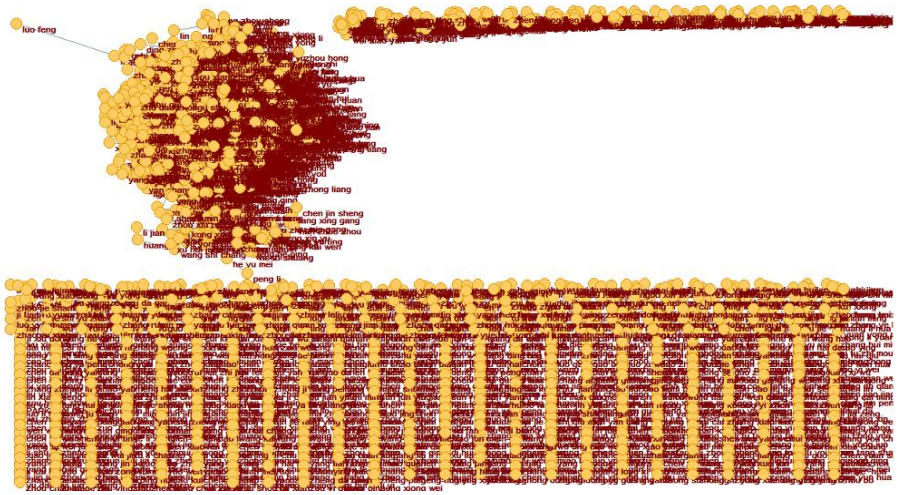

Figure 3. Distribution of co-authorship network of condensed subsets of Guangdong Academy of Agricultural Sciences

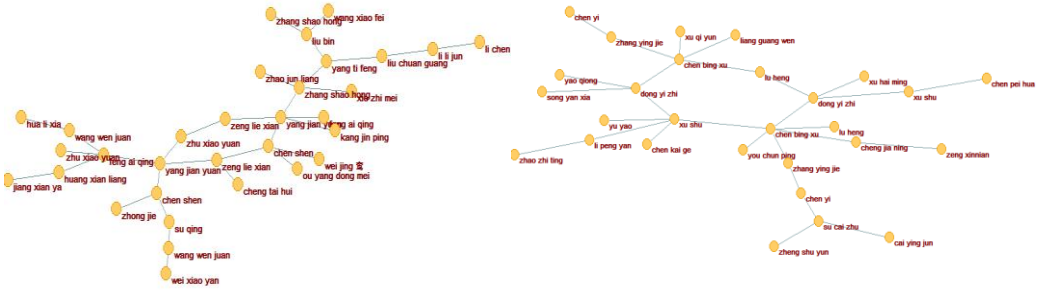

Figure 4. Part of medium-sized condensed subsets

Analysis on Authors' Effects

The centrality of certain nodes in the network reflects the position and influence of corresponding individuals in the network. Therefore, the analysis of the influence of authors can be converted to the analysis of node centrality of co-authorship network accordingly. The advantages and disadvantages of the co-authorship network could be found to provide experience for improving research collaboration in the future.

Results (Table 1) showed that different nodes of the co-authorship network of Guangdong Academy of Agricultural Sciences were connected closely, among which the top 50 authors collaborated with other scientific research personnel frequently. From the analysis of the authors' identities, it was found that the top 50 authors were usually the leader of the subject and led a corresponding subject team. From the perspective of centrality (Table 2), centrality of nodes ranking top 50 played an important role in the co-authorship collaboration network and the collaboration of whole research network would be highly dependent on those nodes. Compared to the top 50 authors, the authors with centrality ranking top 50 played a different role in a team. Some authors were still the leader of corresponding subject, such as Taisen Liao. Some authors conducted research of wide fields and connected the whole network, like Xia Feng and Junrong Qiu etc. Some authors connected the whole network because of subject area, such as the incumbent or former members of Institute of Agricultural Economics and Rural Development: Yelu Zheng, Canfang Zhou, Xiujie Huang, Zhong Wan, Haowen Luo, Jianjun Hong, Wei Fang etc. From the research results of centrality, if one author has collaborated with the authors in several cohesive subsets and he would function as a bridge that connected these subgroups. The shortest path of other authors in these subgroups would inevitably connect this author (if there was only one author functioned as a bridge between these subgroups), the degree of this node became higher accordingly.

Table1. Authors of Top 50 ranking individual degree value of co-authorship network of Guangdong Academy of Agricultural Sciences

Ranking	Intensity	Author	Title/Position
1	80	Jun-ming CAO	Deputy secretary/Researcher
2	75	Sen-tai LIAO	Secretary/Researcher
3	67	Geng-sheng XIAO	Deputy dean/Researcher
4	64	Ming-wei ZHANG	Director/Researcher
5	55	Yu-juan XU	Deputy Director/Researcher
6	51	Zong-yong JIANG	Former Dean/Researcher
7	46	Zhong WAN	Director/Researcher
8	42	Can-fang ZHOU	Director/Research Associate
9	38	Pei-zhi XU	Deputy Director/Researcher
9	38	Gan-jun YI	Deputy Dean/Researcher
11	37	Ye-lu ZHENG	Former Director/Researcher
12	35	Shao-chuan ZHOU	Director/Researcher
13	34	Li-xian YAO	Researcher
13	34	Chun-ling LI	Director/Researcher
13	34	Chuan-guo LI	Director/Researcher
16	31	Xue-ming LIU	Director/Researcher
17	28	Zhi-ping PENG	Director/Researcher
17	28	Shao-ying AI	Deputy Director/Researcher
19	27	Li FENG	Director/Researcher
19	27	Ji-wu ZENG	Deputy Director/Researcher
21	26	Dong CHEN	Former Deputy Dean/Researcher
22	25	Xiao-ming HE	Deputy Director/Researcher
22	25	Jian-guang HU	Director/Researcher
22	25	Hao-wen LUO	Director/Researcher
22	25	Ying-an ZANG	Professor
26	24	Han-cai CHEN	Director/Researcher
27	23	Lu-xiang ZHAN	Director/Researcher Associate
27	23	Yan ZHANG	Deputy Researcher
27	23	Ai-tian PENG	Director/Researcher
27	23	Shi-li SUN	Deputy Director/Researcher Associate
27	23	Shuan-hu TANG	Director/Researcher
27	23	Gen-fa ZHU	Deputy Director/Researcher
33	22	Xiao-fang LI	Former Deputy Director/Researcher
33	22	Wei-jun LIN	Deputy Director/Researcher
33	22	Gui-hua LI	Associate Researcher
36	21	Bao-mei YANG	Research Assistant
36	21	Xing-hong HUANG	Director/Researcher Associate
36	21	Qing HUANG	Director/Researcher
36	21	Li-hua LV	Team Leader/Researcher
36	21	Yong-hong HUANG	Researcher
41	20	Xin-hua XIE	Researcher
41	20	Zhi-qiang LI	Researcher Associate
41	20	Bi-run LIN	Director/Researcher
41	20	Ying-cai LIN	Deputy Director/Researcher
41	20	Da-jian PAN	Director/Researcher
41	20	Pei-yuan YUAN	Deputy Director/Researcher
47	19	Da-sen XIE	Director/Researcher
47	19	Shi-zi KUANG	Senior Agronomist
47	19	Guo-liang LI	Research Assistant
47	19	Kai-zhi XIE	Researcher Associate
47	19	Fa-yuan DING	Researcher Associate
47	19	Guo-qing LUO	Secretary/Researcher
47	19	Zi-fu HE	Secretary/Researcher
47	19	Dao-bang TANG	Researcher Associate
47	19	Yuan-shan YU	Research Assistant

Table 2. Authors of Top 50 Ranking Individual Centrality of Co-authorship Network of Guangdong Academy of Agricultural Sciences

Ranking	Centrality Value	Author	Title/Position
1	0.083341912	Ye-lu ZHENG	Former Director/Researcher
2	0.080564024	Can-fang ZHOU	Director/Researcher Associate
3	0.0722431130	Sen-tai LIAO	Secretary/Researcher
4	0.0644594530	Zong-yong JIANG	Former Dean/Researcher
5	0.0539313100	Ting RONG	Research Assistant
6	0.0539217640	Bing-zhi HUANG	Director/Researcher
7	0.0533251920	Xiao-lang TANG	Researcher
8	0.0469808530	Geng-sheng XIAO	Deputy Dean/Researcher
9	0.0458913110	Zhi-qiang LI	Researcher Associate
10	0.0454178660	Xiu-jie HUANG	Director/Researcher Associate
11	0.0435778790	Pei-yuan YUAN	Deputy Director/Researcher
12	0.0412373490	Dong CHEN	Former Deputy Dean/Researcher
13	0.0372351330	Jun LIU	Director/Researcher
14	0.0333968080	Zhuang CHEN	Form Deputy Director/Researcher
15	0.0330784630	Zhong WAN	Dean/Researcher
16	0.0320723430	Qiu-shuang WANG	Research Assistant
17	0.0307430790	Zhi-hong XU	Director/Researcher
18	0.0291020380	Zong-hua QIN	Research Assistant
19	0.0290600290	Jun-xi CAO	Director/Researcher
20	0.0262476340	Lu-xiang ZHANG	Director/Researcher Associate
21	0.0247090890	Jun-ming CAO	Deputy secretary/Researcher
22	0.0243164020	Gui-hua LI	Researcher Associate
23	0.0241588430	Shi-li SUN	Deputy Director/Researcher Associate
24	0.0227977590	Wei-jun LIN	Deputy Director/Researcher
25	0.0226466000	Li-hua LV	Researcher
26	0.0210680490	Jun-rong QIU	Deputy Director/Researcher
27	0.0204933800	Wei-ming ZHANG	Director/Researcher
28	0.0196495220	Cai-jin LING	Director/Researcher
29	0.0187760610	Dong-mei LI	Research Assistant
30	0.0182200200	Jian-feng YUAN	Research Assistant
31	0.0177483210	Yu-juan XUAN	Deputy Director/Researcher
32	0.0172363890	Hua-ling WU	Director/Researcher Associate
33	0.0172041350	Ying-an ZANG	Professor
34	0.0156173010	Xuan-qiang LIANG	Director/Researcher
35	0.0154057220	Ji-shui QIU	Director/Researcher
36	0.0153589970	Li-xia MU	Research Assistant
37	0.0152279800	Hao-wen LUO	Director/Researcher
38	0.0150110650	Han-cai CHEN	Director/Researcher
39	0.0146090310	Xiao-ming HE	Deputy Director/Researcher
40	0.0137874290	Gen-fa ZHU	Deputy Director/Researcher
41	0.0136551040	Zhi-yong FENG	Director/Researcher
42	0.0134358790	Dao-bang TANG	Researcher Associate
43	0.0132749050	Yu-rong HE	Professor
44	0.0128554070	Yue-rong WEI	Researcher Associate
45	0.0128420020	Jian-jun HONG	Section Chief/Researcher
46	0.0127063500	Shuan-hu TANG	Director/Researcher
47	0.0127024240	Wei FANG	Director/Researcher Associate
48	0.0121551570	Ying-jie MEI	Section Chief/Research Assistant
49	0.0119582090	Xia FENG	Deputy Director/Researcher
50	0.0119337670	Shao-hai YANG	Deputy Director/Researcher

Conclusions

The results showed that Guangdong Academy of Agricultural Sciences had 3746 co-authorship network nodes and 9307 connection lines. The average network path was 12.81183 and network density was 0.00158670. For the total 3746 network nodes, the average degree was 2.96796583, among which the maximum was 80 and the minimum was 1. The connection distribution of collaboration network was uneven, a large number of nodes had little connection while a few nodes had most of connection in the network. If classified based on condensed subset, the network was distributed to 597 condensed subsets, among which the largest condensed subset had 2156 nodes, accounting for 57.555% of the total nodes. There were 24 medium-sized subsets and the number of nodes was about 6 to 22. The co-authorship network was incomplete connected and the integral connection was fairly close. There were some closely connected groups in large sub-network and the integral co-authorship status was perfect. In addition, there were 572 small-sized networks in the co-authorship network and most of them were composted of 3 to 5 nodes. Different nodes of the co-authorship network were connected closely, among which the top 50 authors collaborated with other scientific research personnel frequently. From the analysis of the authors' identities, it was found that the top 50 authors were usually the leader of the subject and led a corresponding subject team. From the perspective of intermediary, centrality of nodes ranking top 50 played an important role in the co-authorship collaboration network and the collaboration of the whole research network would be highly dependent on those nodes. Compared to the top 50 authors, the authors with centrality ranking top 50 played a different role in a team. Some authors were still the leader of corresponding subject. Some authors conducted research of wide fields and connected the whole network. Some authors connected the whole network because of subject area.

Results showed that such kind of organization form of Guangdong Academy of Agricultural Sciences yet had great advantages in key agricultural science breakthroughs. It was reflected in:

(1) The forming mechanism of large-scale co-authorship network had close connection with the stability and durability of talents in this field. From the research results, it was found that the research team composted of key authors such as Junming Cao, Sentai Liao, Zongyong Jiang, Gengsheng Xiao and Zong Wan etc., had great advantages in the scale of co-author network and the number of collaboration organizations. In the network, there were many core authors and bridge-oriented authors in the largest cohesive subgroups, which led to the close collaboration of the affiliated scientific research institutes and the small groups could be connected to large-scale co-authorship network.

(2) The breakthrough of key scientific projects could also lead to the formation of large-scale co-authorship network. For the breakthrough of major projects, the current national funding system played a leading role in scientific research collaboration. There were two types of academic team: The first type was problems-tackling academic team, which referred to the scientific research team formed to tackle major problems of national economy and social development. The second type was loose-collaboration academic team, which developed due to common interests or common views spontaneously. Per the research results, the largest cohesive subsets in the co-authorship network of Guangdong Academy of Agricultural Sciences could be regarded as problem-tackling team composted of major research groups of crops, soil

and fertilizer, plant protection, genome and industrial economics and had natural advantages in the application and implementation of significant programs.

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