RESEARCH ARTICLE Legume Research- An International Journal, Volume 44 Issue 11: 1301-1307 (November 2021)

Bibliometric Analysis of the Research Characteristics and Trends in Legume Mycorrhiza Field

S.X. Xu[1,2]

10.18805/LR-612

ABSTRACT

Background: Legumes are notable for wide distribution and indispensable food function. Majority of legume species are known to form mycorrhizal symbioses. The visualized and quantitative analysis legume mycorrhiza research has been reported although much attention has been paid in this field.

Methods: This study reviewed and analyzed systematically the research characteristics and trends in legume mycorrhiza by bibliometric method based on the citation data collected from the Web of Science Core Collection by CiteSpace software.

Result: The publication concerning legume mycorrhiza research increases rapidly and is still a hotspot. The most active collaboration countries are USA, France, Germany, China and Australia, whereas the two institutions of University of Western Australia and Chinese Academy of Sciences collaborate most with others. The intellectual structure analysis showed that the main intellectual base is nitrogen-fixing of cereal. The top ranked of keyword by bursts was rhizobia with strength value of 5.2899, which began from 2016 and ended in 2018. The distinction of 24 bursting keywords is relatively small, which showed that the research hotpot and trend should be interaction between legume plants and mycorrhizal fungi for improving nutrition absorption, N-fixation, resistance to stress and their mechanisms in future.

Key words: Bibliometrics, Legumes, Mycorrhiza, Research characteristics, Research trend.

INTRODUCTION

Bibliometric methods are used in the field of library and information science, which is often employed to evaluate systematically the current study characteristics and trends in a specific scientific field based on published literatures because literature is the main form of representation of scientific research output (Huang and Zhao 2008; Homrich *et al.* 2018). As the third-largest land plant family, legumes distribute widely in ecosystems. Meanwhile, legumes are vital cultivated crop for their important agricultural, economic and ecological functions as food, forage, timber, cover and green manure crop in agricultural ecosystem (Hardy and Havelka, 1975; Manners *et al.,* 2020). In addition, legumes are notable for their symbiotic nitrogen (N) fixing ability, which contributes between one-third and one-half of the total input N to agricultural land (Herridge *et al.,* 2008). Therefore, the symbiotic relationship between legumes and microorganisms has been paid great attention (Ahmed *et al.*, 2020; Stella *et al.*, 2021). At the same time, mycorrhiza, as the vast most symbiosis, exit in more than 80% terrestrial plant species, has been also concerned in the legume studies (Shi *et al.*, 2017, 2021). Moreover, the symbiosis also involves mycorrhizal fungi on the basis of legume-rhizobia association (Garcia-Parisi *et al.,* 2017; Shi *et al.,* 2017). Therefore, it is very necessary to reveals some of the characteristics of legume mycorrhiza by deeply mining the information about publication in this field.

Further, mycorrhizal status of plants is the most typical belowground traits (van der Heijden *et al.,* 2015), which affect and regulate the relationship between aboveground plant performance and belowground microorganisms (Khaitov *et al.,* 2015). Numerous studies have also showed that mycorrhiza plays important roles in regulating legume growth, N-fixing ability and nutrition (Garcia-Parisi *et al.,* 2017; Roy *et al.,* 2020). As a result, the study on legume mycorrhiza has caused wide attention over the recent years. However, most publications focus only on one aspect of legume mycorrhiza, such asmycorrhizal function in a specific aspect of legume species (Rai *et al.,* 2021). In my knowledge, no study has reviewed systematically studies on legume mycorrhiza and none of them has been reviewed in a visualizing study based on bibliometric analysis.

Therefore, I explored the knowledge base of the studies on the legume mycorrhiza based on mining and visual quantitative analysis of the literatures using Citespace software because CiteSpace, has been widely affirmed for analyzing the relationships between popular frontier research topics and the determination of the knowledge base in many field (Chen, 2004) which will promote researches

[1]Library, Henan University of Science and Technology, Luoyang 471000, Henan Province, China.
[2]Henan Engineering Research Center for Rural Human Settlement, Luoyang 471023, China.

Corresponding Author: S.X. Xu, Library, Henan University of Science and Technology, Luoyang 471000, Henan Province, China. Email: xushx@126.com

How to cite this article: Xu, S.X. (2021). Bibliometric Analysis of the Research Characteristics and Trends in Legume Mycorrhiza Field. Legume Research. 44(11): 1301-1307. DOI: 10.18805/LR-612.

Submitted: 26-01-2021 **Accepted:** 18-08-2021 **Online:** 15-09-2021

to refine the research directions and issues on legume mycorrhiza.

MATERIALS AND METHODS

Data collection

The literature data were obtained from Web of Science (WOS) Core Collection provided by Clarivate Analytics including database of SCI-EXPANDED, CPCI-S, CPCI-SSH, CCR-EXPANDED, IC, which are the most frequently used database in bibliometric studies and is regarded as the most reputational academic journal system in which the published papers are ensured with rigorous peer review process. The data were retrieved on 15 January 2021. In the WOS Core Collection, the "topic" tag was selected in "Advanced Search" to search for the literature relevant to the research of legume mycorrhiza. The topic was set to "TOPIC: (legume*) AND TOPIC: (mycorrhiza*)" and "Timespan: 1985-2020". The titles and abstracts of publications obtained from the search were checked to determine their relevance to legume mycorrhiza. Irrelevant literature was excluded from the analysis. A total of 837 records were selected and exported as a text-based format for further analysis.

Data analysis

The change of publications in WOS core collection with years was analyzed and simulated by the SPSS software package version 19.0 (SPSS, Chicago, IL). CiteSpace was used to analyze the cooperation characteristics among countries, institution, cited references and to reveal the popular research topics and trends by clustering keywords. All works were conducted in Henan University of Science and Technology in January of 2021.

RESULTS AND DISCUSSION

The research characteristics

A total of 837 publications on legume mycorrhiza had been retrieved in WOS core collection from 1985 to 2020. The first article was published in PHYTOCHEMISTRY in 2005 in this field. The annual change of publication in the field was presented in Fig 1, which indicated that publications in the field increased markedly with the change of years from 2009 to 2020 (R^2=0.5196). There were not any studies in the research of legume mycorrhiza between 2006 and 2008.

Country collaboration maps showed visually that the collaboration research on legume mycorrhiza involved in 78 countries (Fig 2). Their cooperation characteristics in top 20 countries suggested that the 5 most active collaboration countries are USA, France, Germany, China and Australia (Table 1). However, the highest centrality of countries produced changes with the top 5 countries of Australia, France, USA, India and China, which indicated that these 5 countries contributed more among international exchange in the field than other countries (Fig 2, Table 1).

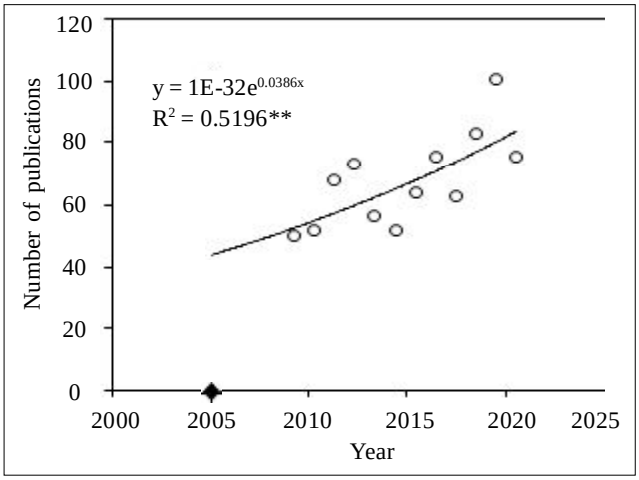

Fig 1: The changes of publications in research of legume mycorrhiza based on publications in web of science core collection. ** means the significant regression at P<0.01 between year and number of publications.

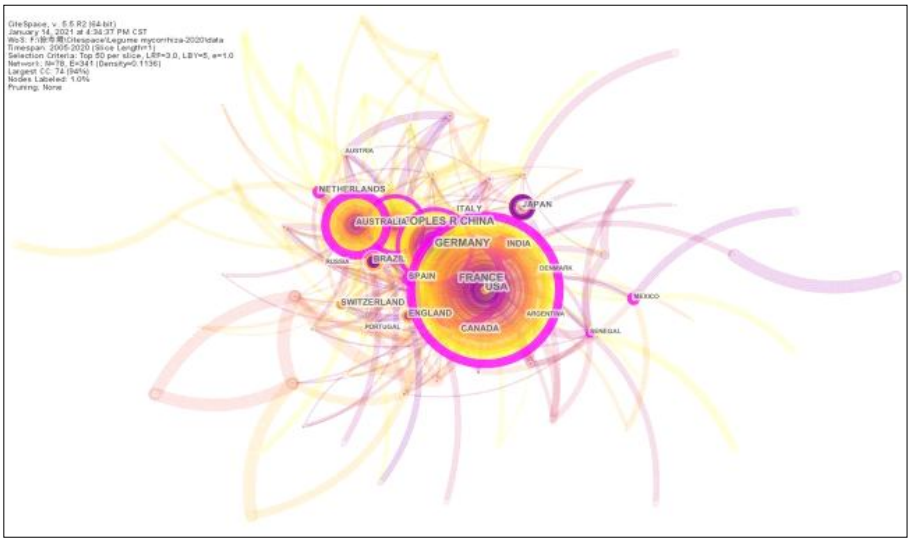

Fig 2: The network of country collaboration in research legume mycorrhiza.

The network of institution collaboration showed that 931 institutions collaborated with each other to publish papers in this field (Fig 3). Among them, University of Western Australia and Chinese Academy of Sciences contributed a greater number collaboration than other institutions with 33 and 30 times, respectively. Further, the institutions with strongest citation bursts suggested that there were four institutions bursts with the value from 3.7119 to 3.9420 in the field (Table 2).

The annual publications are usually considered as an important indicator for reflecting development and evolution in given research field (Mongeon and Paul-Hus, 2016). The current result showed that the study in legume mycorrhiza was paid more and more attention (Table 1), which can be expected to be more in-depth and to be improved in this field. Collaboration maps among countries and institutions drawn by CiteSpace is able to identify the relationships among scholars, countries or institutions in a given research field, which provide the basis for evaluating their academic influence and discover noteworthy countries and institutions (Xing *et al.,* 2020). France is more willing to international exchanges and cooperation recently with 2 institutions in strongest citation bursts on the study of legume mycorrhiza (Aleixandre-Benavent *et al.,* 2017).

Table 1: The cooperation characteristics and frequency in top 20 countries.

Country	Year	Frequency	Centrality
Australia	2009	88	0.31
France	2009	117	0.3
USA	2009	181	0.26
India	2009	43	0.23
Peoples R China	2009	93	0.18
Spain	2009	42	0.14
Germany	2005	106	0.11
Netherlands	2009	36	0.11
Mexico	2009	27	0.11
Senegal	2009	22	0.11
Scotland	2010	9	0.06
Canada	2009	47	0.05
England	2009	46	0.05
Switzerland	2009	34	0.05
Malaysia	2018	2	0.05
South Korea	2010	2	0.05
Italy	2010	35	0.04
Belgium	2011	9	0.04
Zambia	2014	2	0.04
Brazil	2009	46	0.03

Intellectual structure analysis

Five key document co-citation clusters are obtained (Table 3) based on co-citation constructed network with the modularity Q value of 0.6559 and mean silhouette value of 0.2833 (Fig 4). Further, the top ten cited literatures were listed in Table 4. The top ranked item by citation counts is Maillet F (2011) in Cluster #1 sourced from Nature with citation counts of 95.

Clusters are considered well structure in CiteSpace when modularity is more than 0.3. Larger silhouette values indicate higher homogenization of nodes in the cluster and “silhouette” >0.7 generally suggests that the cluster has high credibility (Chen, 2017, 2018). In this study, the modularity Q value is 0.6559, which indicates the clustering effect is significant. However, the low mean silhouette value of 0.2833 is probably caused by numerous small clusters (Yan *et al.,* 2020). The bigger burst value means the more rapid growth of citation frequency (Yang *et al.,* 2019).

Research trend

Eleven clusters were obtained based on keyword clustering analysis (Fig 5). The clustering characteristics of 4 largest clusters are summarized in Table 5. The modularity Q and mean silhouette value of keyword clustering network are

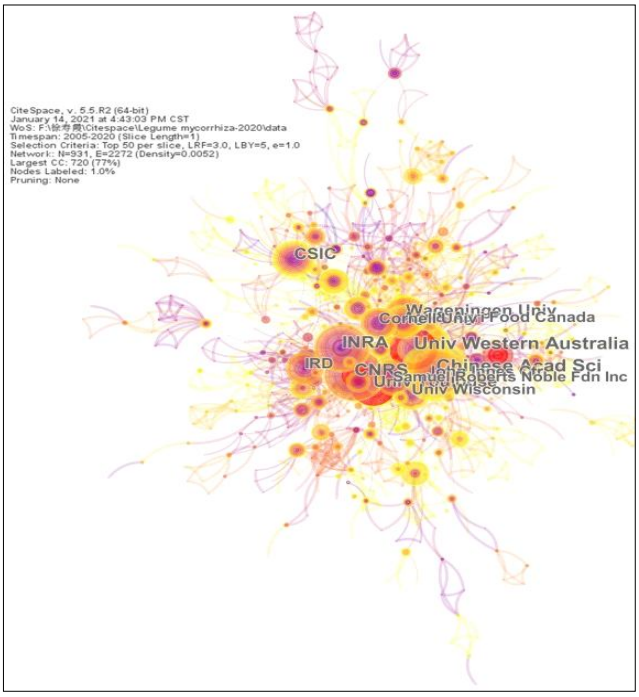

Fig 3: The network of institution collaboration in research of legume mycorrhiza.

Table 2: Institutions with the strongest citation bursts in research of legume mycorrhiza.

Institutions	Strength	Begin	End
National Institute of Agrobiological Sciences	3.9287	2010	2014
CNRS	3.9420	2011	2013
University of Western Australia	3.8751	2017	2018
University of Toulouse	3.7119	2018	2020

0.4836 and 0.4901, respectively. The largest cluster (#0) has 79 members with silhouette value of 0.757 labeled as *Lotus japonicus*.

A total of 25 burst keywords are identified in the keyword co-occurrence network. Twenty-four keywords with high burstiness were identified and are listed in Table 6. These keywords show the research topics in the research of legume mycorrhiza and their changes in different periods. Begin and end year following each keyword indicates the duration of citation bursts. The top ranked of keyword by bursts was rhizobia with the bursts strength value of 5.2899, which began from 2016 and ended in 2018. Further, assessing

Table 3: Co-citation clusters in research of legume mycorrhiza.

Cluster ID	Size	Silhouette	Label (LLR)	Mean (Cite year)
0	91	0.806	Nitrogen-fixing cereal	2007
1	68	0.654	Ectomycorrhizal symbioses	2012
2	63	0.732	Plant interaction	2015
3	47	0.823	Genetic discoveries	2017
4	44	0.78	Biotic interaction	2010

Table 4: Top 10 cited references based on frequency.

Freq	Burst	Author	Year	Source	Cluster ID
95	18.4	Maillet F.	2011	Nature	13
66	15.79	Parniske M.	2008	Nat. Rev. Microbiol.	0
59	18.16	Oldroyd G.E.D.	2013	Nat. Rev. Microbiol.	6
52	12.48	Smith S.E.	2008	Mycorrhizal Symbiosis	56
44	10.32	Oldroyd G.E.D.	2008	Annu. Rev. Plant Biol.	0
42	12.24	Genre A.	2013	New Phytol.	4
37	5.33	Madsen L.H.	2010	Nat. Commun.	0
37	8.57	Kosuta S.	2008	P. Natl. Acad. Sci., USA	0
34	8.03	Den C.R.O.	2011	Science	2
34	9.48	Yano K.	2008	P. Natl. Acad. Sci., USA	0

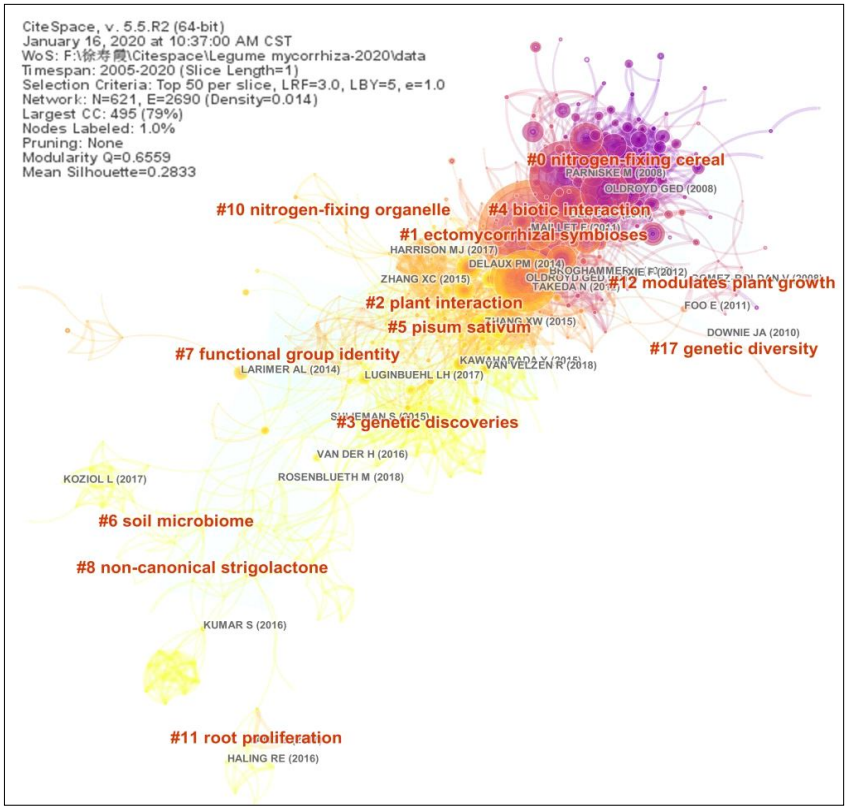

Fig 4: The network of Clusters of the document co-citation in research of legume mycorrhiza.

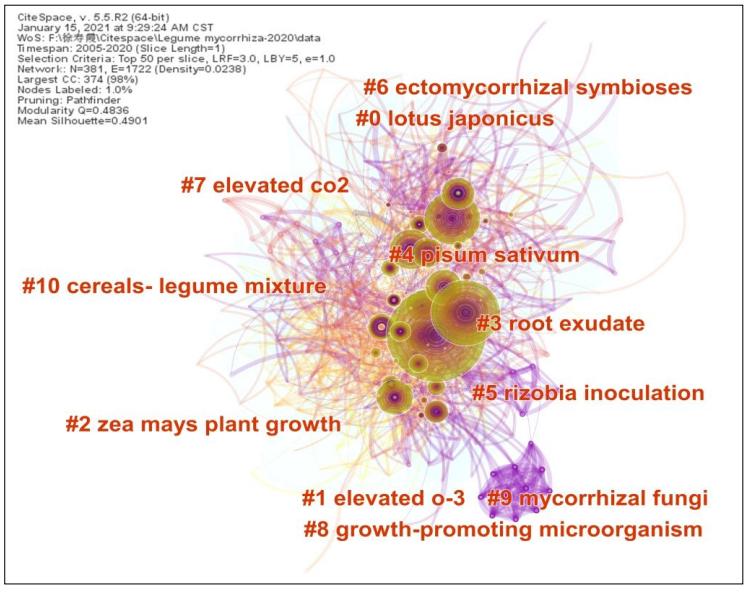

Fig 5: The network of Clusters of keyword in research of legume mycorrhiza.

Table 5: Keyword clusters in research of legume mycorrhiza.

Cluster ID	Size	Silhouette	Label (LLR)	Mean (Cite year)
0	79	0.757	*Lotus japonicus*	2011
1	59	0.564	Elevated o-3	2013
2	55	0.641	*Zea mays* plant growth	2013
3	49	0.670	Root exudate	2011

Table 6: Keywords with the strongest citation bursts in research of legume mycorrhiza.

Keywords	Strength	Begin	End
Signal transduction	3.4213	2009	2010
Arbuscular mycorrhizae	3.2109	2009	2011
Resistance	3.8298	2009	2010
Mycorrhizae	3.134	2009	2010
Receptor like kinase	3.7306	2010	2011
Frankia	3.0927	2011	2013
Arbuscular mycorrhiza fungi	3.0927	2011	2013
Dependent protein kinase	3.1184	2011	2015
Phosphate transporter	4.4339	2011	2013
Ca^{2+} spiking	3.3736	2012	2016
Medicago truncatula root	3.1921	2012	2014
Acquisition	3.1248	2013	2015
Mutualism	4.9842	2014	2018
Nod factor	3.037	2014	2015
Root nodule	3.6804	2015	2016
Productivity	3.8514	2015	2017
Rhizobia	5.2899	2016	2018
Cover crop	3.4248	2016	2018
Rhizophagus irregulari	3.0441	2016	2020
Phaseolus vulgari	4.0775	2017	2020
L.	2.9599	2017	2020
Management	3.3618	2017	2020
Salicylic acid	2.9673	2018	2020
Ethylene	2.9673	2018	2020

the 24 keywords according to their bursting period, it shows that similar studies were able to be paid repeatedly attention in different periods, such as “arbuscular mycorrhizae” and “arbuscular mycorrhiza fungi”. Meanwhile, the distinction of some keywords is relatively small, such as “nod factor”, “root nodule” and “rhizobia”.

In the constructed network of keywords, the Q value of the modularity was more than 0.3. Therefore, the clustering effect was highly significant (Li *et al.,* 2020). The clustering network of keywords is almost reasonable with mean silhouette value of 0.4901 because a cluster with a silhouette >0.5 is considered reasonable (Chen, 2004; Guo *et al.,* 2020). In the CiteSpace co-occurrence analysis, burst keywords usually reflect topics that have attracted the attention of peer scientists and are often used to explore the hotspots and research frontiers of a research field (Zhang *et al.,* 2019, 2020). Therefore, the research hotpot and trend should be interaction between legume plants and mycorrhizal fungi for improving nutrition absorption, N-fixation, resistance to stress and their mechanisms.

The visual bibliometric analysis of this study bridged thoroughly the gap between extant literatures in the study of legume research and their characteristics including changes with years, publishing institutions and their cooperation, *etc*. because much attention has been given to legume research. However, no previous studies mapped out the linkage or working relationships among the clusters of research institutes and their countries in this field.

Previous studies have never analyzed deeply research corpus including such broad aspects such as collaboration of country or institutions, co-citation clusters, cited references, keywords and all kinds of visual maps.

The most obvious advantage of CiteSpace is that it allows scholars to investigate the specific research areas by analyzing the citations, co-citations, keyword burst and cluster, thus drawing very useful visual conclusion. At the same time, the analysis of the network of cooperation among countries or institution, document co-citation and keyword clusters by CiteSpace based on published literatures in the WOS core collection are helpful for obtaining more accurate and complete information in the international study in this field. Further, quantified analysis, intellectual structure and emerging trends provided insights into research hotpots and trend by different perspectives in the future.

The significance of this study provided an overall picture and development path for legume mycorrhizal research to help scholars to broaden their research horizons and determine future research directions. The overall analysis of research characteristics also provided an important reference for academic research and relevant policy formulation in the future.

However, there were some limitations in this current study. For examples, I did not collect all the related literatures published in non-english language. Some similar keywords are not able to be combined in the software of CiteSpace. In my opinion, future literature mining should consider more databases as well as non-english literatures and blending analysis of similar keywords based on these limitations. Further, I also suggest conducting more in-depth content interpretation and analysis in future studies.

CONCLUSION

This study offers a comprehensive bibliometric analysis in the field of legume mycorrhiza. Over the past 16 years, there were 837 publications in the field of legume mycorrhiza. The number of publications increased markedly from 2009 to 2020, which indicated that the research of legume mycorrhiza is still a hotspot. Meanwhile, international collaborations among different countries and institutions were intimate. The most active collaboration countries are USA, France, Germany, China and Australia. University of Western Australia and Chinese Academy of Sciences collaborate are the most willing to cooperate with other institutions. Co-cited references analysis showed that nitrogen fixation and its related studies have received more attention in the past. The strongest citation bursts analysis was performed for exploring the research hotpot and trend, which indicated that the research hotpot and trend should be interaction between legume plants and mycorrhizal fungi for improving nutrition absorption, N-fixation, resistance to stress and their mechanisms in future.

ACKNOWLEDGEMENT

The project was supported by Scientific and technological research projects in Henan province (192102110128), Humanities and Social Science Research Project of Education Department of Henan Province (2020-ZDJH-104), Research project of Henan social science association (SKL-2021-2509).

REFERENCES

Ahmed, K., Mohamed, B., Cherki, G. (2020). Effect of soil available phosphorus levels on chickpea (*Cicer arietinum* L.) - rhizobia symbiotic association. Legume Research. 43: 878-883.

Aleixandre-Benavent, R., Aleixandre-Tudo, J.L., Castello-Cogollos, L., Aleixandre, J.L. (2017). Trends in scientific research on climate change in agriculture and forestry subject areas (2005-2014). Journal of Cleaner Production. 147: 406-418.

Chen, C. (2004). Searching for intellectual turning points: Progressive knowledge domain visualization. Proceedings of the National Academy of Sciences of the United States of America. 101: 5303-5310.

Chen, C. (2017). Science Mapping: A Systematic Review of the Literature. Journal of Data and Information Science. 2: 1-40.

Chen, C. (2018). Eugene Garfield's scholarly impact: A scientometric review. Scientometrics. 114: 489-516.

Garcia-Parisi, P.A., Lattanzi, F. A., Grimoldi, A. A., Druille, M., Omacini, M. (2017). Three symbionts involved in interspecific plant-soil feedback: *Epichloid endophytes* and mycorrhizal fungi affect the performance of rhizobia-legume symbiosis. Plant and Soil. 412: 1-2.

Guo, P., Tian, W., Li, H., Zhang, G., Li, J. (2020). Global characteristics and trends of research on construction dust: Based on bibliometric and visualized analysis. Environmental Science and Pollution Research. 27: 37773-37789.

Hardy, R.W. and Havelka, U.D. (1975). Nitrogen fixation research: A key to world food? Science. 188: 633-643.

Herridge, D.F., Peoples, M.B., Boddey, R.M. *(2008).* Global inputs of biological nitrogen fixation in agricultural systems. Plant and Soil. 311: 1-*18.*

Homrich, A.S., Galvao, G., Abadi, L.G., Carvalho, M.M. (2018). The circular economy umbrella: Trends and gaps on integrating pathways. Journal of Cleaner Production. 175: 525-543.

Huang, Y. and Zhao, X. (2008). Trends of DDT research during the period of 1991 to 2005. Scientometrics. 75: 111-122.

Khaitov, B., Patino-Ruiz, J.D., Pina, T., Schausberger, P. (2015). Interrelated effects of mycorrhiza and free-living nitrogen fixers cascade up to aboveground herbivores. Ecology and Evolution. 5: 3756-3768.

Li C., Ji X. and Luo X. (2020). Visualizing hotspots and future trends in phytomining research through scientometrics. Sustainability. 12: 4593.

Manners, R., Varela-Ortega, C., van Etten, J. (2020). Protein-rich legume and pseudo-cereal crop suitability under present and future European climates. European Journal of Agronomy. 113: 125974.

Mongeon, P. and Paul-Hus, A. (2016). The journal coverage of web of science and scopus: a comparative analysis. Scientometrics. 106: 213-228.

Rai, K.K., Pandey, N., Meena, R.P., Rai, S.P. (2021). Biotechnological strategies for enhancing heavy metal tolerance in neglected and underutilized legume crops: A comprehensive review. Ecotoxicology and Environmental Safety. 208: 111750.

Roy R., Reinders, A., Ward, J.M., McDonald, T.R. (2020). Understanding transport processes in lichen, *Azolla* - cyanobacteria, ectomycorrhiza, endomycorrhiza and rhizobia - legume symbiotic interactions. F1000Research: 39.

Shi, Z.Y., Xu, S.X., Yang, M., Zhang, M.G., Lu, S.C., Chang, H.Q., Wang, X.G., Chen, X.N. (2021). Leaf nitrogen and phosphorus stoichiometry are closely linked with mycorrhizal type traits of legume species. Legume Research. 44: 81-87.

Shi, Z.Y., Zhang, X.L., Xu, S.X., Lan, Z.J., Li, K., Wang, Y.M., Wang, F.Y., Chen, Y.L. (2017). Mycorrhizal relationship in lupines: A review. Legume Research. 40: 965-973.

Stella, M., Sharma, R., Nema, S., Ramakrishnan, R.S., Kumar, A. (2021). Genetic characterization and diversity of rhizobia isolated from root nodules of green gram (*Vigna radiata* L.) found in central plateau of India. Legume Research. 44: 353-361.

van der Heijden, M.G., Martin, F.M., Selosse, M.A., Sanders, I.R. (2015). Mycorrhizal ecology and evolution: The past, the present and the future. New Phytologist. 205: 1406-1423.

Xing, S., Li, X., Xiao, X., Zhou, C., Li, F., Xie, Y., Yin, B., Wang, J. (2020). Visualization analysis of research progress in organic fertilizer study based on CiteSpace. Soils. 52: 659-667.

Yan T., Xue J., Zhou Z., Wu Y. (2020). The trends in research on the effects of biochar on soil. Sustainability. 12: 7810.

Yang, H., Shao, X., Wu, M. (2019). A review on ecosystem health research: A visualization based on CiteSpace. Sustainability. 11: 4908.

Zhang, L., Zhong, Y., Geng, Y. (2019). A bibliometric and visual study on urban mining. Journal of Cleaner Production. 239: 118067.

Zhang, Y., Li, C., Ji, X., Yun, C., Wang, M., Luo, X. (2020). The knowledge domain and emerging trends in phytoremediation: A scientometric analysis with CiteSpace. Environmental Science and Pollution Research. 27: 15515-15536.