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BIBLIOMETRIC ANALYSIS OF LITERATURE ON SILAGE: AN ALTERNATIVE FODDER CONSERVATION TECHNIQUE TO REDUCE PRESSURE ON THE FOREST

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SUMMARY

Livestock is the sub-sector of the agriculture sector that contributes directly to the livelihoods and food security of almost a billion people in India. It is estimated that by 2025,there will be a 65% deficit in green fodder and a 25% deficit in dry fodder. Forests and village common lands, that have traditionally been the mainstay of sustaining this occupation, have already become degraded due to increasing biotic pressure and lack of adequate focus on their rehabilitation and management. Ensiling is one of a fodder preservation method to produce silage. Silage research is constantly increasing to meet the needs of agricultural systems and reduce the uncontrolled grazing pressure on forests. However, the adoption of this fodder preservation technique has not been widely approached in the country. A bibliometric method was applied to investigate the general situation of the research on silage in India with respect to other countries. The upward trend in the number of papers published confirms the rising need for silage as fodder alternatives in the world. India with 41 papers in comparison to the United States of America with 1371 papers, contributes very little in the area of research on ensiling. This paper explores the international advances in silage studies by analyzing articles published between 2011 and 2021 using VOSsviewer – a software tool for constructing and visualizing bibliometric networks.

Key words : Bibliometric analysis, fodder, silage, unsustainable grazing, VOSviewer

The growing world population is expected to reach 9.2 billion by 2050 and most of the population growth will occur in developing countries. (FAO, 2009). Driven by population growth and increasing incomes, the demand for animal source foods in the developing countries is growing rapidly. Livestock contributes to poverty alleviation, food security and provides essential elements to the national economies across the globe. Livestock supports livelihoods and food security of 1.30 billion people in the world (World Bank, 2022) and affects the diet and health of many more. The term 'feed and fodder' consists of all the plant material forms such as hay, strains, silage, compressed pelleted feeds, oils-mixed rations, sprouted grains-legumes, etc. which can be used for feeding livestock. Global Perspective Studies Unit at FAO has disaggregated spatially for the years 2000 and 2030 the estimate of supply and demand for animal source foods. FAO, 2018 published detailed maps and tables of change in supply and demand from 2000 to 2030 highlighting the most dramatic change in the projected increase in demand in South Asia; 725 per cent increase overall.

The shortage and fluctuating quality and quantity of year-round feed supply is a major constraint to animal production in the developing countries. By far, the costliest input to intensification of livestock production is feed. As livestock production intensifies, it de-couples from the land resources; increasingly dependent on traded feed concentrates than on locally available feed resources. In 2004, for example, 34 percent of the global cereal harvest, a total of 690 million tonnes, were fed to livestock (Steinfeld *et al.*, 2006). A rapid growth of intensive production of livestock will call for commensurate increases in the production of feed, which will exert considerable pressure on land and water resources in some areas of the world. In the absence of adequate fodder from agriculture sector, a large percentage of people collect fodder from the forest. They lop branches of trees and shrubs, cut ground vegetation, especially grass, and bring to their homes to feed to animals. Regenerating plants of forest species are also

cut or damaged in this activity. There is seasonal scarcity of fodder in the forest too. Lack of adequate fodder in forest is one of the reasons behind largescale damage to agricultural crop by wild animals such as neelgai. In several areas, animals are driven into the forest to graze without bothering about damage to the forest. Countless species of flora and fauna are thus disappearing very fast. Singh (2003) opined that if the populace living near the fringes of forest are unable to meet their biomass and fodder demands, no amount of stringent policing can prevent them from damaging the forest for meeting their requirements.

As per 20th livestock census of India, the country is the world's highest livestock owner at about 536.76 million livestock showing an increase of 4.8% over 19th livestock census of 2012 (Ministry of Fisheries, Animal Husbandry and Dairying, 2018). Due to ever increasing population pressure of human, the arable land is mainly used for food and cash crops, thus there is a little chance of having good quality arable land available for fodder production. The increasing cattle population, due partly to the animal husbandry policies, without corresponding attention towards enhancing the forage production, is likely to put further pressure on the already scarce fodder resources in the country.

One of the promising alternatives to provide quality fodder is silage. The utilization of silage is one such technology that would allow farmers to plan ahead and strategically manage the feed for livestock. Silage making refers to preserving forage produced during the season of easy availability and feeding it to stall-fed or partially zero-grazed animals during the lean season. Wilkinson *et al.,* (2010) defined silage as the material produced by the controlled fermentation of a crop of high moisture content. Ensiling is the name given to the process, and the container, if used, is called the silo. Till date various studies have been carried out to successfully ensile various crops (Mendieta-Araica *et al.,* 2011, Phiri *et al.*, 2007, Malaviya *et al.*, 2015, Thomas *et al.*, 2018, Wang *et al.*, 2018).

In the past five decades, developments in silage conservation technologies, as reviewed by Wilkinson and Rinne (2018), have led to increased speed of physical and microbiological processes.

Bibliometrics is a quantitative study of various aspects of literature on topics and is used to identify the patterns of publication authorship, citations and/ or secondary journal coverage with the objective of getting an insight into the dynamics of the growth of knowledge in the areas under consideration globally. Sengupta (1990) defined bibliometrics as the 'organization, classification and quantitative evaluation of publication pattern of all macro- and micro-communications along with their authorship by mathematical and statistical calculus. Research trends are often studied using bibliometric studies. Pritchard (1969) introduced bibliometry as a method of mathematical and statistical analysis. Citations and content analysis are now widely used in bibliometrics.

This paper provides a review and synthesis of the silage literature to develop concise insights for future strategic research and development. We seek to obtain the answers of the following questions:-

(i) How has the amount of research on silage evolved over the decade from 2011 to 2021?
(ii) What is the distribution of papers among different countries?
(iii) Who are the most prominent researchers?
(iv) Which journals and organizations are the most prolific and influential in their publication related to silage research?
(v) How far India has contributed to the field of silage research?

MATERIALS AND METHODS

1.1. Study Design

A bibliometric analysis was performed using the database published in journals indexed in Dimensions database (https://app.dimensions.ai).The articles published between 2011 and 2021 were included.

1.2. Source of Information

Dimensions is an open-source database that provides a comprehensive collection of research work. It is a collection of linked data from grants, publications, datasets, and clinical trials to patents and policy documents in a single analytics and insightsplatform. It provides a researcher, free access to a vast collection of well curate research outputs and tools to source exactly according to need for the study.

1.3. Search Strategy

This paper focuses on the investigation of the silage research with respect to country and discipline

distributions, articles and keywords analysis. Hence the term 'silage' was searched to collect the dataset. The records were obtained with the query 'silage' in its title, abstract or keywords. The core dataset was named 'S_{ALL}', which contains all bibliographic records found in the result list of 'silage' from year 2011 to 2021.The data was retrieved from Dimensions.ai repository on 17 August 2021.

1.4. Data Analysis

The information for the documents that meet the requirements contained, year of publication, language, journal, title, author, affiliation, keywords, document type, abstract and counts of citation which were exported into CSV format and imported to Microsoft Excel 2007. The data was analysed. The dataset S_{ALL} contain 9496 records published in 1434 sources, across 201 countries and associated with 20 fields of research categories. The data was cleaned for 36 duplicates. Total S_{ALL} equalled to 9460.

1.5. Creating and Visualizing Maps

VOSviewer (version 1.6.17) was used to create and visualize bibliometric maps, evaluate collective state of silage and identify hotspots in research. It is a software tool for building and depicting networks based on bibliometric data. VOSviewer can be used to construct networks of scientific publications, scientific journals, researchers, research organizations, countries, keywords, or terms. Items in these networks can be connected by co-authorship, co-occurrence, citation, bibliographic coupling or co-citation links.

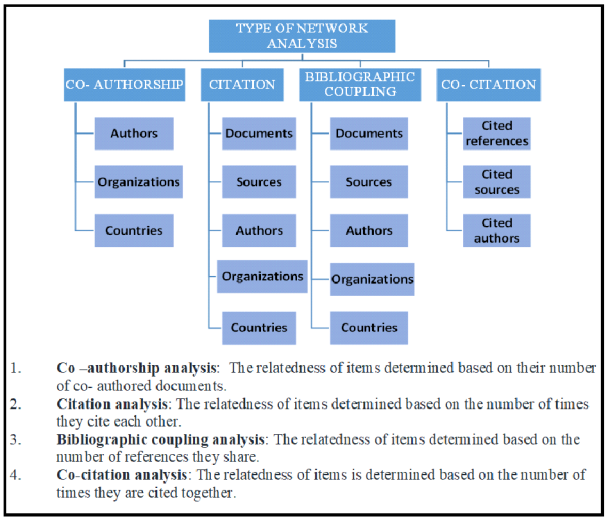

Fig. 1. Types of Network Analysis provided in VOSviewer(version 1.6.17) for SALLdataset. (Source: https://www.vosviewer.com/)

For the dataset $S_{ALL,}$ it provided four types of network analyses (Fig. 1). A link is a connection or a relation between two items. To analyse the co-authorship, citation, bibliographic coupling, and co-citation themes, two standard weight attributes were applied which were defined as "Links attribute" and "Total link strength attribute".

VOSviewer provides three modes of visualization viz. network visualization, overlay visualization, and density visualization. Network visualization shows the links between countries, organisations or journals depending on the link strength. Overlay visualisation can be used to analyse the trend of publications over a period of time as well as average citations and density.

Co-citation analysis is the most common method which helps in identifying the intellectual base of the discipline, research frontiers, important authors, and other relevant bibliometric information (Chen, 2004; Vargas-Quesada *et al.*, 2017).

RESULTS

Some of the potential results are presented here graphically using similarity visualization program (VOSviewer).

1.6. Publication by Year

Documents were retrieved from Dimensions database from the year 2011 to 2021. Fig. 2 illustrates number of publications in respective years. It is observed from the analysis that in the year 2011, 626 articles and in 2021, 777 articles were published. The number of publications reached a peak in 2020 with 1223 published articles. This indicates that work is being continuously carried out and hence there is a good scope of working in this area in coming years.

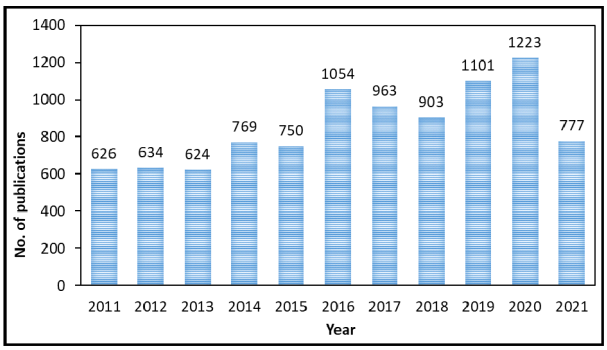

Fig. 2. Number of Publication on Silage from Year 2011- 2021.

It is also noteworthy that data collection was carried out in August, 2021 and, therefore, as it is a growing topic, more papers are expected to have been published in 2021 than in 2020.

The 9460 articles are divided into twenty categories as shown in Fig. 3. Silage is the area that is mostly covered in agriculture and veterinary sciences field. About 52.23% of papers in database are from agriculture and veterinary sciences followed by biological sciences (27.21%) and engineering (18.45%). It is important to note that the same article can be classified under more than one category, which may impair partial and total statistics.

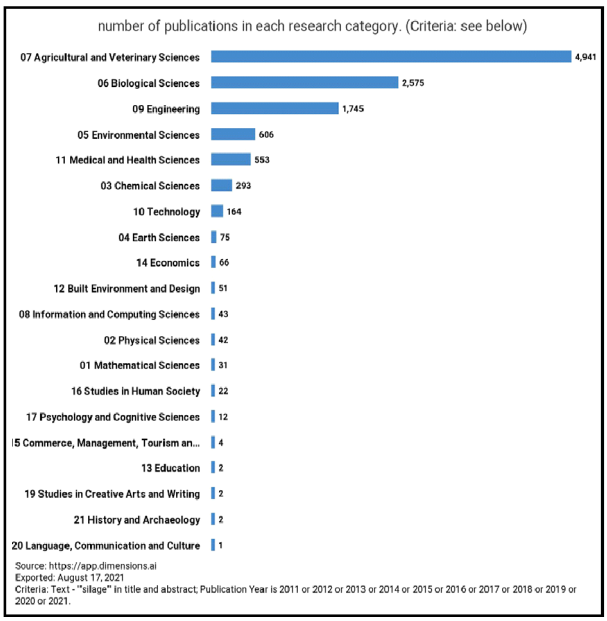

Fig. 3. Number of Publication on Silage in Each Research Category.

1.7. Publication by Journal

Sundry sources such as conferences, journals, book chapters, notes and so on are indicated in the database of Dimensions.ai. Fig. 4 shows the graphical representation of top 20 most relevant sources in the dataset S_{ALL}. Journal of Dairy Science published the maximum number of documents (742) during the period 2011 to 2021.

1.8. Geographical Analysis of Publications

Dimensions database was analysed for numerous countries by considering total number of documents published. It was noticed after analysing the authors' countries that this topic is global. Out of 69 countries, the United States of America has the highest number of papers published followed by Brazil,

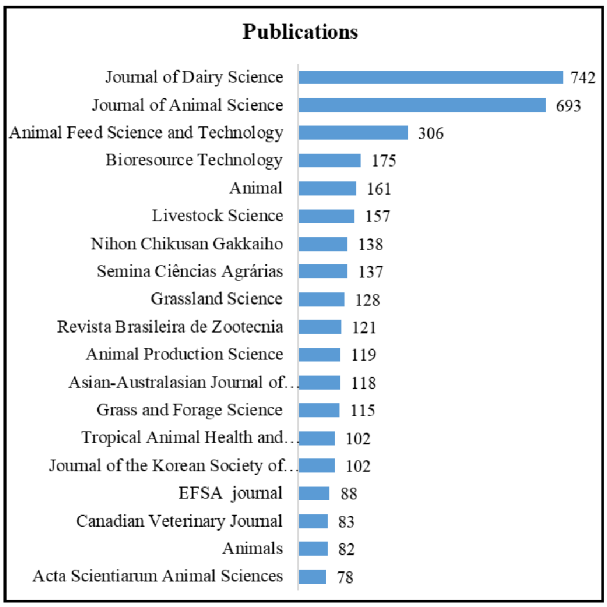

Fig. 4. List of Top 20 Sources with the Number of Publications on Silage.

China, Germany and Canada (Table 1, Fig. 5). India stands at 35th position with a tally of 41 number of papers published.

TABLE 1
List of Top five Countries on the Basis of Maximum Number of Publications

S. No.	Country	Documents
1.	United States of America	1371
2.	Brazil	1116
3.	China	829
4.	Germany	542
5.	Canada	528

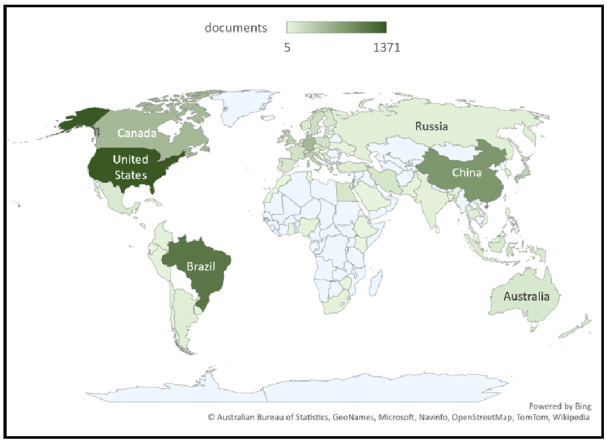

Fig. 5. Map Visualization of Published Documents.

Fig. 6 shows the country co-authorship map that was drawn from the sample of 9460 articles.The database for Silage consisted of documents spread

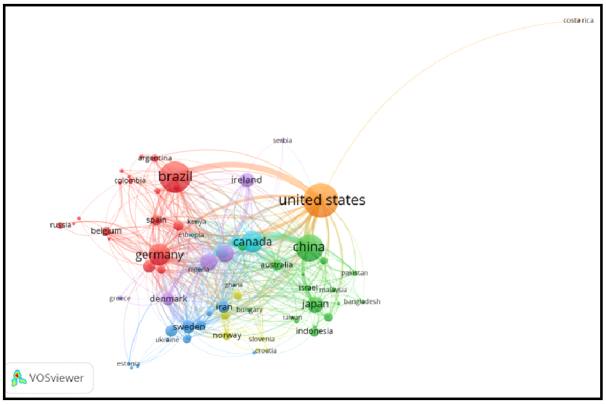

Fig. 6. Co-authorship analysis Overlay Visualization of Countries.

over 207 countries. After applying the default threshold, only 69 countries were considered for the analysis. These were grouped into 7 clusters with 560 links and 2412 total link strength. The coloured lines connecting the points shown on the map indicate the co-authorship between countries and the distance between the clusters indicates the strength between them (link strength) and how much these countries publish in co-authorship.The highest number of publications were found from the United States of America whereas, the highest linked documents belonged to the China, followed by the United States of America. The number of publications from India was 41, with 289 citations and 26 link strength.

It was observed in bibliographic coupling of countries that Green colour of United States (Fig. 7) indicated its strongest bibliographic coupling link happened between years 2016 and 2017, whereas India's dark orange colour indicated its strongest link occurred in 2018.

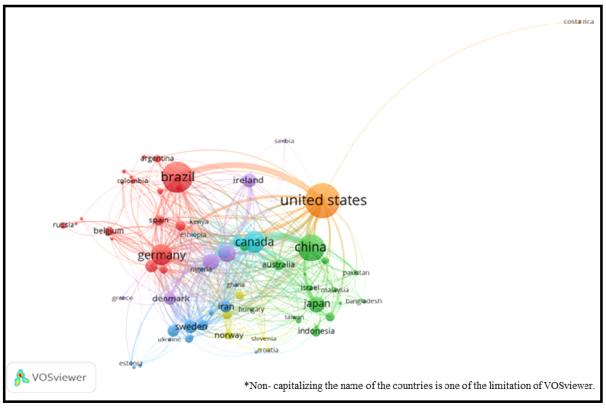

Fig. 7. Co-authorship analysis Overlay Visualization of Countries.

1.9. Analysis of Publications by Organization

The database contained 2125 organizations, out of which 503 met the default threshold. These were grouped into 20 clusters, 2886 links and 6357 total link strength. The largest set of connected items was 496. Agriculture and Agri-Food Canada had highest total link strength of 458 with 343 number of documents and 4596 citations followed by China Agricultural University with 224 documents (Table 2). Fig. 8 shows overlay visualization map of co-authorship analysis with organizations.

TABLE 2
List of Top Ten Organizations on the Basis of Number of Publications

S. No.	Organization	Documents	Total Link Strength
1.	Agriculture and Agriculture-Food Canada	343	458
2.	China Agricultural University	224	196
3.	Swedish University of Agricultural Sciences	188	239
4.	Teagasc-The Irish Agriculture And Food Development Authority	171	209
5.	University Of São Paulo	164	263
6.	Federal University Of Viçosa	150	198
7.	University Of Wisconsin-Madison	150	141
8.	São Paulo State University	147	147
9.	Wageningen University & Research	143	115
10.	Aarhus University	136	127

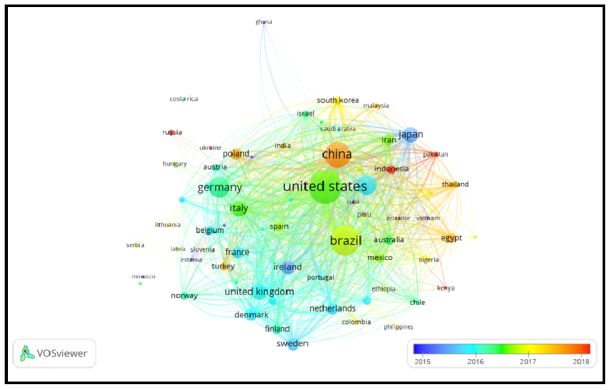

Fig. 8. Bibliographic coupling overlay visualization of countries.

1.10. Analysis of Citations

Mulet-Forteza et al. 2018 discusses about the most widely used method of assaying the impact of authors, journals and articles, for the analysis of article citations since it identifies the key papers in the research area.

All 9460 authors met the threshold. Paper titled "Mitigation of methane and nitrous oxide emissions from animal operations: A review of enteric methane

mitigation options" (Hristov *et al.*, 2013) had the highest number of 425 citations whereas, paper titled "Recent advances in silage microbiology" (Muck, 2013) had the highest 150 total link strength (Fig. 9).

Journal of Dairy Science (Table 3, Fig. 10) had the highest link strength of 4300. It also had the highest number of 742 documents along with highest number of 12905 citations.

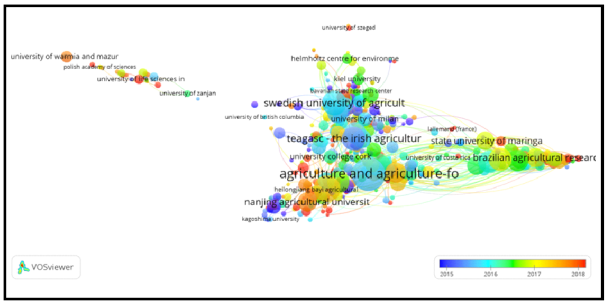

Fig. 9. Co-authorship analysis Overlay Visualization of Organizations.

TABLE 3
List of Top 5 Sources in Citation Analysis Overlay Visualization

S. No.	Source	Documents	Citations	Total link strength
1.	Journal of Dairy Science	742	12905	4300
2.	Animal Feed Science and Technology	306	3905	2560
3.	Bioresource Technology	175	5132	1668
4.	Grass and Forage Science	115	1237	1248
5.	Journal of Animal Science	693	3890	1092

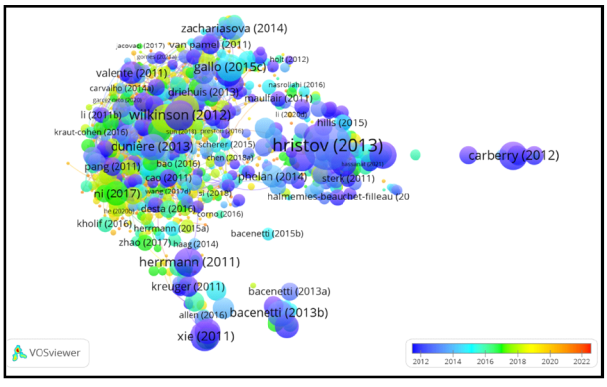

Fig. 10. Citation analysis Overlay Visualization of Publications.

1.11. Analysis by Author

Table 4 shows Azimonti, Giovanna with the highest link strength in co-authorship analysis. Citation analysis of author (Table 5) showed that Shao, Tao had highest number of 75 documents.

Through the analysis of the bibliographic coupling of authors, it is possible to see which articles and authors are correlated, through multiple citations. It was observed that 1000 items were distributed in 7 clusters. Shao Tao and Li Junfeng reflected total link strength of 37183, 241634 respectively (Fig. 11).

TABLE 4
Top 3 Authors with the Highest Total Link Strength of 345.

S. No.	Authors	Document	Citation
1.	Azimonti, Giovanna	17	15
2.	Bampidis, Vasileios	17	15
3.	Kouba, Maryline	17	15

TABLE 5
List of Top 5 Authors in Citation Analysis Overlay Visualization.

S. No.	Author	Documents	Citations	Total link strength
1.	Shao, Tao	75	743	4137
2.	Li, Junfeng	49	443	2978
3.	Zhang, Qing	38	383	2699
4.	Dong, Zhihao	46	375	2649
5.	Cai, Yimin	50	740	2270

Co citation network visualization of authors shows the frequency with which two documents are cited together by other authors. The map (Fig. 12) is defined by total five clusters. The fifth cluster with 17 items displayed zero links with other cited authors in four clusters. Authors Kung, L. (cluster 2), Van Soest, P.J. (cluster 3), Huhtanen, P. (cluster 1), Dijkstra, J. (cluster 1) and Lewis, B.A. (cluster 3) are the top five major co-cited authors.

DISCUSSION

Silage production is important for animal production systems in all the inhabited climatic zones of the world. Due to increasing competition for arable land, there is a growing demand for quality silage as a conserved forage feed for livestock (Elgersma, *et al.*, 2019). This paper explores the global research trends and maps the current research status on silage systematically. The significant contributions at country and organization levels have been discussed. From our current study, publications about silage indexed in Dimensions.ai core database were analysed. During the analysed period of silage publications, the numbers had shown an upward trend, with the highest output in 2020 (1223 publications) and the trend predicts as increase in the number of publications in the coming years (Fig. 2). The sudden drop in the publications in the year 2021 may be attributed to mid-year time of

data retrieval (August, 2021). The trend revealed the increasing interest of research community in this subject. It is evident from the analysis that certain journals are popular for particular fields of research, for example, the Journal of Dairy Science and the Journal of Animal Science were popular journals for documents on silage. India published 41 documents whereas, United States of America (1371) made the most outstanding contribution within this important field followed by Brazil (1116) and China (829). It was observed that out of total 560 links, India, which belonged to cluster 3 had 18 links and 26 total link strength in co-authorship countries analysis. The 18 links depict that, the countries with Indian researchers had co-authored documents. It was noted that India had co-authored with United States of America, China, Canada, Germany, United Kingdom (top 5 countries, Table 2). The most prominent researchers AzimontiGiovanna, Shao Tao, Wilkinson, Li Junfeng, Van Soest, Kung, L. and few others were identified from each type of network analysis. The most prolific and influential universities such as Agriculture and Agriculture Food Canada, University of Sao Paulo and others in their publication on silage were also identified. The visualization maps also indicated the rise in contribution and global recognition of India since year 2018 in the field of silage studies. Awareness and adoption of silage in India is being promoted across the states. States like Punjab, Gujarat, Maharashtra, Tamil Nadu, Uttar Pradesh, Karnataka, Haryana and Madhya Pradesh are suitable for adoption of silage technology in India (ICAR IGFRI, Proven Technology V). These states have been ensiling traditional crops such as maize, sorghum etc. Uttarakhand faces fodder scarcity in almost all places. ICAR IGFRI, 2021 developed state specific Fodder Resource Development Plan as a part of National Initiative for Accelerating Fodder Technology Adoption (NIAFTA) for Uttarakhand. It emphasized upon adoption of holistic approach for fodder production (interlink activities), conservation (in form of silage and hay) and scientific utilization. Economic Survey (2020-21), Part 1, published by Directorate of Economics and Statistics mentions about the sanctioned amount of Rs.35 lakhs for production of silage using maize in Dehradun and Haridwar districts (28 villages). The New Indian Express (2021) reported setting up of silage unit for Bhawanipatna, a city in Odhisa. This set up augmented the income of tribal farmers and migrant labourers of 27 villages. Another example of successful silage adoption in India is from the state of Telangana. To meet the growing demands of milk in Telangana and Hyderabad, Karimnagar Dairy Authorities launched the preparation of corn silage on its premises (The Hindu, 2015). Accelerated Fodder Development Programme (AFDP, 2011) by Ministry of Agriculture, Delhi has published guidelines for promoting technologies like fodder block making units, chaff cutter for fodder processing and silage making in the selected/targeted clusters by the ministry. Private startups in India are also working towards combating fodder scarcity. Cornext is one such example of an innovative company with a single goal to promote baled silage in India as a solution to fodder crisis.

CONCLUSION

The above bibliometric analysis provided data about research on silage for countries, organisations, years, journals as well as authors or groups of authors who are conducting more studies on this topic. The potential of ensiling other forages other than agricultural crops such as leaves of deciduous trees cannot be ignored. To reduce fodder scarcity during lean period and reduce dependence on forest along with unsustainable grazing ensiling unconventional feeds, fodder should be promoted in India. Although this study presents a broad overview of silage research trends, some inherent limitations cannot be ignored. Since some researchers lack subscription to popular digital inventories such as Web of Science and Scopus, the free access to bibliometric data available on dimensions.ai platform remains a good option to them. Despite its extensive archive of data, it is currently in the development stage. As a result, the findings may not be comparable with those of studies conducted using more popular databases. It was nonetheless found that the analysis conducted with the open-access database resulted in a reasonable understanding of considerably growing silage studies at various levels as desired. This method of bibliometric analysis can be adopted by the researchers in their early phase to gain a broader perspective about the current global trends.

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