Visualization analysis of research on rice with fertilizer from the 'agronomy' category based on CiteSpace

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In the present study, a total of 1757 documents of article and review relating to rice with fertilizer from the 'agronomy' category were analysed based on the Web of Science during the period 1990–2018. Using CiteSpace software, visualization analysis on co-authors, co-institutions, author co-citation, citation analysis and keyword co-appearance network was performed. It was observed that the number of publications has grown rapidly over the past years. The top five most productive authors were Ladha, J. K. (India), Dobermann, A. (UK), Peng, S. B. (China), Fageria, N. K. (Brazil) and Haefele, S. M. (Philippines). India was the most productive country, followed by China, USA, Japan, Philippines and Australia. The top three institutions were International Rice Research Institute in Philippines, Indian Council of Agricultural Research (ICAR) and Chinese Academy of Sciences (CAS). The top 15 keywords were rice, yield, soil, nitrogen, management, fertilizer, growth, system, wheat, grain yield, lowland rice, phosphorus, plant, productivity and use efficiency, each cited more than 100 times. This article highlights the status and future trends of research on rice with fertilizer.

Keywords: Agronomy, fertilizer, rice research, scientometrics, visualization analysis.

AS the global population continues to steadily increase, staple crop yields must also increase to meet the demand for food[1]. Rice (*Oryza sativa* L.) occupies the core position in grain crops[2]. It is the staple food for more than 65% of the population in China[3], and the main staple in tropical Latin America and East, South and Southeast Asia[4,5]. The interacting systems of soil organic matter with its continuous transformations of carbon, nitrogen, phosphorus and sulphate mediated by soil biota and cation exchange capacity (CEC) of the colloidal phase of soils determine soil fertility for crop nutrition that holds and exchanges nutrients with plant roots[6]. Nitrogen fertilization is the main agronomic practice that affects rice yield and quality. Its mismanagement can affect both economic and environmental aspects of crop production, and lead to a large decrease in fertilizer-N use efficiency and pollute both the atmosphere and aquatic system through N leaching and N_2O and NH_3 emission[7,8]. In rice production, farmers often apply more nitrogen (N) fertilizers than required for maximum crop growth and grain yield[9]. Compared to chemical N, organic fertilizer markedly increases soil organic matter content, promotes grain N accumulation and improves rice production[10]. The development of integrated technologies to increase synergies using decision support tools would enable rice farmers to improve resource use efficiency and rice productivity and profitability[11,12].

Clarivate Analytics's Web of Science (WoS) is the world's leading scientific citation search and analytical information platform. In recent years, based on the WoS Core Collection, bibliometrics has been broadly used in many scientific research fields such as water use efficiency in agriculture[13], planthopper[14], rice physiology and management in China[3], water footprint research[15], wastewater irrigation[16] and biomass energy and environment[17]. In this study, bibliometric analysis of 1757 articles reported in the WoS Core Collection and searched using keywords 'fertilizer' and 'rice' from 1990 to 2018 was carried out up to 21 December 2018. Global scientific research on rice has been analysed at the level of overview, subject category, country/region, institution and author. A bibliometric approach was applied to quantitatively and visually analyse documents using CiteSpace software. The hotspots for rice research were explored by analysing articles published in high-quality journals. This study highlights research on rice across the world, as well as provides clues about relevant hot research topics.

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Data and methodology

Data collection

This study surveyed papers in the Scientific Citation Index Expanded (SCIE) database of the WoS published from January 1990 to 2018 (retrieval data last updated: 21 December 2018). We used the keywords 'rice and fertilizer' to search the database in terms of topic (including four parts: paper title, abstract, author keywords and *KeyWords Plus*) to retrieve the bibliographic records[18]. The document types were both articles and reviews, then refined by the WoS categories as agronomy. The impact factors (IF 2017) were taken from the *Journal Citation Reports* (*JCR*) published in 2018, which had the latest data available.

CiteSpace (version 5.3.R4.SE)

CiteSpace, freely available at http://cluster.cis.drexel.edu/~cchen/citespace/, was used to analyse and visualize patterns in scientific literature retrieved from the WoS. It is a Java-based application for analysing co-citations, generating visual maps and finding trends and patterns. The intellectual landscape of a scientific field is represented by a network of different entities in CiteSpace, such as countries, authors, keywords and cited references. This analysis can offer researchers a comprehensive picture of the overall development of specific research[3,14,19–25]. The parameters of CiteSpace were as follows: time slicing (1990–2018), years per slice (1), term source (all selection), node type (choose one at a time), pruning (pathfinder) and visualization (cluster view-static, show merged network).

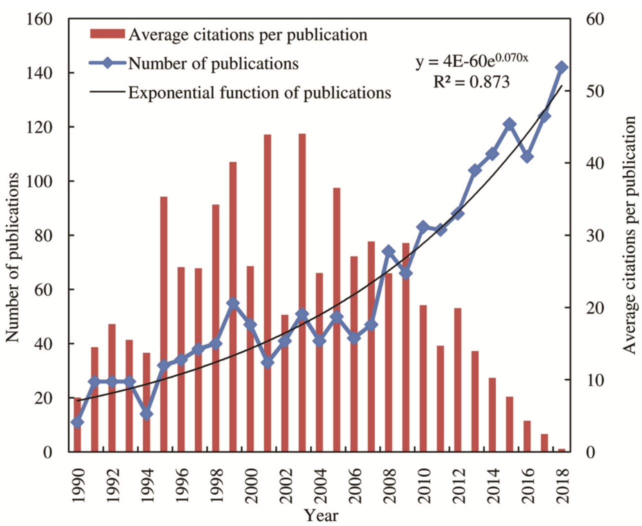

Figure 1. Number of publications with average citations per publication from 1990 to 2018.

Results and discussion

Publication output

With the aim of knowing the research trend in fertilizer on rice research, a total number of 1757 publications were obtained from the on-line version of SCIE database between 1990 and 2018. The document types were both articles (1686 papers and 95.959%) and reviews (71, 4.041%). Among them the proceedings papers (46, 2.618%) and the book chapters (16, 0.911%) belonged to articles or reviews. Figure 1 shows the publication trend and mean citations per article. The data were collected on 21 December 2018; the number of on-line publications in 2018 was over 142. The number of annual publications has been increasing over the past 29 years, but with some fluctuations. The publications every 10 years from 1990 to 2018 are 302, 492 and 963 respectively. Almost 34.5% of the articles were published in the last five years (2014–2018) and 54.81% published in the last 10 years (2010–2018). This suggests that research on rice and fertilizer has been increasing remarkably. The growth of rice literature can be fixed to the exponential growth (R^2 = 0.8733) and the mean citation was not stable. There are 31,814 total citations for 1757 papers; so the mean citation rate was 18.107 per paper, and the highest mean citation rate was 44.04 in 2003.

Web of Science categories

Each article belongs to one or more subject categories indexed by the WoS. All publications were first refined by the agronomy of the WoS subject categories, so, the total articles are belong to Agronomy category, and also

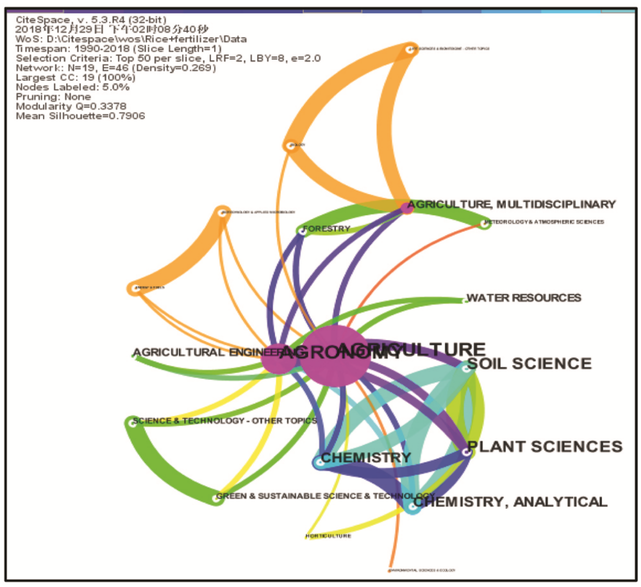

Figure 2. Co-occurrence network of different subject categories.

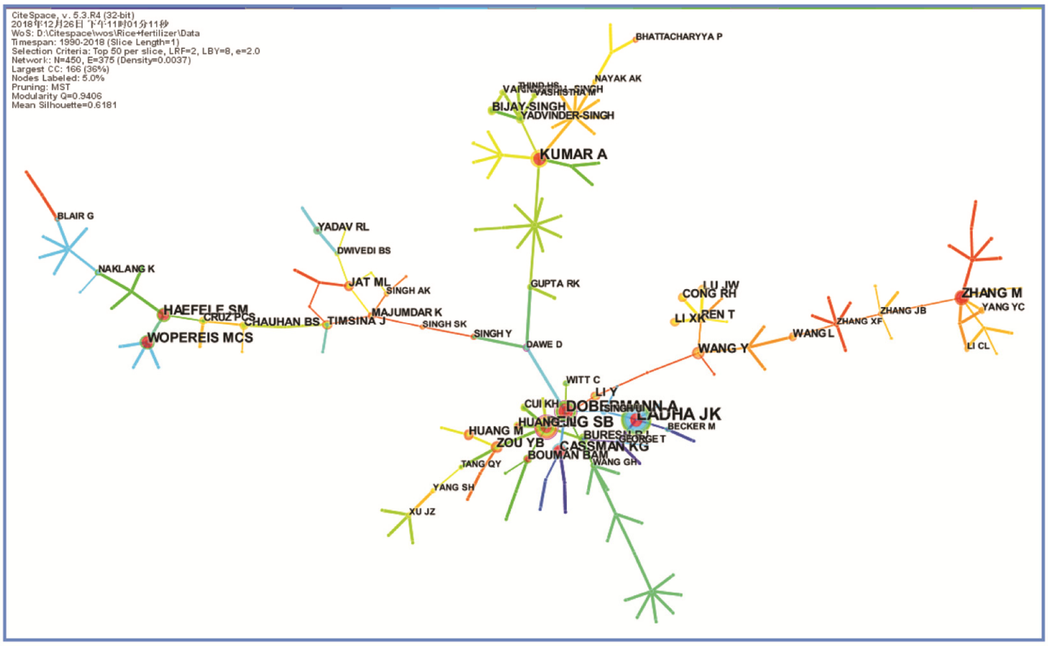

Figure 3. Collaboration network of authors. The size of the circles represents the number of publications of the authors, and the lines represent cooperation network among researchers. The shorter distance between two circles suggests more collaboration between individual authors. The colour of the circles represents authors in the same cluster.

followed to other categories. That is, journals or papers may be classified in two or more categories in the WoS. It also shows the multidisciplinary character of this research field[18]. The 1757 publications belong to 24 WoS categories, and the top 10 categories are agronomy (1757 papers and 100%), plant sciences (517, 29.425%), soil science (501, 28.515%), analytical chemistry (221, 12.578%), agricultural engineering (71, 4.041%), agriculture multidisciplinary (61, 3.472%), water resources (44, 2.504%), forestry (30, 1.707%), green sustainable science technology (30, 1.707%) and horticulture (19, 1.081%). Figure 2 shows the relationship among different subject categories from the WoS.

Publication distribution by authors

By analysing high-impact authors, the development and research trajectories of scientific studies and the authors' academic influence can be determined according to the number of publications and the frequency of citations[22]. Publication is arguably the major component for evaluating an academic scientist for hiring, promotion and grants. A complete list of authors is always captured for all publications in WoS, including given name, surname and initials. The results of author analysis have identified those researchers who have made significant contributions.

The 1757 publications were written by a total of 5167 authors and participated 8302 times in related studies. Thus, there is about 0.340 articles per author (1757 publications to 5167 authors) and the average number of authors per paper is 4.725 (8302 records of authors for 1757 papers). The analysed records listed 5167 authors, among whom 3853 (74.57%) had only one publication, 702 (13.59%) had two publications, 255 (4.94%) had three publications and 148 (2.86%) authors had four publications. A total of 4555 (88.16%), 4810 (93.09%) and 4958 (95.96%) authors had published ≤2, 3 and 4 papers respectively.

The collaboration network of authors consists of 450 nodes and 375 links, generating numerous closed-loop circuits (Figure 3). The size of the circles represents the number of publications by the authors, and the shorter distance between two circles suggests more collaboration between individual authors. The same colour of circles represents authors in the same cluster. It is obvious that the strongest collaboration exists in a primary circuit with several core authors such as Ladha, J. K., Peng, S. B., Fageria, N. K., Dobermann, A. and Kumar, A., of the whole collaboration network. It can be seen that many authors tend to cooperate with a relatively stable group of collaborators, generating several major clusters of authors, each usually having two or more core authors. In Figure 3, the major clusters with core authors present the most representative research groups in the field, which can offer highly individualized scientific research information to other researchers[25]. It can be seen that the density of the collaboration network structure is quite low (0.0037).

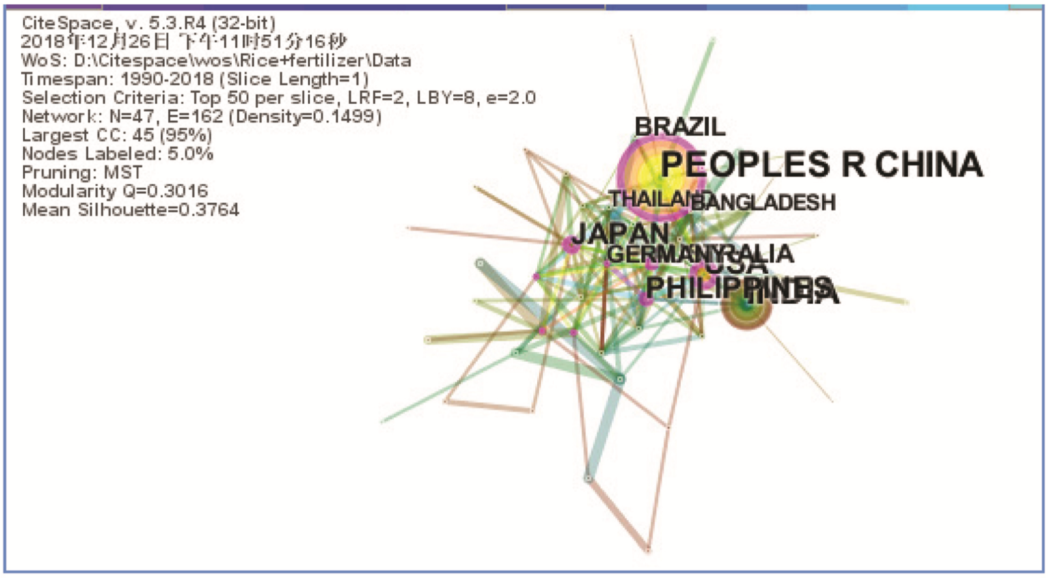

Figure 4. Map of productive countries or territories. The major countries of origin and collaborative activities of research on rice and fertilizer of agronomy categories. The bigger the circle, the more original the research.

Countries/regions

Publication count of countries in a field is a reference for evaluating their research performance[26]. The top 10 countries/regions were ranked by the number of total publications. India was identified as the largest contributor, China was in second place, followed by USA, Japan, Philippines, Australia, Brazil, Germany, Bangladesh and Thailand. Collaborative patterns have been analysed using CiteSpace, Figure 4 shows that almost all countries have a cooperative relationship with the others. We set the 'node types' to 'country', and other options to default. The ring size and colour showed the published accounts and specific time of every country or district. The collaboration network of the countries consists of 47 nodes and 162 links, generating numerous closed-loop circuits. Each node represents a different country or region. If the node of a country or district is big, it means that it is more important. The ring colour shows the time of cited, and thickness of the ring represents the number of references. Purple rings represents the key nodes and their thickness represents the centrality of nodes. The greater the thickness, higher is the centrality. The link between two nodes represents cooperation between two countries/territories, and link thickness represents the intensity of collaboration. A country linked with another cluster is involved in another focus with partial attention. Thus, it is easy to determine the top-level research countries worldwide using CiteSpace.

Organizations and institutions

The contribution of different institutes was estimated by the affiliation of at least one author of the published papers. The top five organizations and institutions each published more than 50 papers. The International Rice Research Institute (IRRI), Philippines, ranks first with 176 publications, followed by Indian Council of Agricultural Research (ICAR; 163), Chinese Academy of Sciences (CAS; 85), Punjab Agricultural University (52) and Chinese Academy of Agricultural Sciences (50). Other organizations in China, such as Institute of Soil Science, CAS (46), Huazhong Agricultural University (40), Zhejiang University (40), Nanjing Agricultural University (39), China Agricultural University (38), University of Chinese Academy of Sciences, CAS (33) have published more than 33 papers in the agronomy field of rice and fertilizer among the top 15 organizations.

The collaboration network of institutions consists of 206 nodes and 239 links, generating numerous closed-loop circuits. The collaborations of the institutions were analysed and Figure 5 shows the collaboration network. It is seen that the density of this collaboration network structure is low (0.0113). As previously mentioned, each node indicates a different institution. The connecting lines between nodes show their collaboration, and thickness of the lines indicates the collaboration degree. The distribution of the institutions is quite concentrated, and the most productive institutions can be observed as the core institutions of some main collaborations. These institutions have a strong academic team, and therefore have strong academic strength and research capabilities, making great contributions to the study. This also demonstrates that several institutions may establish a stable partnership of collaboration and they also achieved great productivity on the research of agronomy of fertilizer on rice.

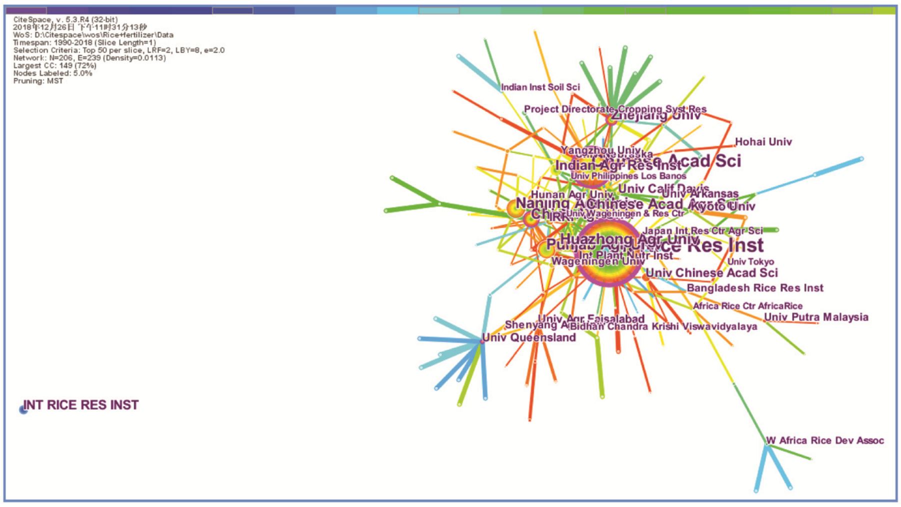

Figure 5. Map of the most productive institutions with collaborative links. Cooperation network among institutions for the research on rice and fertilizer of agronomy category. Lines represent cooperation network among institutions.

Analysis of keywords

Analysis of keywords can identify the current hot research topics and future orientation. Keywords of a contribution are used to identify the focus of research. Authors tend to list a number of keywords that facilitate framing scientific contribution in the field or subject matter most closely related to the topic addressed in their study. It is also common for reviewers and especially editors to expand such information with additional keywords obtained from databases based on the subject text in the publication. Therefore, analysis of keywords can be used to identify evolving research frontiers relating to a knowledge domain. The keywords derived from the WoS include paper title, abstract, 'author keywords' and 'keywords Plus'[27]. For further insights into the field, articles that have excessive citations within a particular period have also been identified.

We conducted statistical analysis of the high-frequency keywords. The top 20 keywords are listed in Table 1, and the top 15 keywords appeared more than 100 times ranked as: rice, yield, soil, nitrogen, management, fertilizer, growth, system, wheat, grain yield, lowland rice, phosphorus, plant, productivity and use efficiency. Table 1 also shows the strength of the citation along with the starting and ending years of the citation burst keywords.

In order to explain the network structures, the betweenness centrality value was estimated as it is an effective method to reveal the indirect relationship between components of the network structure. It is equal to the number of shortest paths from all vertices to all others that pass through a node. The node with a high betweenness centrality would be particularly informative in understanding why two clusters are connected. The betweenness centrality of a node helps identify structural holes where good ideas are more likely to appear than other areas of the network. The subjects with the top 20 highest betweenness centrality are shown in Table 1; the keywords with betweenness centrality more than or equal to 0.06 are soil (0.14), fertilizer (0.14), rice (0.13), lowland rice (0.12), phosphorus (0.12), growth (0.11), system (0.11), nitrogen (0.09), wheat (0.08), efficiency (0.08), wetland rice (0.08), zinc (0.08), grain yield (0.07), *Oryza sativa* (0.07), nitrogen fertilizer (0.07), weed (0.07), yield (0.06), plant (0.06), China (0.06) and nitrogen use efficiency (0.06).

Table 1 also presents the top 20 keywords with the strongest citation bursts, along with the strength and occurrence time span. These keywords were ranked as China (12.0025), green manure (11.6072), Asia (9.6695), wetland rice (9.5084), crop (9.2495), greenhouse gas emission (8.3404), rice (7.1889), biochar (6.7905), *Oryza sativa* L (6.3728), climate change (6.3364) and N15 (6.0582), paddy field (5.7804), maize (5.6655), nutrient (5.3994), fixation (5.3729), soil fertility (5.323), N use efficiency (5.2523), quality (5.1433), fertilizer (5.0438) and fertilizer nitrogen (4.9952). The time interval is the period of a burst keyword indicating the beginning and end of the time interval of each burst. According to Table 1, the five most recent keywords (period 2016–2018) are shown as follows: crop, greenhouse gas emission, biochar, climate change and nutrient.

Analysis of cited references

The co-citation relationship exists when two documents appear together in the bibliography of the third document. In bibliometrics, the frontier in a field of research

Table 1. Top 20 keywords ranked by count and betweenness centrality and strongest citation bursts

Rank	Keywords	Count	Betweenness centrality	Keywords	Strength of burst	Beginning of burst	End of burst
1	Rice	495	0.1	China	12.0025	2014	2018
2	Yield	325	0.06	Green manure	11.6072	1992	1998
3	Soil	260	0.14	Asia	9.6695	2003	2007
4	Nitrogen	241	0.09	Wetland rice	9.5084	1991	1999
5	Management	202	0.04	Crop	9.2495	2016	2018
6	Fertilizer	198	0.14	Greenhouse gas emission	8.3404	2016	2018
7	Growth	183	0.11	Rice	7.1889	1990	1999
8	System	181	0.11	Biochar	6.7905	2016	2018
9	Wheat	166	0.08	*Oryza sativa* L	6.3728	2003	2010
10	Grain yield	143	0.07	Climate change	6.3364	2016	2018
11	Lowland rice	135	0.12	^{15}N	6.0582	1992	2004
12	Phosphorus	116	0.12	Paddy field	5.7804	2014	2018
13	Plant	109	0.06	Maize	5.6655	2010	2013
14	Productivity	108	0.04	Nutrient	5.3994	2016	2018
15	Use efficiency	100	0.04	Fixation	5.3729	1997	2004
16	China	97	0.06	Soil fertility	5.323	1999	2005
17	Copping system	89	0.05	N use efficiency	5.2523	2009	2012
18	*Oryza sativa* L	88	0.07	Quality	5.1433	2012	2018
19	Nitrogen use efficiency	78	0.06	Fertilizer	5.0438	1995	1997
20	Maize	72	0.06	Fertilizer nitrogen	4.9952	1993	2003

Note: Betweenness centrality is a measure of centrality in a graph based on the shortest paths. Bursting keywords (emerging trends or abrupt changes) can be used as indicators to study the research frontiers.

Table 2. Top 15 cited references ranked by count

Rank	Count	Strength of burst	Author	Year	Source	Volume	First page	Half-life
1	49	5.71	Ju, X. T.	2009	*Proceedings of the National Academy of Science, USA*	106	3041	5
2	39	6.99	Guo, J. H.	2010	*Science*	327	1008	6
3	37	6.75	Peng, S. B.	2010	*Agronomy for Sustainable Development*	30	649	6
4	36	17.79	Witt, C.	1999	*Field Crops Research*	63	113	5
5	27	13.15	Dobermann, A.	2002	*Field Crops Research*	74	37	4
6	26	8.96	Peng, S. B.	2006	*Field Crops Research*	96	37	6
7	23	11.56	Timsina, J.	2001	*Field Crops Research*	69	93	5
8	21	10.97	Cassman, K. G.	1998	*Field Crops Research*	56	7	5
9	20	4.23	Buresh, R. J.	2010	*Plant and Soil*	335	35	4
10	19	7.42	Mueller, N. D.	2012	*Nature*	490	254	5
11	16	9.32	Cassman, K. G.	1993	*Plant Soil*	155	359	6
12	16	8.57	Cassman, K. G.	1996	*Field Crops Research*	47	1	4
13	16	8.57	Peng, S.	1996	*Field Crops Research*	47	243	5
14	16	8.61	Dobermann, A.	1998	*Field Crops Research*	56	113	5
15	16		Peng, S. B.	2009	*Plant Production Science*	12	3	5

Note: Strength of burst indicates a higher citation rate than a similar article published in the same period. Half of the cited articles of journals were published more recently than the cited half-life.

represents the current developmental state of a discipline, and the references in the frontier article constitute the intellectual base of the field[22]. Reference analysis examines the network of co-cited references to obtain the key articles and academics contributing to knowledge transfer[28]. CiteSpace summarizes the co-citation relationship between documents in terms of nodes and edges, and generates a co-citation network which is composed of dots that represent documents (i.e. papers) referred to as nodes, and two nodes are connected by a line (i.e. edge) if the two documents have been cited together in another paper. CiteSpace decomposes the network into clusters using a Silhoute measure that quantifies the extent to which nodes represented in a strongly connected component are actually homogeneous[24].

Using CiteSpace, we can find out the burst of citations to a reference. A node with a strong burstness usually indicates a potentially interesting work that has attracted

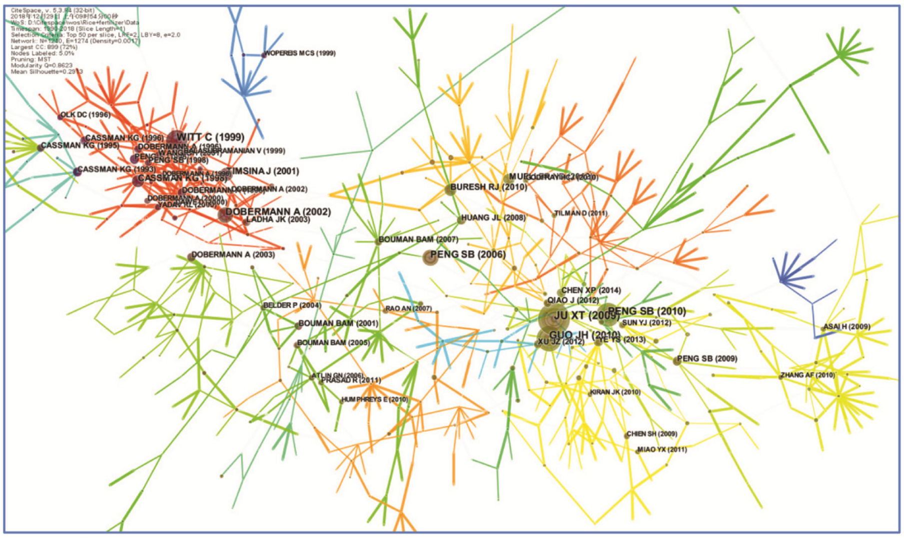

Figure 6. Map of co-cited references: Cluster view. Note: The document co-citation network shows only the most co-cited works. Each node represents one reference (only first authors are named), and edges represent the co-citations of two references. Difference in node size indicates relative difference in document co-citation frequency.

Table 3. Top 15 cited authors ranked by frequency

Rank	Frequency	Strength of burst	Year	Authors	Half-life
1	263		1998	Dobermann, A.	14
2	221		1992	Cassman, K. G.	17
3	169		1996	Peng, S. B.	17
4	169		1991	Bremner, J. M.	18
5	155		1992	Ladha, J. K.	18
6	155		1991	Yoshida, S.	20
7	150	11.09	1998	Fageria, N. K.	16
8	111	8.97	1992	Walkley, A.	22
9	110	5.72	1991	Buresh, R. J.	19
10	107		1992	Jackson, M. L.	20
11	106	7.69	2004	Bouman, B. A. M.	8
12	105	5.78	1999	Witt, C.	11
13	97		1998	Peng, S.	12
14	94	5.5	1998	Olsen, S. R.	15
15	90	20.39	1995	Anonymous	20

Note: Strength of burst indicates a higher citation rate than a similar article published in the same period. The cited half-life is the median age of the citations received by a journal during the *Journal Citation Report* (*JCR*) year. The age of a citation is equal to the publication year of the citing item (i.e. *JCR* year) minus the publication year of the cited item. By definition, half of the earned citations of journals are to items published before the cited half-life, and half are to items published after the cited half-life.

significant attention within a short period of time. With the support of CiteSpace, 46,574 references from 1757 articles were analysed. According to the results of CiteSpace, Table 2 shows the top 15 cited references ranked by count each more than 16. The most highly cited reference was by Ju, X. T. published in *Proceedings of the National Academy of Science, USA*, in 2009 with 49 count times. In Table 2, journal source is ranked as *Field Crops Research* (8), and *Plant and Soil* (2), and one each for *Proceedings of the National Academy of Science, USA*, *Science*, *Agronomy for Sustainable Development*, *Nature* and *Plant Production Science* respectively.

A citation burst indicates that the reference it is associated with has received a sharp increase in the number of citations over a year or multiple years. The size of the increase in citations is indicated by the strength of the citation burst, which takes account of both the number of citations and length of the period over which the citations occur. In addition, a clustering analysis of the references was done. The clustering of similar references resulted in co-citation clusters, which could be used to explore the main topics in the intellectual base. In Figure 6, the co-citation network of cited references is presented. It is seen that the density of the co-cited references network

Table 4. Top 15 cited journals ranked by frequency

Rank	Frequency	Betweenness centrality	Year	Source	Half-life	Impact factor (2017)
1	848	0.03	1990	*Plant and Soil*	21	3.306
2	788	0.08	1991	*Field Crops Research*	22	3.127
3	783	0.05	1999	*Nutrient Cycling in Agroecosystems*	14	2.105
4	733	0.03	1991	*Agronomy Journal*	20	1.897
5	680	0.01	1990	*Soil Science Society of America Journal*	21	1.92
6	445	0.04	1992	*Communications in Soil Science and Plan Analysis*	21	0.54
7	427	0.1	1992	*Advanced in Agronomy*	21	5.073
8	403	0.1	1991	*Biology and Fertility of Soils*	22	3.808
9	389	0.12	1995	*Agricultural Ecosystems and Environment*	19	3.541
10	349	0.09	1991	*Soil Biology and Biochemistry*	22	4.926
11	344	0.06	1991	*Soil Science*	20	1.387
12	303	0.09	1991	*Soil Science and Plant Nutrition*	21	1.128
13	299	0.05	1991	*Crop Science*	21	1.635
14	291	0.09	1996	*Journal of Plant Nutrition*	17	0.565
15	251	0.06	1995	*Geoderma*	8.6	3.740

Note: Half of the cited articles of journals were published more recently than the cited half-life.

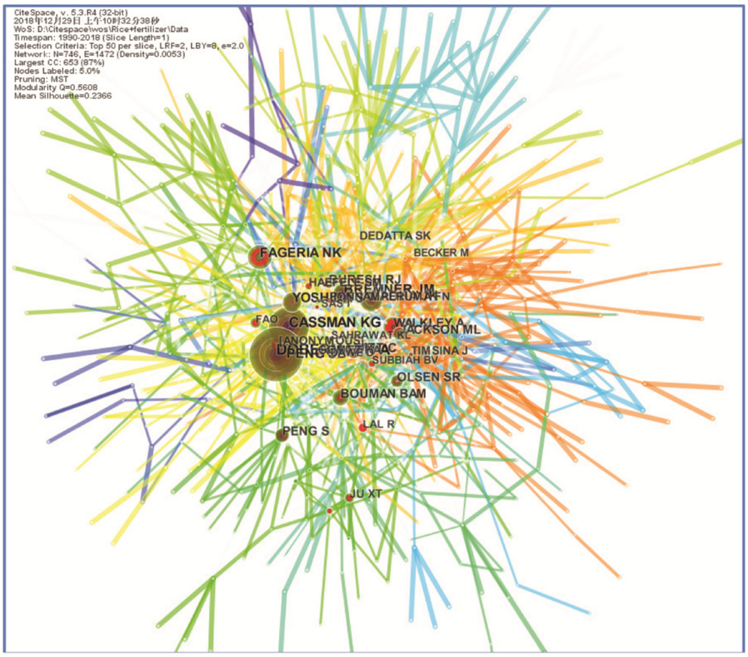

Figure 7. Map of co-cited reference authors. Note: The author co-citation network shows only the most co-cited authors. Each node represents one author and edges represent the co-citation relationship of two authors. Difference in node size indicates relative difference in author co-citation frequency.

structure is quite low (0.0017). It is obvious that the homogeneity of the network is also low (mean silhouette value = 0.2913), and has a loose structure (modularity Q = 0.8623). The nodes denote the cited references and the first author and the publication year; the larger nodes represent references which are frequently cited. Furthermore, reference analysis using CiteSpace can overcome a lack of literature survey, because even though the reviewed literature is limited, the references contain enough information about key papers in a field; hence, it directs further suitable papers to review[20].

Co-citation analysis of cited authors

The most influential authors from the 46,574 references were analysed using the same slice configuration as keywords (Table 3). In Table 3, the top 15 cited authors are ranked by count. The top 7 cited authors ranked by frequency more than 150 times are Dobermann, A. (263), Cassman, K. G. (221), Peng, S. B. (169), Bremner, J. M. (169), Ladha, J. K. (155), Yoshida, S. (155) and Fageria, N. K. (150). This suggests that their research has an important influence on the field of rice and fertilizer.

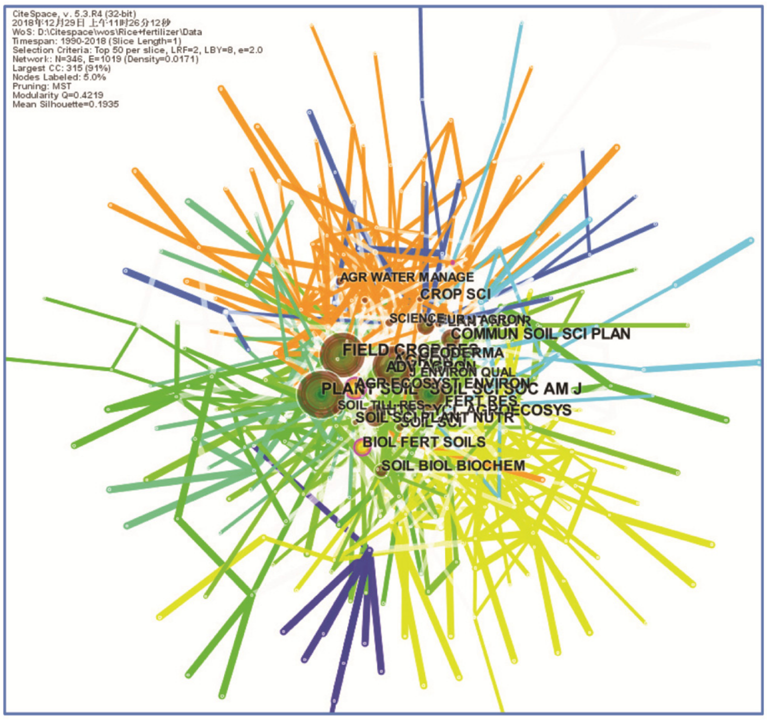

Figure 8. Map of co-cited reference journals. Note: The journal co-citation network shows only the most co-cited journals. Each node represents one journal and edges represent the co-citations relationship of two journals.

The authors of articles analysed within the framework of this study and all the other authors included in the references of these articles were evaluated in order to reveal the network structure of co-cited authors. The co-citation network of cited authors is shown in Figure 7, in which 748 nodes and 1472 links are generated. Figure 7 shows the co-cited authors network structure of the authors of the articles analysed within the framework of this study and the authors cited in the references of these articles. It is seen that the density of this network structure is quite low (0.0053). It is clear that the homogeneity of the network is also low (mean silhouette value = 0.2366) and has a loose structure (modularity $Q = 0.5608$). Similar to the previous reference analysis results, the most important authors were from earlier years, which may imply that no author has conducted groundbreaking research in recent decades[20].

Reference journals

Table 4 lists the top 15 cited journals with their impact factors (2017). *Plant and Soil* is the most cited journal with 848 citations. It is also the top journal in the research field, with an impact factor of 3.306, followed by *Field Crops Research* (788, 3.127), *Agronomy Journal* (733, 1.897) and *Soil Science Society of America Journal* (680, 1.92) respectively. In terms of centrality, *Agricultural Ecosystems and Environment* ranks first (0.12) with 389 citations. It is also the top journal in the research field, with an impact factor of 3.541, followed by *Advanced in Agronomy* (0.1 centrality, 427 citation frequency, 5.073 impact factor), *Biology and Fertility of Soils* (0.1, 403, 3.808), *Soil Biology Biochemistry* (0.09, 349, 4.926) and *Journal of Plant Nutrition* (0.09, 291, 0.565).

By comparing the journals from Table 4, it can be found that the reference journals are more influential than the citing journals, similar result to organizational culture[20]. As we have noted, bigger circles indicate higher citation frequency (Figure 8). Figure 8 shows the journal citation network structure of articles included in this study. It is observed that the density of the resulting journal citation network structure is low (0.0171). The homogeneity of the network is also low (mean silhouette value = 0.1935) and has a moderate loose structure (modularity $Q = 0.4219$).

Conclusion

In this bibliometric study, we analysed 1757 research articles published on rice and fertilizer from the 'agronomy' category based on the WoS for the period 1990–2018. It was observed that the number of publications has increased rapidly over the past years. India was the most productive country, followed by China, USA, Japan, Philippines and Australia. The top three institutes were IRRI, ICAR and CAS. The top 15 keywords were rice, yield, soil, nitrogen, management, fertilizer, growth, system, wheat, grain yield, lowland rice, phosphorus, plant, productivity and use efficiency, each occurring more than 100 times. In addition, the analyses performed were mainly based on frequency and centrality using the visualization software CiteSpace. It was seen that there were even more specific words with high centrality value. It was found that the leading keywords were almost the same and general terms according to their frequency and centrality value. The fact that keywords are general words is a factor that makes it harder to reach a particular study. It was seen that journals that were most frequently cited in the field and that have a high centrality value were from different fields. This work would be useful to researchers to know the trends in fertilizer and rice research.

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