Ciência Rural, Santa Maria, v.54:05, e20220438, 2024 http://doi.org/10.1590/0103-8478cr20220438

ISSNe 1678-4596
SOIL SCIENCE

Visual analysis of Chinese and international green manure research based on bibliometrics

Xueting Ma[1,2] **Jiean Liao**[1,2*] **Jinfei Zhao**[1,2]

[1]College of Mechanical and Electrical Engineering, Tarim University, Alar, 843300, China. E-mail: 120100010@taru.edu.cn. *Corresponding author.
[2]Modern Agricultural Engineering Key Laboratory at Universities of Education Department of Xinjiang Uygur Autonomous Region, Alar, China.

ABSTRACT: To investigate the development and dynamics of green manure research, we collected 802 and 4588 papers on green manure research from China national knowledge infrastructure (CNKI) and Web of Science (WoS) between 1992 and 2021, respectively, and conducted quantitative and visual analyses based on bibliometric methods on the annual number of publications, authors and institutions, keywords, and emergent words. The main research hotspots in the field of green manure are discussed and summarized based on the results of the visualization analysis and the important publications explored by the results of the visualization analysis. The results showed that: the overall number of publications on green manure research exhibits an increasing trend, and research in this field is receiving more and more attention; the United States is the core country in this research field, with a great influence; although, the number of Chinese publications is large, the intermediary centrality value is small and the level of scientific research needs to be improved; the research characteristics in the field of green manure research mainly focus on green manure cultivation technology, the effects on soil and crops, and the effects on pests and diseases. The study was conducted based on CiteSpace, a visualization tool of bibliometrics, with comprehensive literature information and intuitive results, providing important references for relevant researchers to understand the extent of research in this field, academic communication, and grasp research dynamics.
Key words: green manure, CiteSpace, visual analysis, bibliometrics.

Análise visual da pesquisa chinesa e internacional de adubo verde com base na bibliometria

RESUMO: Para investigar o desenvolvimento e a dinâmica da pesquisa de adubo verde, coletamos 802 e 4.588 artigos sobre pesquisa de adubo verde da infraestrutura nacional de conhecimento da China (CNKI) e da Web of Science (WoS) entre 1992 e 2021, respectivamente, e realizamos estudos quantitativos e visuais. Análises baseadas em métodos bibliométricos sobre o número anual de publicações, autores e instituições, palavras-chave e palavras emergentes. Os principais focos de pesquisa na área de adubação verde são discutidos e resumidos com base nos resultados da análise de visualização e nas importantes publicações exploradas pelos resultados da análise de visualização. Os resultados mostram que: o número total de publicações sobre a pesquisa de adubação verde apresenta uma tendência crescente, e as pesquisas nessa área estão recebendo cada vez mais atenção; os Estados Unidos são o país central neste campo de pesquisa, com grande influência, embora o número de publicações chinesas seja grande, o valor de centralidade intermediária seja pequeno e o nível de pesquisa científica precise ser melhorado; as características da pesquisa no campo da pesquisa de adubo verde concentram-se principalmente na tecnologia de cultivo de adubo verde, nos efeitos sobre o solo e as culturas e os efeitos sobre pragas e doenças. O estudo foi realizado com base no CiteSpace, ferramenta de visualização da bibliometria, com informações bibliográficas abrangentes e resultados intuitivos, fornecendo referências importantes para pesquisadores relevantes compreenderem a extensão da pesquisa neste campo, a comunicação acadêmica e a compreensão da dinâmica da pesquisa.
Palavras-chave: adubação verde, CiteSpace, análise visual, bibliometria.

INTRODUCTION

Green manure is a form of organic fertilizer that is both environmentally friendly and effective. It serves as a microbial soil amendment that helps to enhance crop quality and yield (MA et al., 2021; PINTO et al., 2017). Green manure can be categorized into two types: leguminous and non-leguminous. Leguminous green manure consists of purple clover, alfalfa and camelina, while non-leguminous green manure includes rape and ryegrass (ASGHAR & KATAOKA, 2022; SALGADO et al., 2022; DA SILVA et al., 2022; HWANG et al., 2015). The common practice in agriculture is to plant green manure crops before planting subsequent cash crops. Once the green manure plants mature, they are turned in situ, allowing for decomposition in the soil. This process results in the formation of a nutrient-rich organic fertilizer (MASILIONYTE et al., 2021; CHERR et al., 2006). As it contains a variety of essential nutrients required by crops, it can be effectively utilized as a base fertilizer for planting crops. This helps in fertilizing the soil, improving its physicochemical properties, and supplying necessary

Received 08.03.22 Approved 06.20.23 Returned by the author 11.21.23
CR-2022-0438.R2
Editors: Leandro Souza da Silva Anderson Luis Nunes

nutrients for crop growth. Additionally, it also promotes the prompt development of crop roots.

After years of development, research on green manure has continued to advance, resulting in the maturation of certain theories and technologies. Therefore, it is imperative to review the relevant accomplishments in the field of green manure. Previous reviews on green manure research were mainly based on summarizing relevant literature, sorting out research results, and the research direction was relatively single, only macroscopically describing qualitatively and revealing certain laws and conclusions. For example, some scholars focused on the effects of green manure on the growth environment of a certain cash crop (WANG et al., 2021a), some scholars focused on the effects of green manure on soil-borne diseases (WEI et al., 2021), and some scholars focused on the weed suppression effects of green manure crops (OSIPITAN et al., 2019). While the existing reviews offer valuable insights into the research on green manure, they primarily rely on qualitative methods and cover a limited number of topics. As a result, they do not provide a comprehensive or objective overview of the field and its development.

As a research method in the fields of scientometrics and informetrics, CiteSpace-based bibliometrics can reveal the sources of knowledge, development patterns, and research characteristics of specific research fields, and it can be quantitatively analyzed in a visual form, which is more intuitive and reliable (ZHONG et al., 2020). Therefore, more and more researchers use this method to study the current situation and development trend of specific fields. WANG et al. (2020) used the CiteSpace software to analyze the development of urban metabolism research and its current status from multiple perspectives, with the goal of revealing research hotspots and predicting future trends. The results showed that urban metabolism has gradually developed from a concentrated ecological or environmental discipline to a multidisciplinary one with three key knowledge bases: characteristics of urban ecosystems, development of urban metabolism theory, and methodological frameworks. In addition, the research focus has gradually shifted from quantifying environmental impacts to analyzing the internal processes of urban systems. ZONG et al. (2022) analyzed 1820 Web-of-Science-indexed articles from 1991 to 2021 by CiteSpace. The results showed that the research hotspots of industrial glucoamylase were glucoamylase strain directional improvement, Aspergillus niger glucoamylase, glucoamylase immobilization, application of glucoamylase in ethanol production, and "customized production" of porous starch. As we all know, CNKI is a database that Chinese researchers contribute more, and most of the green manure-related manuscripts submitted are based on Chinese orchards. The WoS database has a rich collection of literature from all regions of the world, and is the preferred database for bibliometric methods. In this study, we visualized and analyzed the collected green manure research literature using CNKI database and WoS database based on CiteSpace, and then make an objective overview and evaluation of the development lineage and research status of green manure, and provide some reference for researchers on the dynamics and trends of green manure research. Specifically, we aimed to answer the following seven questions:

RQ1: What was the annual trend of green manure publications?

RQ2: What were the most prolific countries/regions, and authors?

RQ3: What were the collaborative relations among prolific countries/regions and authors?

RQ4: What were the major research topics?

RQ5: How did these topics evolve?

DATA SOURCE AND METHODOLOGY

Data source

In this study, CNKI database and Web of Science (WoS) database were used as data sources. Among them, CNKI selected "core journals", and entered "green manure" under subject search settings. The publication time range was from 1992 to 2021. We excluded publications that did not meet the requirements such as cover introduction, journal message, seminars and conferences, and finally obtained 802 valid publications. All downloaded publications were exported in "RefWorks" format, and the WoS database search was conducted by selecting "WoS core collection search" and setting the theme as "green manure". The search results were further filtered by language (English) and literature type (review and dissertation), and 4588 publications were obtained with the help of CiteSpace data de-duplication function. (The data in this research came from public databases, so it did not involve ethical approval.)

2.2 *Methodology*

Excel was used to analyze the publication trend. The polynomial model $f(x) = ax^3 + bx^2 + cx + d$ was applied to forecast the growth of publications in the following year. Variable x stands for the publication year and $f(x)$ stands for the number of publications.

We utilized bibliometric data to gather metrics based on the CiteSpace software, such as the number of publications per year, total number of publications, citations, and average citations per publication per journal, distribution of publications, co-authors, institutional and international collaborations (YAO et al., 2020).

To ensure a close correlation between the analysis of the article and green manure, we conducted manual screening to ensure that the main content pertained to research conducted with green manure as the research object (CHEN et al., 2023). This study utilized CiteSpace to cluster publications and keywords based on correlation and similarity strength (LI et al., 2020). The cluster analysis can uncover current research topics and trends in this field, providing valuable insights for researchers and practitioners alike.

RESULTS

Characteristics of publication outputs

The number of publications is a crucial metric for assessing the progress and advancement of a particular field. A higher number of publications signifies greater attention and research efforts dedicated to the field (LI et al., 2020). The number of publications in the field of green manure research based on CiteSpace statistics was plotted as a line graph and analyzed (Figure 1).

The temporal distribution of publications from both CNKI and WoS showed an overall increasing trend. The number of publications from CNKI exhibited a relatively volatile change, with a slow growth phase before 2007, a steady growth phase from 2008 to 2017, and a significant growth phase from 2018 to 2021. During the significant growth phase, the number of publications issued in a mere 4 years accounted for 36.04% of the total, with 2021 seeing the highest number of publications at 361. These trends in publication numbers indicated a phased change in green manure research in China, with the overall performance showing an increasing focus on this field of study. In recent years, various regions in China have been promoting the green manure industry and implementing green manure planting subsidy policies. This has resulted in the rapid development of green manure research. The number of publications from WoS has shown a consistent increase, suggesting a rise in global investment towards green manure research over the years.

Analysis of nation cooperation network

The number of publications included in the WoS database reflects the scientific strength of a country in a certain research field to some extent. Based on the CiteSpace country collaboration analysis function, 4588 search results were analyzed for the number of publications published by different countries, and their node size, inter-node linkage and linkage width represent the number of publications published by each country, the collaboration relationship and the intensity of collaboration between the publishing countries, respectively (Figure 2). In the visualization mapping, the intermediary centrality value characterizes the influence size, and the outer edges of nodes with intermediary centrality values higher than 0.1 show purple color (CHEN et al., 2020). It should be noted that the sum of the total number of publications shown in each country was greater than the total number of publications retrieved because the authors of a single publication may be involved in more than one country. The cooperation of the publishing countries was analyzed based on CiteSpace (Figure 2, Table 1, Figure 3). In the cooperation network, N = 221, E = 789, Density = 0.0325, and the cooperation between countries in the field of green manure research was relatively close. Especially, the United States had established collaborations with numerous countries in this field, including China, Japan, and Germany with relatively close ties. It is noteworthy that the United States had the largest node, indicating the highest number of publications. In addition, the edge of its node was purple. Combining with table 1, among all countries, the betweenness centrality value of the United States was the largest (0.48), indicating that the level of scientific research was high and the influence of communication was large. The research was paid more attention and a lot of work had been done, making great contributions in the international arena. Table 1 showed that the United States, India, China, Brazil, Canada and other countries were the primary publishing countries with 794, 635, 520, 281, and 226 published publications, respectively. The percentages of published publications were 13.96%, 11.17%, 9.19%, 4.95%, and 3.87%, respectively. The countries with betweenness centrality values greater than 0.1 were the United States, the United Kingdom, Australia, and Canada, in descending order. The respective values were 0.48, 0.17, 0.16, and 0.11, respectively. The results revealed that the scientific research level of these nations was comparatively high, with good quality publications and significant contributions and influence of in the field communication. China had a relatively high number of publications in this field; however, its betweenness centrality value was only 0.05. This suggested that China needed to improve its research depth and publication quality. The table also

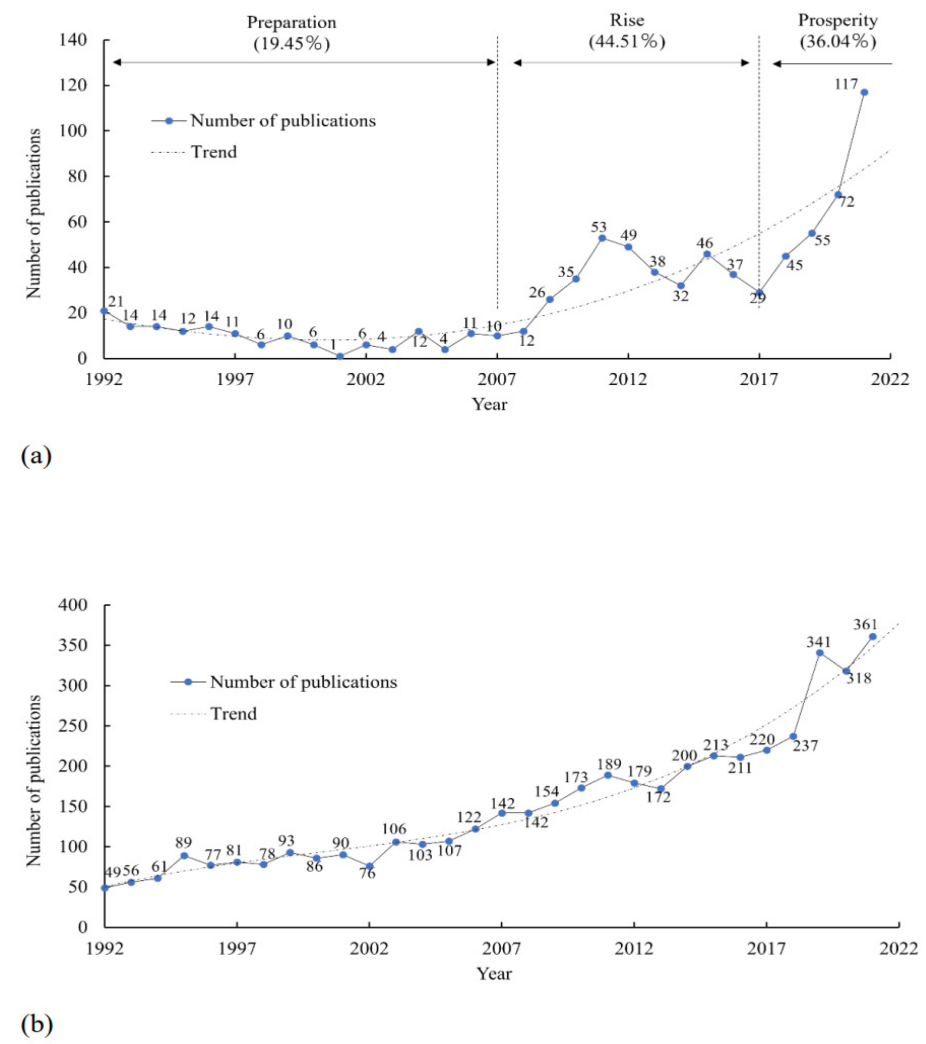

Figure 1 - Statistics of publications issued. (a) Number of publications from CNKI (China National Knowledge Infrastructure); (b) Number of publications from WoS (Web of Science).

revealed that most countries with high publication numbers and intermediary centrality were developed nations, indicating a close relationship between scientific research and national economic strength.

Analysis of author cooperation network

The study utilized CiteSpace's author analysis function to obtain the cooperation network of authors in the field of green manure research, which reflects the core authors and their collaborations (Figure 4). The node size, connection between nodes, and width in the network represent the number of published publications, cooperation relationships, and relationship strength between authors. In the CNKI database, 792 authors and 1362 cooperative connections were identified, resulting in a low density of only 0.0043. The network was characterized by scattered points, thin lines and unevenness. The top 5 published publications were authored by Weidong Cao, Songjuan Gao, Xingguo Bao, Jianwei Lu, and Yajun Gao. Weidong Cao from the Institute of Agricultural Resources and Agricultural Zoning of the Chinese Academy of Agricultural Sciences was the scholar who published the most papers in this research field. He formed a research group with himself as the core. Looking at the entire map, except for Weidong Cao's large node, other nodes were too small, indicating that China had few core members in the field of green manure research, and the cooperation between groups was not close, which was not conducive to the output of research results.

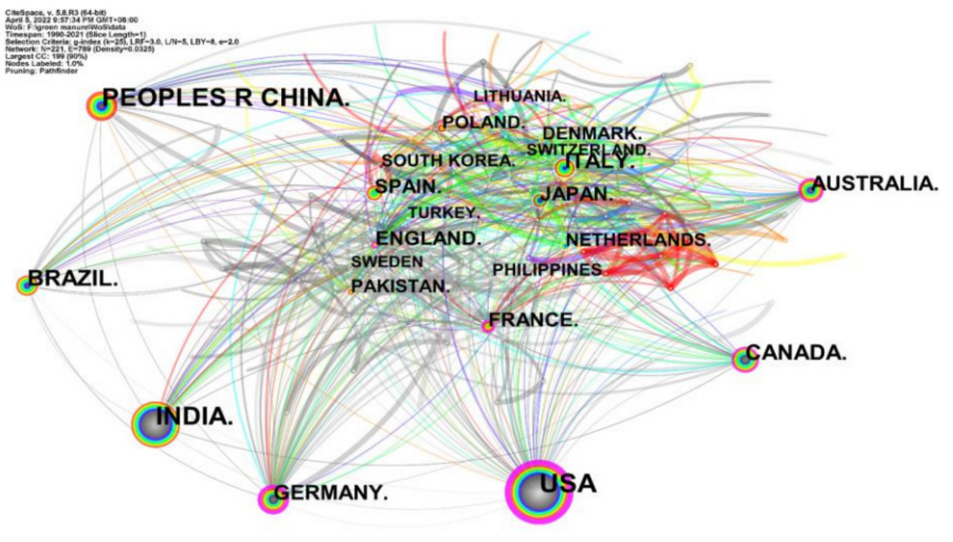

Figure 2 - National cooperative relationship network. The same as for figure 1.

According to the WoS database, there were a total of 1142 authors and 1378 collaboration links, with a density of 0.0021. The research groups were also sparsely connected, resulting in multiple research groups of varying sizes. This indicated that the green manure research author groups worldwide had not been cooperating closely, which might hinder the horizontal and vertical development of research content. Among them, Weidong Cao from the Chinese Academy of Agricultural Sciences was the first in the number of published papers in WoS, which was consistent with the CNKI database, he had cooperative relations with several other large scientific research teams (Table 2).

Characteristics of major journals

Among the journals containing publications in the field of green manure research (Table 3), *Northern Horticulture* and *Chinese Journal of Soil Science* in the CNKI database were listed as the journals with the largest number of publications in this field, both of which were 14, accounting for 2.61% of the total number of publications, followed by *Soil and Fertilizer Sciences in China* and *Journal of Plant Nutrition and Fertilizers*, with 13 and 12 publications, accounting for 2.43% and 2.24%, respectively. *Indian Journal of Agricultural Sciences*, *Agronomy Journal* and *Plant and Soil* in the WoS database were listed as the journals with the largest number of publications in this field, all three of which were 40, accounting for 1.46% of the total, followed by *Biology and Fertility of Soils* and *Soil Biology & Biochemistry*, with 32 and 31, accounting for 1.17% and 1.13%, respectively. Research on green manure had a low representation in both Chinese and international journals, indicating a lack of focus on this topic.

Table 1 - Top 10 high-yield countries in green manure research (1992-2021).

Rank	Country	Centrality	Count	Proportion
1	USA	0.48	794	13.96%
2	India	0.09	635	11.17%
3	China	0.05	520	9.19%
4	Brazil	0.08	281	4.95%
5	Canada	0.11	226	3.87%
6	Italy	0.06	210	3.71%
7	Australia	0.16	188	3.30%
8	Germany	0.3	184	3.22%
9	Japan	0.09	148	2.60%
10	England	0.17	125	2.21%

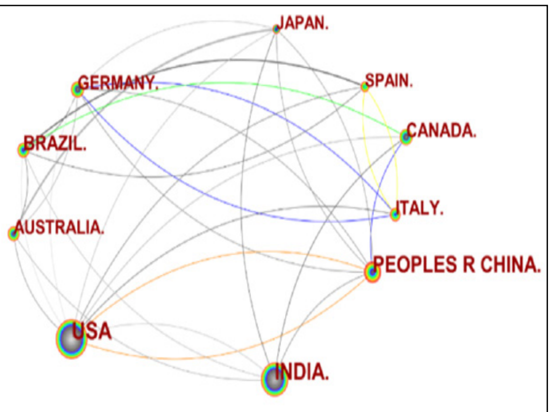

Figure 3 - Top 10 national cooperation networks.

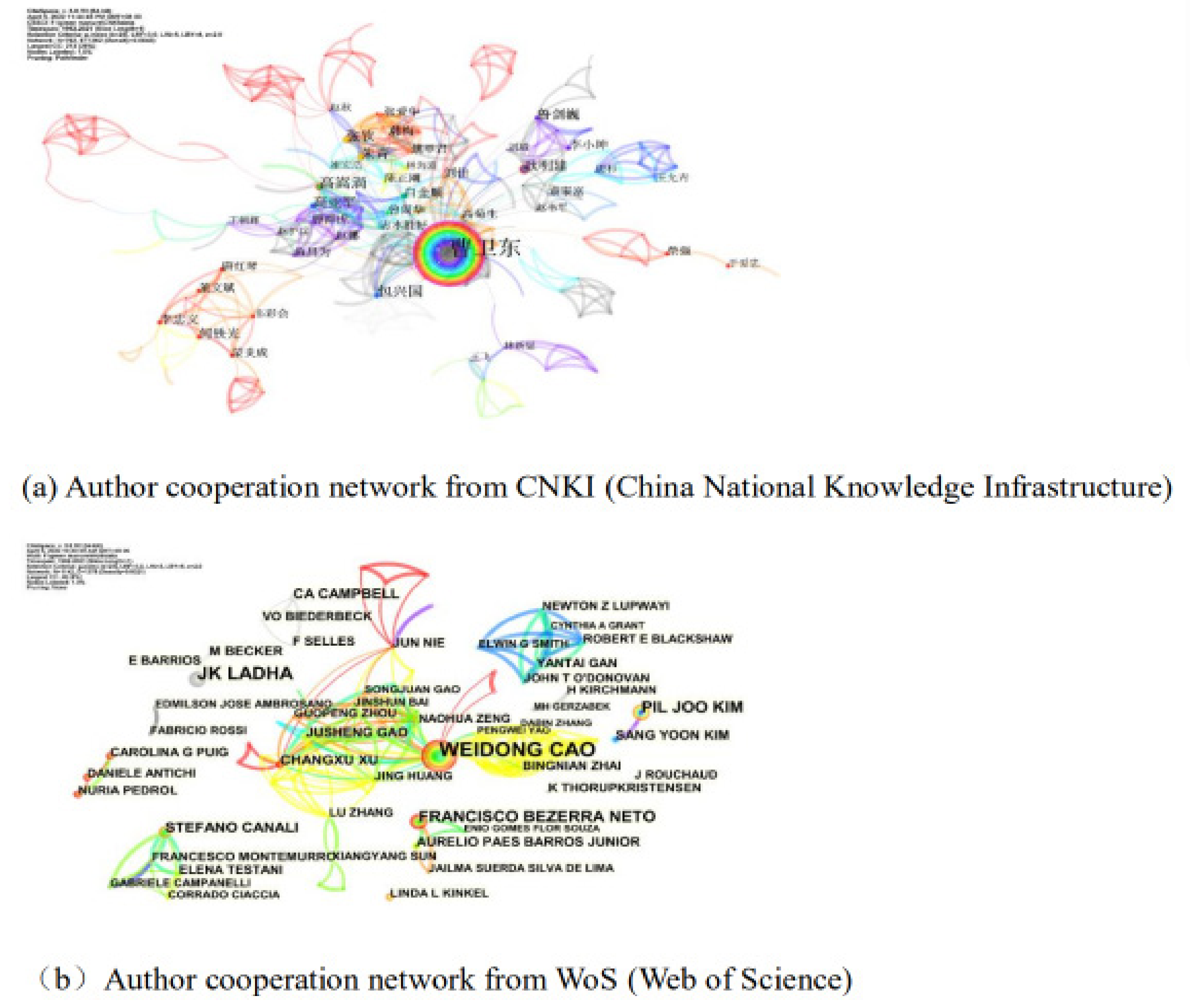

Figure 4 - Author cooperation network map.

Research hotspots

Keywords co-occurrence

Keywords are the condensation of the content of the publications, and keyword co-occurrence is to analyze the degree of connection of keywords in several publications to obtain research hotspots and evolution trends in the research field (YANG et al., 2020b). Based on CiteSpace, the

Table 2 - Analysis of core authors of spectra in CNKI and WoS databases in the field of fruit.

----------------------------CNKI database--------------------------				---------------------------------WoS database------------------------------			
Author	Institution	Count	Year	Author	Institution	Count	Year
WEIDONG Cao	Chinese Acad Agr Sci	133	1999	Weidong Cao	Chinese Acad Agr Sci	39	2015
Songjuan Gao	Nanjing Agr Univ	19	2013	Jk Ladha	Int Rice Res Inst	26	1992
Xingguo Bao	Gansu Acad Agr Sci	18	1993	Pil Joo Kim	Gyeongsang National Univ	17	2012
Jianwei Lu	Huazhong Agr Univ	16	2009	Francisco Bezerra Neto	Universidade Federal Rural do Semi-Árido	17	2016
Yajun Gao	Northwest A&F Univ	15	2011	Stefano Canali	Ist Sperimentale Nutr Piante	13	2013

Table 3 - Statistics of main journals from CNKI (China National Knowledge Infrastructure) and WoS (Web of Science).

----------------------------CNKI database---------------------------			---------------------------------WoS database------------------------------		
Journal	Number	Proportion	Journal	Number	Proportion
Northern Horticulture	14	2.61%	Indian Journal of Agricultural Sciences	40	1.46%
Chinese Journal of Soil Science	14	2.61%	Agronomy Journal	40	1.46%
Soil and Fertilizer Sciences in China	13	2.43%	Plant and Soil	40	1.46%
Journal of Plant Nutrition and Fertilizers	12	2.24%	Biology and Fertility of Soils	32	1.17%
Pratacultural Science	11	2.05%	Soil Biology & Biochemistry	31	1.13%

CNKI and WoS keyword co-occurrence networks were obtained respectively (Figure 5), and the related information of the top 20 keywords in CNKI and WoS was counted (Table 4 and Table 5). Each node in the network represented a keyword. The size of the node font, the size of the node annual ring, and the connection between nodes represented the frequency of the keyword, the number of citations of

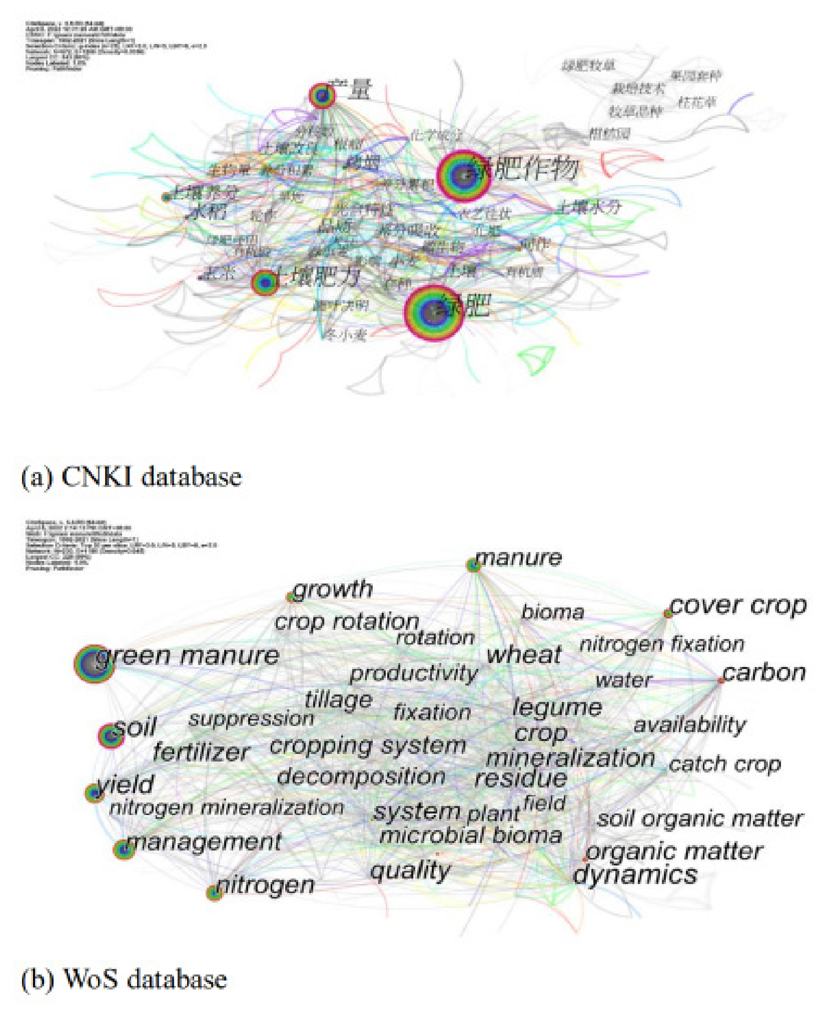

Figure 5 - Keyword co-occurrence network.

Table 4 - Top 20 high-frequency keywords in CNKI (China National Knowledge Infrastructure) database.

No.	Keyword	Count	Centrality	Year	No.	Keyword	Count	Centrality	Year
1	Green manure	263	0.54	1995	11	Fertilizer	12	0.01	1996
2	Green manure crops	194	0.68	1992	12	Decomposition	11	0.01	2015
3	Soil fertility	103	0.17	1993	13	Soil moisture	10	0.03	1993
4	Yield	101	0.21	1993	14	Soil	10	0.03	2008
5	Soil nutrients	35	0.06	1993	15	Wheat	10	0.01	1993
6	Roasted tobacco	28	0.03	2007	16	Green manure return	9	0.01	2006
7	Rice	26	0.08	1992	17	Nutrient uptake	8	0.02	2011
8	Corn	19	0.04	2000	18	Winter wheat	8	0.01	2010
9	Quality	19	0.02	2007	19	Photosynthetic characteristics	8	0.01	2008
10	Intercropping	14	0.02	2006	20	Double-season rice	8	0	2003

the publications with the keyword and the degree of connection between the keywords.

According to figure 5 and table 4, the CNKI database's network graph consisted of 672 network nodes and 1268 network connections, resulting in a network density of 0.0056.

In the keyword frequency statistics, except for the keyword "green manure", "green manure crop" had the highest frequency of occurrence, with a total of 194 occurrences, and the betweenness centrality was 0.68, indicating that the communication influence was large. Followed by "soil fertility", with 103 occurrences and a mediated centrality value of 0.17, "yield" (101 times), "tobacco" (28 times), and "rice" (26 times). From table 4, we could preliminary conclude that the research in the field of green manure in CNKI mainly focused on the effects of green manure on yield and quality of cash crops and the effects of green manure on soil, etc. The network map of the WoS database had 230 network nodes, 986 network connections, and a network density of 0.045. The keywords were closely related. Among them, except for the keyword "green manure", "soil" had the highest frequency of occurrence, with a total of 683 occurrences, and the betweenness centrality value was 0.21, indicating that the communication influence was large; the frequency of occurrence of "management" ranked second, with 543 occurrences. Keywords such as "nitrogen" (515), "yield" (486), and "cover crop" (413) followed closely. Based on the analysis of high-frequency keywords, it could be inferred that the research on green manure in WoS primarily concentrated on investigating the impact of green manure on soil, exploring various planting and management techniques of green manure, and examining the correlation between green manure and crop yield. These research areas aligned with the current research trends observed in the CNKI database.

Table 5 - Top 20 high-frequency keywords in WoS (Web of Science) database.

No.	Keyword	Count	Centrality	Year	No.	Keyword	Count	Centrality	Year
1	green manure	1166	0.11	1992	11	carbon	285	0.11	1992
2	soil	683	0.21	1992	12	quality	242	0.09	1992
3	management	543	0.04	1992	13	cropping system	240	0.09	1994
4	nitrogen	515	0.08	1992	14	tillage	213	0.04	1993
5	yield	486	0.09	1992	15	fertilizer	210	0.08	1992
6	cover crop	413	0.13	1994	16	dynamics	186	0.1	1992
7	growth	396	0.07	1992	17	residue	182	0.1	1994
8	manure	346	0.08	2002	18	decomposition	163	0.03	1992
9	organic matter	306	0.17	1992	19	crop	156	0.08	1992
10	system	289	0.06	1995	20	microbial bioma	149	0.05	1992

Burst keywords analysis

Keyword emergence refers to a sharp increase in the frequency of keyword citations within a short period, and the research content of the field attracts the close attention of related scholars, which can reflect the changing dynamics of research topics in the related field (Zhai et al., 2020). Based on CiteSpace, we obtained the keywords of CNKI database and WoS database respectively, as well as their emergence intensity and starting and ending years. The CNKI database revealed that research topics in the field of green manure had evolved over time, as evidenced by the emergence of new keywords. Initially, research focused on the cultivation and selection of green manure crops. Later, attention shifted towards exploring the impact of green manure on soil. Recently, there was a growing interest in applying green manure in the cultivation of certain economic crops (Figure 6). Compared with the CNKI database, the WoS database was richer in keywords (Figure 7), and research on the application of green manure in fields had been conducted since the beginning of 1992, especially on the nitrogen sequestration capacity of leguminous green manure, and then on the application of green manure in various environments (ponds, orchards, fields, etc.), and the research was more in-depth and detailed.

Analysis of co-citation reference clusters

The keyword clustering network can further detect the closeness relationship between high-frequency keywords, mine the hidden information, and present the hot field of green manure research (DAI et al., 2020). To draw the research hotspots more clearly, a K-means clustering analysis was performed on the keywords through CiteSpace. The results showed that the Q value of the cluster map was 0.5551 and the S value was 0.8097. When the Q value is greater than 0.3, it means that the clustering structure is significant. When the S value is greater than 0.7, the clustering is highly efficient and convincing, so the results here were acceptable. The research used the LLR algorithm to generate cluster labels based on the naming method of keywords. For the publications in the CNKI database, six main categories of research topics (green manure, yield, nutrient content, rice, tobacco, and soil fertilization) were formed through clustering (Table 6). For the publications in the WoS database, five main categories of research topics (green manure, sesbania rostrata, cropping system, N mineralization, and soil) were formed through clustering (Table 7). At the same time, the cluster names were modified twice by tracing back and reading the original publications. Combined with the comprehensive analysis of table 6 and table 7, it could be seen that in the field of green manure research, the research contents of green manure planting technology, the effects of green manure on crops, the effects of green manure on soil, the effects of green manure on pests and diseases were the current research hotspots.

DISCUSSION

Through CNKI and WoS clustering results, it could be seen that green manure research mainly focused on green manure planting technology, the effects on soil and crops, and the effects on pests and diseases. Combined with the clustering results and related publications, the above research contents were summarized.

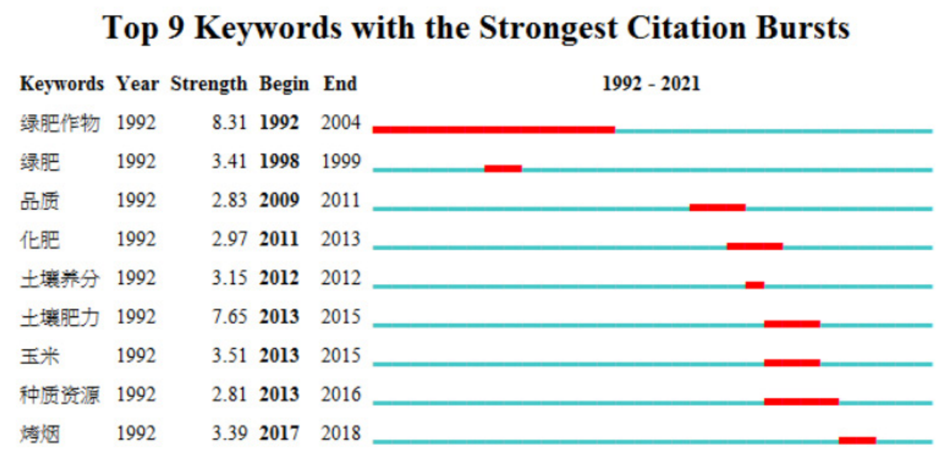

Figure 6 - Keyword emergence in CNKI (China National Knowledge Infrastructure).

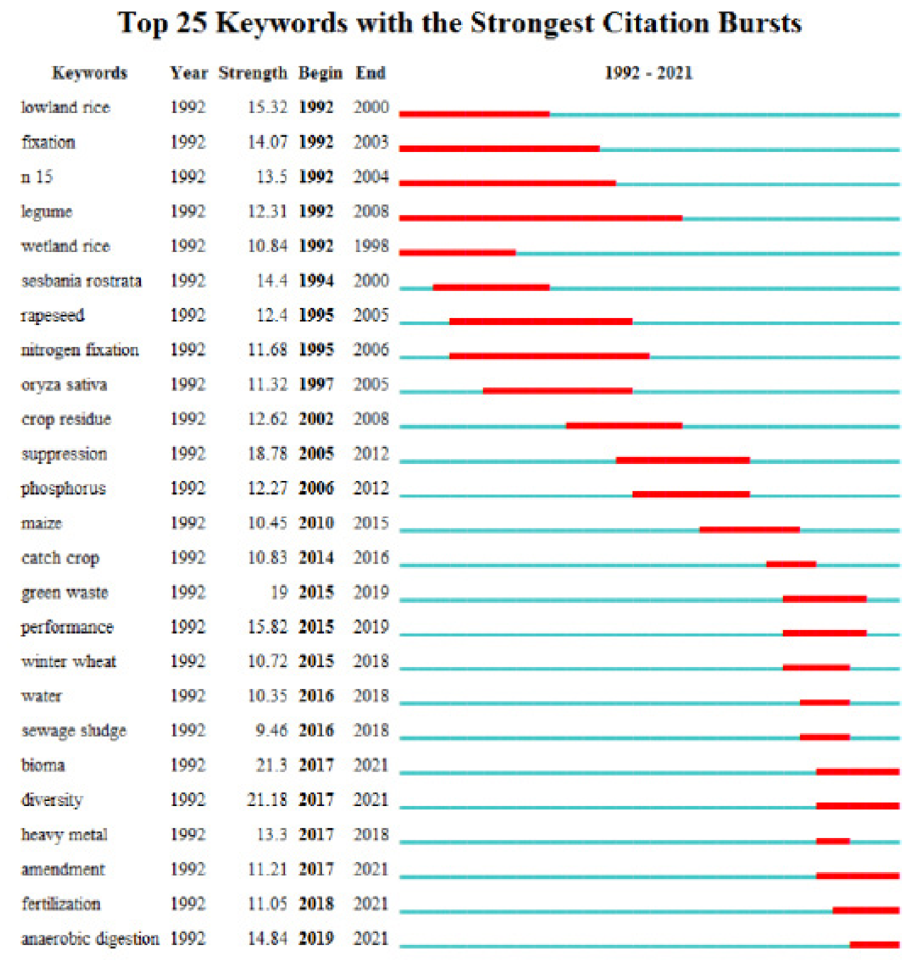

Figure 7 - Keyword emergence in WoS (Web of Science).

Research on green manure planting management technology

Green manure can improve soil structure and the environment, provide nutrients for crop growth, and is receiving more and more attention from scholars and farmers. In recent years, with the in-depth study of green manure planting technology, a variety of green manure planting methods have gradually emerged, specifically the following.

(1) Single-crop green manure

That is, only one green manure crop is planted on the same cultivated land, for example, a wasteland is selected and then the wasteland is reclaimed and first planted with green manure plants for one season or one year to increase soil fertility and promote the growth of subsequent crops (LIU et al., 2018; BOGUZAS et al., 2022).

(2) Intercropping green manure

Green manure crops are planted interspersed with other crops on the same plot and within the same season (ZHOU et al., 2018; SU et al., 2021), such as melilotus officinalis is planted between tobacco rows (ZHAO et al., 2019), and soybean is planted between tea tree rows (WANG et al., 2022). Interplanting green manure can make full use of the land power, to use the land to nourish the land and reduce weeds and diseases. Interplanting green manure can fully improve the utilization of soil fertility, reduce the damage of weeds and pests, and contribute to crop growth. If the green manure planted is leguminous, it can also improve the nitrogen uptake and increase the nitrogen nutrition of the main crop (LI et al., 2019; LIANG et al., 2021; CHEN et al., 2021). ZHAO, et al (ZHAO et al., 2019) showed that intercropping green manure can enhance the ability of soil microorganisms

Table 6 - Results of keyword cluster analysis (CNKI).

ClusterID	Size	Silhouette	Keyword	Cluster labels (LLR)	Manual naming
0	49	0.934	green manure, quality, legume green manure, spring wheat intercropping, corn, soil fertility, green manure crops, chemical fertilizer reduction	green manure	Planting technology of green manure crops
1	15	0.896	yield, straw, cotton, soil improvement, Vicia villosa var., glabresens	yield	Effects of green manure on crops
2	10	0.866	nutrient content, rubber plantation, nutrient release, cover green manure	nutrient content	Mechanism of green manure on orchard and field
3	10	0.769	rice, mucuna pruriens, straw returning, rice growth	rice	Effects of green manure on rice growth
4	6	0.88	tobacco, soil moisture, photosynthetic characteristics, economic traits, overturning	tobacco	Effects of green manure on tobacco planting
5	3	0.989	soil fertilization, return amount, mulching return, degradation characteristics	soil fertilization	Mechanism of green manure crop's effects on soil

of utilizing carbon sources and improve the diversity of soil microbial community structure and community function in tobacco-growing soils.

(3) Interplanting green manure

Green manure was sown between the rows of the main crop before harvest (SONG et al., 2016). For example, purple yew or broad beans are sown in the late-maturing stage of rice, and grass miscanthus is planted in wheat fields (ZHANG et al., 2021b). In addition to the role of intercropping, interplanting green manure enables green manure to make full use of the growing season, prolong the growing time, and increase the yield of green manure (WANG et al., 2017).

(4) Mixed green manure cropping

In the same plot, more than two green manure crops are mixed and sown at the same time (LIU et al., 2018). These two green manure crops are preferably able to be different species, such as leguminous green manure mixed with non-leguminous green manure (ZHU et al., 2020), and specialized green manure mixed with native plants (REIS et al., 2019), which can regulate nutrients between each

Table 7 - Results of keyword cluster analysis (WoS).

ClusterID	Size	Silhouette	Keyword	Cluster labels (LLR)	Manual naming
0	44	0.737	green manure, microbial biomass, carbon, system, composting	green manure	Effects of green manure crops on soil ecology
1	33	0.761	sesbania rostrate, green manuring, cyanobacteria, nitrogen fixation, Azolla	sesbania rostrata	Nitrogen sequestration ability of green manure crops
2	31	0.713	cropping system, Triticum aestivum, fertilizer, dryland cropping system, cropping systems	cropping system	Management methods of green manure planting
3	16	0.85	n mineralization, quality, nutrient release, plant residue, litter	N mineralization	Effect of green manure on nitrogen in soil
4	16	0.784	Soil, lupin, plant parasitic nematode, plant extract, Columbia root-knot nematode	soil	Effect of green manure on soil nematodes

other. Mixed green manure cropping produces higher yields and improves the soil more effectively, but may present management difficulties.

(5) Green manure rotation

Green manure plants can be rotated with cash crops, i.e., after the cash crops are harvested in autumn, green manure crops are planted in the winter fallow period to increase the ground cover of winter farmland. This can effectively reduce the ground exposure of the soil during the fallow period and help to reduce the impact of wind and water erosion on soil quality (LEE et al., 2020; HUANG et al., 2016). Campanella et al (CAMPANELLA et al., 2020) showed that Brassica crop rotations can reduce the occurrence of wheat root rot.

Effects of green manure on soil

Effect of green manure on soil physical properties

The scope of effects on soil physical properties mainly includes the effects on soil moisture, temperature, and soil structure. Please avoid paragraphs with just one phrase.

Green manure can change soil water content by slowing down the erosion of rainwater on the ground and reducing ground evaporation. The effect of green manure on soil moisture is related to seasons and rainfall. In the dry season, green manure crops such as white clover, ryegrass, and alfalfa compete with fruit trees for water, which reduces the water content of the soil layer in the range of 0-60 cm. There was no significant difference in soil water content between green manure treatments and clean tillage treatments (MIKO et al., 2008; MOOLEKI et al., 2016; GYURICZA et al., 2009; YANG et al., 2012). There are mainly 3 reasons about green manure' effectively improving soil aggregate structure and improving soil fertility. First, the growth of green manure's root system makes the soil looser and more porous, reducing soil compactness and thus reducing soil capacity (NASCIMENTO et al., 2021; ORTIZ-SALGADO et al., 2021). Second, root decay and decomposition of organic matter by microorganisms leave space for the original root system to grow, thus increasing soil porosity and facilitating the exchange of soil air and atmosphere (DONG et al., 2021). Third, green manure is overburdened and roots decomposed, the organic matter content in the soil increases, the smaller particles in the soil are cemented into large water-stable aggregates, the soil structure is improved, and the permeability is increased (GAO et al., 2020).

In addition, green manure can impact the exposure of the ground to solar radiation, which can buffer changes in ground temperature. The presence of green manure crops slows down the efficiency of temperature transfer when the temperature rises or falls, resulting in slower surface temperature changes that can be beneficial for the growth of fruit trees (YANG et al., 2020a; GUO et al., 2021).

Effect of green manure on soil chemical properties

Soil organic matter is an important component of the soil solid phase, which is of great significance to soil formation, soil microbial activity, and crop growth, and is an important indicator to measure soil fertility (MACIAS-BENITEZ et al., 2020). After planting green manure crops, a large number of residual roots, fallen leaves, dead stems and fresh grass become an important source of organic matter. GAO et al. (2018) showed that planting rapeseed and vetch in red soil can significantly increase soil organic matter content, thereby improving soil fertility and sustainability. Green manure itself contains a lot of active and moderately active organic phosphorus, and some organic acids generated after being applied to the soil can have a complex reaction with the metal ions of insoluble phosphate in the soil to release the phosphorus in it. Long-term application of green manure Other organic fertilizers can increase the content of soil available phosphorus, inorganic phosphorus and organic phosphorus to varying degrees (KRAVTSOVA et al., 2021; HONG et al., 2019).

In addition, rhizobia in leguminous green manure can fix free nitrogen in the air and increase the available nitrogen content of soil (TAUTGES et al., 2018), which is an important source of soil nitrogen. Moreover, the cultivation of green manure increased soil microbial biomass, especially during the decomposition of green manure, the activity of soil microorganisms was enhanced, which helped to promote soil nitrogen mineralization and crop absorption (ZHOU et al., 2020).

Effect of green manure on soil microorganisms

Soil microorganisms are important decomposers in farmland or orchard ecosystems. The advantages of green manure crops are highly dependent on the decomposition of cover crop residues by soil microorganisms, and the nutrient of cover crop residues is also crucial for the growth of microorganisms (WANG et al., 2021b). After green manure crops are planted and returned to the field, under the action of improving soil Physicochemical properties, the number and diversity of fungi, bacteria and other microorganisms have increased, and the diversity of fungal species has increased more significantly (LONGA et al., 2017; ALAGOZ et al., 2020). BOROZAN et al. 2015) showed that mixed green manure of legumes and annual grasses can increase the diversity and quantity of actinomycetes and bacteria. ZHANG et al. (2021a) showed that the application of green manure of wild rockets could increase the number and abundance of Ascomycota near cucumber roots.

Effect of green manure on main crops

Returning green manure crops to the field can improve the root activity of main crops and promote root growth (ZHULANOVA et al., 2020). This is because the improvement of soil physicochemical properties and the improvement of soil fertility have laid a good foundation for crops growth after planting and returning green manure. This is mainly attributable to the following three aspects. First, the growth and return of green manure bring organic matter into the soil, which can improve the aggregate structure of the soil, and the ability of soil to retain water and moisture, thus promoting the extension of the root system of crops (SAYGI, 2021). Second, green manure has changed the quantity and microbial community structure of bacteria, fungi and actinomycetes in the soil. At the same time, different microorganisms may produce hormones such as gibberellin, auxin, cytokinin, etc., which can improve the root system of crops. Physiological functions and activities (MARSHALL & LYNCH, 2018; FERNANDES et al., 2020). Third, the planting of green manure crops alleviates the temperature difference, reduces soil erosion, and provides a good soil and water environment for the growth of main crops (OZTURK & OZER, 2019). Zhulanova et al (ZHULANOVA et al., 2020) showed that the application of green manure was 1.3-1.6 times more biologically active and increased soil fertility by 6-19% compared to complete fallow, which increased wheat crop yield. Also, green manure can be used with farmyard manure or chemical fertilizers to good effect. SAYGI et al. (2021) showed that the mixed use of green manure and chicken manure could improve soil fertility, thereby increasing the yield and quality of strawberries.

Effects of green manure on soil-borne diseases

Most of the studies on the effects of green manure on soil-borne diseases of crops are mainly fungal and nematode diseases, and there are few studies on the diseases caused by other pathogenic microorganisms. This is consistent with the fact that more than 80% of plant diseases reported so far are caused by fungi, and it is also related to the more complex environmental conditions and relatively weak infectivity of bacteria, actinomycetes, viruses, etc. (MEHTA et al., 2014).

Fungi dominate the soil-borne plant pathogens, and Verticillium dahliae, Rhizoctonia solani, Fusarium oxysporum, etc. are typical soil-borne pathogenic fungi (FRANCIOLI et al., 2020; PENG et al., 2019). The planting of green manure crops can improve the biodiversity of field and orchard environments, enhance their natural regulation ability, reduce the incidence and degree of damage of sudden pests and diseases, and at the same time have a good biological control effect (BAYSAL-GUREL et al., 2019). Especially it has a good inhibitory effect on soil-borne fungal diseases after green manure returning (DING et al., 2021). LAZZERI et al. (2003) showed that some green manure crops have biocidal properties, and this green manure can be used for the control of pests and diseases, and proved the inhibitory effect of Brassica green manure on soil-borne plant pathogenic fungi through experiments (LAZZERI et al., 2000).

Plant-parasitic nematodes are another major pathogen that causes soil-borne diseases of crops and is also an important factor affecting crop production (CHANGKWIAN et al., 2019). Root-knot nematodes are the most studied and most damaging plant parasitic nematodes in the world (RASHIDIFARD et al., 2021; LIN et al., 2016). Various root-knot nematodes can damage plant roots, cause secondary infection by fungi and bacteria, directly or indirectly lead to delayed crop maturity and lodging, reduce crop yield and quality, increase production costs, and reduce economic income (COSTA et al., 2020; PAPOLU et al., 2016; JONES et al., 2014). The effect of green manure on root-knot nematodes is affected by factors such as the amount of overburden, soil characteristics, initial nematode population, and treatment time. The inhibitory effect is obvious under the condition of relatively high green manure turning amount, reasonable turning time, and low initial nematode population (NAZ et al., 2015; TSEKE & MASHELA, 2017; RIGA, 2011). The inhibitory effect of green manure on root-knot nematodes was the best in sandy loam soil and the worst in cohesive soil, and gradually weakened with time going on (DJIAN-CAPORALINO et al., 2019).

Limitations

This paper utilized bibliometrics to conduct a comprehensive study on the current research status of green manure and presented several conclusions. In the current retrieval process, errors may occur due to the manual quick decision based on the title. To improve accuracy and efficiency in future research, it is recommended to use machine learning to classify and identify downloaded literature data and exclude weakly relevant literature in batches (CHEN et al., 2023).

CONCLUSION

In this paper, we analyzed the progress of green manure research based on CiteSpace in terms of annual publication volume, journals, authors, national cooperation, and research hotspots, using CNKI database and WoS database as data sources. The key research fields of green manure were discussed in depth according to the keyword clustering results and related important literature, indicating that: (1) Research on green manure has been developing globally; however, in China, it had shown fluctuation, with a significant development. (2) Close cooperation among countries in this field was prevalent, with the United States serving as a central research hub and establishing partnerships with numerous nations. (3) Although, China had a large of publications, proportion of institutions and authors with more publications coming from China, the intermediary centrality values were generally low, indicating that the influence in the field of green manure research was not strong. (4) After analyzing keyword clustering in both CNKI and WoS databases, it was determined that the primary research focus in the field of green manure was on cultivation technology, its impact on soil and crops, and its effects on pests and diseases.

ACKNOWLEDGMENTS

This work was supported by the sub-project of the National Green Fertilizer Industry Technology System Project (CARS-22-G-22), and Youth project funded by the Presidents' Fund of Tarim University (TDZKQN201809).

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

XTM collected data, analysed the results and wrote the manuscript. JAL reviewed and guided the manuscript. JFZ analysed the results. All authors revised the manuscript and approved of the final version.

REFERENCES

ALAGOZ, G. et al. Raised bed planting and green manuring increased tomato yields through improved soil microbial activity in an organic production system. **Biol. Agric. Hortic.**, v.36, p.187-199, 2020. Available from: <https://www.tandfonline.com/doi/abs/10.1080/01448765.2020.1771416?journalCode=tbah20>. Accessed: May, 10, 2022. doi: 10.1080/01448765.2020.1771416.

ASGHAR, W.; KATAOKA, R. Green manure incorporation accelerates enzyme activity, plant growth, and changes in the fungal community of soil. **Arch. Microbiol.**, v.204, 2022. Available from: <https://link.springer.com/article/10.1007/s00203-021-02614-x>. Accessed: May, 21, 2022. doi: 10.1007/s00203-021-02614-x.

BAYSAL-GUREL, F. et al. Effect of Organic Inputs and Solarization for the Suppression of Rhizoctonia solani in Woody Ornamental Plant Production. **Plants-Basel**, v.08, 2019. Available from: <https://www.mdpi.com/2223-7747/8/5/138>. Accessed: May, 21, 2022. doi: 10.3390/plants8050138.

BOGUZAS, V. et al. The Effect of Monoculture, Crop Rotation Combinations, and Continuous Bare Fallow on Soil CO_2 Emissions, Earthworms, and Productivity of Winter Rye after a 50-Year Period. **Plants-Basel**, v.11,2022. Available from: <https://www.mdpi.com/2223-7747/11/3/431>. Accessed: May, 23, 2022. doi: 10.3390/plants11030431.

BOROZAN, A. B. et al. Green Manure Effect on The Actinomycetes Diversity And Soil Bacterial Community Structure. **15th International Multidisciplinary Scientific Geoconference (SGEM),** Albena, BULGARIA, Jun 18-24, p.177-182, 2015. Available from: <https://www.sgem.org/sgemlib/spip.php?article6032>. Accessed: May, 22, 2022. doi: 10.5593/SGEM2015/B32/S13.024.

CAMPANELLA, V. et al. Management of common root rot and Fusarium foot rot of wheat using Brassica carinata break crop green manure. **Crop Protection**, v.130, 2020. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0261219419304193?via%3Dihub>. Accessed: May, 23, 2022. doi: 10.1016/j.cropro.2019.105073.

CHANGKWIAN, A. et al. Physical Localization of the Root-Knot Nematode (Meloidogyne incognita) Resistance Locus Me7 in Pepper (Capsicum annuum). **Front. Plant Sci.**, v.10, 2019. Available from: <https://www.frontiersin.org/articles/10.3389/fpls.2019.00886/full>. Accessed: May, 23, 2022. doi: 10.3389/fpls.2019.00886.

CHEN, L. et al. Effects of Interplanting Six Leguminous Green Manure Plants in Apple Orchard on Soil Carbon and Nitrogen Characteristics. **Acta Agrestia Sinica**, v.29, p.671-676, 2021. Available from: <http://www.cnki.com.cn/Article/CJFDTotal-CDXU202104006.htm>. Accessed: May, 25, 2022. doi: 10.11733/j.issn.1007-0435.2021.04.005.

CHEN, S. et al. Bibliometric and Visualized Analysis of Mobile Technology in Tourism. **Sustainability**, 12, 2020. Available from: <https://www.mdpi.com/2071-1050/12/19/7975>. Accessed: May, 25, 2022. doi: 10.3390/su12197975.

CHEN, X. L. et al. Leveraging deep learning for automatic literature screening in intelligent bibliometrics. **International Journal of Machine Learning and Cybernetics**, v.14, n.4, p.1483-1525, 2023. Available from: <https://link.springer.com/article/10.1007/s13042-022-01710-8>. Accessed: May, 25, 2022. doi: 10.1007/s13042-022-01710-8.

CHERR, C. M. et al. Green manure approaches to crop production: A synthesis. **Agron. J.**, v.98, p.302-319, 2006. Available from: <https://acsess.onlinelibrary.wiley.com/doi/10.2134/agronj2005.0035>. Accessed: May. 25, 2022. doi: 10.2134/agronj2005.0035.

COSTA, S. R. et al. Infection of Medicago truncatula by the Root-Knot Nematode Meloidogyne javanica Does Not Require Early Nodulation Genes. **Front. Plant Sci**., v.11, p.1050, 2020. Available from: <https://www.x-mol.com/paper/1281352310068002816>. Accessed: May, 25, 2022. doi: 10.3389/fpls.2020.01050.

DA SILVA, J. P. et al. Decomposition and nutrient release from legume and non-legume residues in a tropical soil. **Eur. J. Soil Sci**., v.73,2022. Available from: <https://bsssjournals.onlinelibrary.wiley.com/doi/10.1111/ejss.13151>. Accessed: May, 25, 2022. doi: 10.1111/ejss.13151.

DAI, C. et al. Research Hotspots and Evolution of Energy Prosumer: A Literature Review and Bibliometric Analysis. **Math. Probl. Eng**., 2020. Available from: <https://www.hindawi.com/journals/mpe/2020/5703101/>. Accessed: May, 26, 2022. doi: 10.1155/2020/5703101.

DING, T. T. et al. Green Manure Crops Affected Soil Chemical Properties and Fungal Diversity and Community of Apple Orchard in the Loess Plateau of China. **Journal of Soil Science and Plant Nutrition**, v.21, 2021, p.1089-1102, Available from: <https://xueshu.baidu.com/usercenter/paper/show?paperid=c2b51304a51a41f25b2f7ab9b39a40f5&site=xueshu_se&hitarticle=1>. Accessed: May, 26, 2022. doi: 10.1007/s42729-021-00424-0.

DJIAN-CAPORALINO, C. et al. Evaluating sorghums as green manure against root-knot nematodes. **Crop Protection**, v.122, p.142-150, 2019. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0261219419301425?via%3Dihub>. Accessed: May, 26, 2022. doi: 10.1016/j.cropro.2019.05.002.

DONG, N. G. et al. Effects of green-manure and tillage management on soil microbial community composition, nutrients and tree growth in a walnut orchard. **Scientific Reports**, v.11, 2021. Available from: <https://www.nature.com/articles/s41598-021-96472-8>. Accessed: May, 26, 2022. doi: 10.1038/s41598-021-96472-8.

FERNANDES, A. M. et al. Nutrient uptake and removal by sweet potato fertilized with green manure and nitrogen on sandy soil. **Revista Brasileira De Ciencia Do Solo**, v.44, 2020. Available from: <https://www.rbcsjournal.org/article/nutrient-uptake-and-removal-by-sweet-potato-fertilized-with-green-manure-and-nitrogen-on-sandy-soil/>. Accessed: May, 26, 2022. doi: 10.36783/18069657rbcs20190127.

FRANCIOLI, D. et al. Drivers of total and pathogenic soil-borne fungal communities in grassland plant species. **Fungal Ecology**, v.48,2020. Available from: <https://www.sciencedirect.com/science/article/pii/S1754504820300994?via%3Dihub>. Accessed: May, 26, 2022. doi: 10.1016/j.funeco.2020.100987.

GAO, S. J. et al. Contributions of ammonia-oxidising bacteria and archaea to nitrification under long-term application of green manure in alkaline paddy soil. **Geoderma**, v.374, 2020. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0016706119320361?via%3Dihub>. Accessed: May, 26, 2022. doi: 10.1016/j.geoderma.2020.114419.

GAO, S. J. et al. Effects of long-term green manure application on the content and structure of dissolved organic matter in red paddy soil. **Journal of Integrative Agriculture**, v.17, p.1852-1860, 2018. Available from: <https://www.sciencedirect.com/science/article/pii/S2095311917619014?via%3Dihub>. Accessed: May, 23, 2022. doi: 10.1016/s2095-3119(17)61901-4.

GUO, X. R. et al. Effects of grass growing on soil fertility and productivity of orchards in China: A metaanalysis. **The journal of applied ecology**, v.32, 2021, p.4021-4028. Available from: <https://doc.taixueshu.com/journal/20210428yystxb.html>. Accessed: May, 27, 2022. doi:10.13287/j.1001-9332.202111.021.

GYURICZA, C. et al. Soil-Plant Interactions With Production Of Green Manure Plants Under Unfavourable Field Conditions. **Cereal Res. Commun**., 37, 439-442, 2009. Available from: <https://www.webofscience.com/wos/alldb/full-record/WOS:000265784900110>. Accessed: May, 27, 2022.

HONG, X. et al. Effects of different green manure treatments on soil apparent N and P balance under a 34-year double-rice cropping system. **Journal of Soils and Sediments**, v.19, p.73-80, 2019. Available from: <https://link.springer.com/article/10.1007/s11368-018-2049-5>. Accessed: May, 27, 2022. doi: 10.1007/s11368-018-2049-5.

HUANG, J. et al. The Response of Rice Yields on Long-term Double Cropping Rice with Different Winter Green Manure Rotation and Environment. **Ecology and Environmental Sciences**, v.25, p.1271-1276, 2016. Available from: <http://en.cnki.com.cn/Article_en/CJFDTOTAL-TRYJ201608004.htm>. Accessed: May, 27, 2022. doi: 10.16258/j.cnki.1674-5906.2016.08.003.

HWANG, H. Y. et al. Improvement of the value of green manure via mixed hairy vetch and barley cultivation in temperate paddy soil. **Field Crops Res**., v.183, p.138-146, 2015. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0378429015300320?via%3Dihub>. Accessed: May, 27, 2022. doi: 10.1016/j.fcr.2015.08.001.

JONES, J. T. et al. TOP 10 PLANT PARASITIC NEMATODES IN MOLECULAR PLANT PATHOLOGY. **J Nematol**, 2014. Available from: <https://www.webofscience.com/wos/alldb/full-record/WOS:000346299700170>. Accessed: May, 27, 2022.

KRAVTSOVA, E. V. et al. Green fertilizers as a way to preserve fertility of ordinary chernozem. **E V Kravtsova and L V Rudakova 2021 IOP Conf. Ser.: Earth Environ**, Aug 27-28, 2021. Available from: <https://iopscience.iop.org/article/10.1088/1755-1315/659/1/012055>. Accessed: May, 27, 2022. doi: 10.1088/1755-1315/659/1/012055.

LAZZERI, L. et al. Replacing methyl bromide in annual strawberry production with glucosinolate-containing green manure crops. **Pest Management Science**, v.59, p.983-990, 2003. Available from: <https://onlinelibrary.wiley.com/doi/10.1002/ps.726>. Accessed: May, 27, 2022. doi: 10.1002/ps.726.

LAZZERI, L. et al. Soil-borne phytopathogenic fungi control by Cleome hassleriana green manure. **XXVth International Horticultural Congress**, Brussels, Belgium, Aug 02-07, p.53-61, 2000. Available from: <https://www.webofscience.com/wos/alldb/full-record/WOS:000166397200005>. Accessed: May, 27, 2022.

LEE, C. R. et al. Effects of Green Manure-Maize Rotation on Phosphorus Uptake of Crop and Decrease in Phosphorus Accumulation in Organic Upland Soil. **Korean Journal of Soil Science & Fertilizer**, 53, 247-257, 2020. Available from: <https://www.kci.go.kr/kciportal/ci/sereArticleSearch/ciSereArtiView.kci?sereArticleSearchBean.artiId=ART002623339>. Accessed: May, 27, 2022. doi: 10.7745/kjssf.2020.53.3.247.

LI, M. et al. Effects of Brassica chinensis intercropping leguminous green manure on vegetable quality and soil enzyme activities. **Journal of Shanghai University**, v.25, p.275-281, 2019. Available from: <https://www.webofscience.com/wos/alldb/full-record/CSCD:6485982>. Accessed: May, 28, 2022.

LI, R. et al. Research Trends of Acupuncture Therapy on Knee Osteoarthritis from 2010 to 2019: A Bibliometric Analysis. **J. Pain Res.**, v.13, p.1901-1913, 2020. Available from: <https://www.dovepress.com/research-trends-of-acupuncture-therapy-on-knee-osteoarthritis-from-201-peer-reviewed-fulltext-article-JPR>. Accessed: May, 28, 2022. doi: 10.2147/jpr.S258739.

LIANG, Q. et al. Environment, yield and quality improvement of legume green manure planted in hilly citrus orchard of Sichuan province. **Soil and Fertilizer Sciences in China**, p.143-148, 2021. Available from: <https://kns.cnki.net/kcms2/article/abstract?v=3uoqIhG8C44YLTlOAiTRKibYlV5Vjs7iJiJTKGjg9uTdeTsOI_ra5_XVrBvrSb0kvyDgoH3CbQbxNF_vuVcNo0yMZHmsVad3us&uniplatform=NZKPT>. Accessed: May, 28, 2022. doi: 10.11838/sfsc.1673-6257.20480.

LIN, B. et al. A novel nematode effector suppresses plant immunity by activating host reactive oxygen species-scavenging system. **New Phytol.**, v.209, p.1159-1173, 2016. Available from: <https://nph.onlinelibrary.wiley.com/doi/10.1111/nph.13701>. Accessed: May, 28, 2022. doi: 10.1111/nph.13701.

LIU, S. et al. Impact of Substitution of Green Manure under Different Mixed Cropping Modes to Chemical N Fertilizer on Yield Formation Characters of Double Cropping Rice. **Acta Agriculturae Boreali-Sinica**, v.33, p.218-225, 2018. Available from: <https://kns.cnki.net/kcms2/article/abstract?v=3uoqIhG8C44YLTlOAiTRKibYlV5Vjs7i0-kJR0HYBJ80QN9L51zrPycJ-sE0ZHOqH1PEQsShl9W_o1LPzBJnNwQxhft_EOcB&uniplatform=NZKPT>. Accessed: May, 28, 2022. doi: 10. 7668/hbnxb. 2018. 05.030.

LONGA, C. M. O. et al. Soil microbiota respond to green manure in organic vineyards. **J. Appl. Microbiol.**, v.123, p.1547-1560, 2017. Available from: <https://academic.oup.com/jambio/article-abstract/123/6/1547/6714557?redirectedFrom=fulltext&login=false>. Accessed: May, 28, 2022. doi:10.1111/jam.13606.

MA, D. et al. Meta-analysis of green manure effects on soil properties and crop yield in northern China. **Field Crops Res.**, v.266, 2021. Available from: < https://www.sciencedirect.com/science/article/abs/pii/S0378429021000927?via%3Dihub>. Accessed: May. 28, 2022. doi: 10.1016/j.fcr.2021.108146.

MACIAS-BENITEZ, S. et al. Rhizospheric Organic Acids as Biostimulants: Monitoring Feedbacks on Soil Microorganisms and Biochemical Properties. **Frontiers in Plant Science**, v.11, 2020. Available from: <https://www.frontiersin.org/articles/10.3389/fpls.2020.00633/full>. Accessed: May, 28, 2022. doi: 10.3389/fpls.2020.00633.

MARSHALL, C. B.; LYNCH, D. H. No-Till Green Manure Termination Influences Soil Organic Carbon Distribution and Dynamics. **Agronomy Journal**, v.110, p.2098-2106, 2018. Available from: <https://acsess.onlinelibrary.wiley.com/doi/10.2134/agronj2018.01.0063>. Accessed: May, 28, 2022. doi: 10.2134/agronj2018.01.0063.

MASILIONYTE, L. et al. Effect of long-term crop rotation and fertilisation management on soil humus dynamics in organic and sustainable agricultural management systems. **Soil Res.**, 59, 573-585, 2021. Available from: <https://www.publish.csiro.au/SR/SR20101>. Accessed: May, 28, 2022. doi: 10.1071/sr20101.

MEHTA, C. M. et al. Compost: Its role, mechanism and impact on reducing soil-borne plant diseases. **Waste Management**, 2014. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0956053X13005655?via%3Dihub>. Accessed: May, 28, 2022. doi: 10.1016/j.wasman.2013.11.012.

MIKO, P. et al. EFFECTS OF GREEN MANURE PLANTS ON SOIL MOISTURE CONTENT AND SOIL PENETRATION RESISTANCE. **Cereal Res**. Commun., v.36, p.107-110, 2008. Available from: <https://www.webofscience.com/wos/alldb/full-record/WOS:000260963600028>. Accessed: May, 28, 2022.

MOOLEKI, S. P. et al. Effect of green manure crops, termination method, stubble crops, and fallow on soil water, available N, and exchangeable P. **Can. J. Plant. Sci.**, v.96, p.867-886, 2016. Available from: <https://cdnsciencepub.com/doi/10.1139/cjps-2015-0336>. Accessed: May, 28, 2022. doi: 10.1139/cjps-2015-0336.

NASCIMENTO, G. D. et al. Soil physico-chemical properties, biomass production, and root density in a green manure farming system from tropical ecosystem, North-eastern Brazil. **Journal of Soils and Sediments**, 21, 2203-2211, 2021. Available from: <https://link.springer.com/article/10.1007/s11368-021-02924-z>. Accessed: May, 28, 2022. doi: 10.1007/s11368-021-02924-z.

NAZ, I. et al. Control of Southern root knot nematode Meloidogyne incognita (Kofoid and White) Chitwood on tomato using green manure of Fumaria parviflora Lam (Fumariaceae). **Crop Protection**, v. 67, p.121-129, 2015. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0261219414003172?via%3Dihub>. Accessed: May, 29, 2022. doi: 10.1016/j.cropro.2014.10.005.

ORTIZ-SALGADO, D. A. et al. Soil physical disturbance reduces maize growth, nutrition, and mycorrhiza formation in a green manure rotation with vetch. **Rhizosphere**, v.19, 2021. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S2452219821001191?via%3Dihub>. Accessed: May, 28, 2022. doi: 10.1016/j.rhisph.2021.100423.

OSIPITAN, O. A. et al. Impact of Cover Crop Management on Level of Weed Suppression: A Meta-Analysis. **Crop Sci.**, v.59, p.833-842, 2019. Available from: <https://acsess.onlinelibrary.wiley.com/doi/abs/10.2135/cropsci2018.09.0589>. Accessed: Jun. 09, 2022. doi: 10.2135/cropsci2018.09.0589.

OZTURK, B.; OZER, H. Effects of Grafting and Green Manure Treatments on Postharvest Quality of Tomatoes. **Journal of Soil Science and Plant Nutrition**, v.19, p.780-792, 2019. Available from: <https://link.springer.com/article/10.1007/s42729-019-00077-0>. Accessed: Jun. 09, 2022. doi: 10.1007/s42729-019-00077-0.

PAPOLU, P. K. et al. Expression of a Cystatin Transgene in Eggplant Provides Resistance to Root-knot Nematode, Meloidogyne incognita. **Front. Plant Sci.**, v.07, 2016. Available from: <https://www.frontiersin.org/articles/10.3389/fpls.2016.01122/full>. Accessed: Jun. 09, 2022.

PENG, T. L. et al. Soil-Borne Entomopathogenic Bacteria and Fungi, Microbes for Sustainable Insect Pest Management. **An Eco-Friendly Approach**, v.01, p.23-41, 2019. Available from: <https://www.doc88.com/p-6979930311501.html?r=1>. Accessed: Jun. 09, 2022. doi: 10.1007/978-3-030-23045-6_2.

PINTO, R. et al. Organic production of horticultural crops with green manure, composted farmyard manure and organic fertiliser. **Biol. Agric. Hortic**., v.33, p.269-284, 2017. Available from: <https://www.tandfonline.com/doi/abs/10.1080/01448765.2017.1347521?journalCode=tbah20>. Accessed: Jun. 09, 2022. doi: 10.1080/01448765.2017.1347521.

RASHIDIFARD, M. et al. A Pilot Approach Investigating the Potential of Crop Rotation With Sainfoin to Reduce Meloidogyne enterolobii Infection of Maize Under Greenhouse Conditions. **Front. Plant Sci**., 12, 2021. Available from: <https://www.frontiersin.org/articles/10.3389/fpls.2021.659322/full>. Accessed: Jun. 09, 2022. doi: 10.3389/fpls.2021.659322.

REIS, L. K. et al. Which spatial arrangement of green manure is able to reduce herbivory and invasion of exotic grasses in native species? **Ecological Applications**, v.29, 2019. Available from: <https://esajournals.onlinelibrary.wiley.com/doi/10.1002/eap.2000>. Accessed: Jun. 09, 2022. doi: 10.1002/eap.2000.

RIGA, E. The effects of Brassica green manures on plant parasitic and free living nematodes used in combination with reduced rates of synthetic nematicides. **J Nematol**, v.43, n.2, p.119-121, 2011. Available from: <https://www.webofscience.com/wos/alldb/full-record/WOS:000302527400009>. Accessed: Jun. 09, 2022.

SALGADO, G. C. et al. Yield and nutrient concentrations of organic cherry tomatoes and legumes grown in intercropping systems in rotation with maize. **Biol. Agric. Hortic**., v.38, p.94-112, 2022. Available from: <https://www.tandfonline.com/doi/abs/10.1080/01448765.2021.1992796?journalCode=tbah20>. Accessed: Jun. 09, 2022. doi: 10.1080/01448765.2021.1992796.

SAYGI, H. Effects of green manure and poultry manure on strawberry production and soil fertility. **International Journal of Recycling of Organic Waste in Agriculture**, v.10, p.439-448, 2021. Available from: <https://www.webofscience.com/wos/alldb/full-record/WOS:000741375000009>. Accessed: Jun. 09, 2022. doi: 10.30486/ijrowa.2021.1910637.1139.

SONG, L. et al. Effects of Interplanting Green Manure on Soil Physico-chemical Characters in Tea Plantation. **Soils**, v.48, p.675-679, 2016. Available from: <http://en.cnki.com.cn/Article_en/CJFDTOTAL-TURA201604008.htm>. Accessed: Jun. 09, 2022. doi: 10.13758/j.cnki.tr.2016.04.008.

SU, L. et al. Experimental study and Economic Benefit Analysis of Different Green Manures Intercropping and Green Manure Returning in Newly Planted Sugarcane. **Chinese Journal of Tropical Crops**, v.42, p.747-753, 2021. Available from: <http://www.cnki.com.cn/Article/CJFDTOTAL-RDZX202103020.htm>. Accessed: Jun. 09, 2022. doi: 10.3969/j.issn.1000-2561.2021.03.020.

TAUTGES, N. E. et al. Nitrogen fertility effects of alfalfa, pea green manure, and poultry manure on organic wheat productivity in a semiarid climate. **Agroecology and Sustainable Food Systems**, v.42, p.169-188, 2018. Available from: <https://www.tandfonline.com/doi/abs/10.1080/21683565.2017.1380739?journalCode=wjsa21>. Accessed: Jun. 09, 2022. doi: 10.1080/21683565.2017.1380739.

TSEKE, P. E.; MASHELA, P. W. Efficacy of Nemafric-BL phytonematicide from fresh Cucumis africanus fruit on suppression of root-knot nematodes and growth of tomato plants. **Research on Crops**, n.18, p.289, 2017. Available from: <https://xueshu.baidu.com/usercenter/paper/show?paperid=9baa1b1cc754a00bc20bcce9a5cd9dec&site=xueshu_se>. Accessed: Jun. 09, 2022. doi: 10.5958/2348-7542.2017.00049.3.

WANG, D. et al. Benefit analysis of various interplanting modes for young macadamia orchard in mountainous region. **Acta Agriculturae Jiangxi**, v.29, p.31-35, 2017. Available from: <http://en.cnki.com.cn/Article_en/CJFDTOTAL-JXNY201707007.htm>. Accessed: Jun. 09, 2022. doi: 10.19386/j.cnki.jxnyxb.2017.07.07.

WANG, Q. et al. Analysis and Research Prospect of Effect of Green Manure Returning on Rice Cropping Ecosystem. **Soils**, 53, 243-249, 2021a. Available from: <https://www.zhangqiaokeyan.com/academic-journal-cn_acta-agrestia-sinica_thesis/0201290914661.html>. Accessed: Jun. 09, 2022. doi: 10.13758/j.cnki.tr.2021.02.004.

WANG, T. et al. Tea plantation intercropping green manure enhances soil functional microbial abundance and multifunctionality resistance to drying-rewetting cycles. **Science of the Total Environment**, v.810, 2022. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0048969721063609?via%3Dihub>. Accessed: Jun. 09, 2022. doi: 10.1016/j.scitotenv.2021.151282.

WANG, X. et al. Germplasm Screening of Green Manure Rapeseed through the Effects of Short-Term Decomposition on Soil Nutrients and Microorganisms. **Agriculture-Basel**, v.11, 2021b. Available from: <https://www.mdpi.com/2077-0472/11/12/1219>. Accessed: Jun. 14, 2022. doi: 10.3390/agriculture11121219.

WANG, X. et al. Progress in urban metabolism research and hotspot analysis based on CiteSpace analysis–ScienceDirect. **Journal of Cleaner Production**, 2020. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0959652620352689>. Accessed: Jun. 14, 2022. doi: 10.1016/j.jclepro.2020.125224.

WEI, Y. et al. Research Progress on the Influence of Green Manures on Soil-borne Diseases in Farmlands. **Acta Agrestia Sinica**, v.29, p.1605-1614, 2021. Available from: <https://www.zhangqiaokeyan.com/academic-journal-cn_acta-agrestia-sinica_thesis/0201290914661.html>. Accessed: Jun. 14, 2022. doi: 10.11733/j.issn.1007-0435.2021.08.001.

YANG, M. et al. Effect of Growing Grass on Soil PhysicochemicalProperties of Greenhouse in Southern Xinjiang. **Acat Agriculturae Boreali-Occidentalis Sinica**, v.29, p.587-594, 2020a. Available from: <http://kns.cnki.net/kcms/detail/61.1220.S.20200507.2219.024.html>. Accessed: Jun. 14, 2022. doi: 10.7606/j.issn.1004-1389.2020.04.012.

YANG, R. et al. Knowledge System Analysis on Emergency Management of Public Health Emergencies. **Sustainability**, v.12, 2020b. Available from: <https://www.mdpi.com/2071-1050/12/11/4410>. Accessed: Jun. 14, 2022. doi: 10.3390/su12114410.

YANG, Z. P. et al. Effects of Long-Term Winter Planted Green Manure on Physical Properties of Reddish Paddy Soil Under a Double-Rice Cropping System. **J. Integr. Agric**., v.11, p.655-664, 2012. Available from: <https://www.sciencedirect.com/science/article/pii/S2095311912600537?via%3Dihub>. Accessed: Jul. 02, 2022. doi: 10.1016/s2095-3119(12)60053-7.

YAO, L. et al. Freshwater microplastics pollution: Detecting and visualizing emerging trends based on Citespace II. **Chemosphere**, v.245, 2020. Available from: <https://linkinghub.elsevier.com/retrieve/pii/S004565351932867X>. Accessed: Jul. 02, 2022. doi: 10.1016/j.chemosphere.2019.125627.

ZHAI, Z. et al. Visualizing the Knowledge Domain of Project Governance: A Scientometric Review. **Adv. Civ.**

Eng., 2020. Available from: <https://www.hindawi.com/journals/ace/2020/6813043/>. Accessed: Jul. 02, 2022. doi: 10.1155/2020/6813043.

ZHANG, X. H. et al. Effects of green manure of wild rocket (Diplotaxis tenuifolia L.) on cucumber rhizosphere fungal community. **Allelopathy J**., v.53, p.93-100, 2021a. Available from: <https://www.allelopathyjournal.com/10.26651/2021-53-1-1330>. Accessed: Jul. 02, 2022. doi: 10.26651/allelo.j/2021-53-1-1330.

ZHANG, Y. et al. Accurate and nondestructive detection of apple brix and acidity based on visible and near-infrared spectroscopy. **Appl. Opt**., v.60, p.4021-4028,2021b. Available from: <https://opg.optica.org/ao/abstract.cfm?uri=ao-60-13-4021>. Accessed: Jul. 02, 2022. doi: 10.1364/ao.423994.

ZHAO, D. et al. The Effects of Intercropping Green Manure on Functional Diversity of Microbial Community in Tobacco Planting Soil. **Acta Agriculturae Boreali-Sinica**, v.34, p.201-207, 2019. Available from: <http://www.cnki.com.cn/Article/CJFDTotal-HBNB201905033.htm>. Accessed: Jul. 02, 2022. doi: 10.7668/hbnxb. 201751398.

ZHONG, D. et al. Epilepsy Occurrence and Circadian Rhythm: A Bibliometrics Study and Visualization Analysis via CiteSpace. **Frontiers in Neurology**, v.11, 2020. Available from: <https://www.frontiersin.org/articles/10.3389/fneur.2020.00984/full>. Accessed: Jul. 02, 2022. doi: 10.3389/fneur.2020.00984.

ZHOU, G. et al. Co-incorporation of rice straw and leguminous green manure can increase soil available nitrogen (N) and reduce carbon and N losses: An incubation study. **Pedosphere**, v.30, p.661-670,2020. Jul. 02, 2022. Available from: <https://www.frontiersin.org/articles/10.3389/fneur.2020.00984/full>. Accessed: Jul. 02, 2022. doi: 10.1016/s1002-0160(19)60845-3.

ZHOU, Q. et al. Influences of rape intercropping with Chinese milk vetch and straw mulching on productive benefits in dryland of southwest China. **Acta Agronomica Sinica**, v.44, p.431-441, 2018. Available from: <https://wenku.baidu.com/view/b35722fe971ea76e58fafab069dc5022aaea46e5?fr=xueshu>. Accessed: Jul. 02, 2022. doi: 10.3724/SP.J.1006.2018.00431.

ZHU, Y. et al. Effects of improving soil fertility by planting different leguminous green manure plants under different mixed cropping patterns. **Pratacultural Science**, v.37, p.889-900, 2020. Available from: <http://www.cnki.com.cn/Article/CJFDTOTAL-CYKX202005009.htm>. Accessed: Jul. 02, 2022. doi: 10.11829/j.issn.1001-0629.2019-0524.

ZHULANOVA, V. N. et al. The influence of green-manured and complete fallow on soil fertility and wheat productivity in Tuva. **3rd International Conference on Agribusiness, Environmental Engineering and Biotechnologies (AGRITECH)**, Krasnoyarsk, RUSSIA, Jun 18-20, 2020. Available from: <https://iopscience.iop.org/article/10.1088/1755-1315/548/7/072045>. Accessed: Jul. 02, 2022. doi: 10.1088/1755-1315/548/7/072045.

ZONG, X. et al. Research progress of glucoamylase with industrial potential. **Journal of Food Biochemistry**, v.46, n.7, 2022. Available from: <https://onlinelibrary.wiley.com/doi/10.1111/jfbc.14099>. Accessed: Jul. 02, 2022. doi: 10.1111/jfbc.14099.