Co-authorship and Pattern of Collaboration among Indian Council of Agricultural Research (ICAR) Scientists

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ABSTRACT

Based on the Web of Science database, the present paper portrays the co-authorship and pattern of collaboration of 19990 publications of ICAR Deemed Universities during 1989-2020 (32 years). The study focuses on axes like the impact of highly productive authors based on various indices, authorship patterns, different collaborative measures, and most productive research area and trend topics and also visualizes the Co-authorship network of authors and countries using VOS Viewer. Bibliometrix R packages, Bibecxel and MS Excel are used to analyze the retrieved dataset. Based on the citation metrics, Singh A K is the author with more impact. Three authorship pattern is dominating and the collaborative measures calculated as 0.98 for Degree of Collaboration, 0.669 for Collaborative co-efficient and 0.671 for Modified Collaborative Coefficient. Agriculture, Veterinary Sciences and Plant Sciences are the most active research areas. The USA is the most collaborative country and the Indian Journal of Animal Sciences is the most productive journal.

KEYWORDS: Co-authorship, Collaborative Measures, Citation Metrics, ICAR Deemed University, VOS Viewer, Web of Science.

1. INTRODUCTION

Numerous initiatives have been launched with the aim of developing collaboration among individual researchers bringing them together, for instance, in new or larger centers of excellence, or alternatively in interdisciplinary research groups. There have also been policies aimed at improving the links between science and technology through fostering research collaboration across sectors--in particular, between university and industry. Furthermore, most governments have been keen to increase the level of inter- national collaboration engaged in by the researchers whom they support in the belief that this will bring about cost savings or other benefits[1]. Collaborative research initiatives seem to have been influenced by numerous social, economic and political factors. Among these, the demands of research funding organizations can be placed high in the scale[2]. Overall, the benefits of collaboration are

held to outweigh costs and, because of this, collaborations are generally encouraged by the various levels of governance. The literature on analysis of the effects of collaboration for research output indeed demonstrates that scientific output resulting from collaboration has a significantly greater impact compared to that produced from intra-mural collaboration [3,4]. Collaboration brings significant benefits for the researchers. Studying research output as reflected in co-authorship networks provided insight into collaboration networks[5]. Scientific collaboration can be quantitatively studied by analyzing the structure and evolution of co-authorship networks. Collaboration can occur inter-institutional, inter-country, inter-state and intra institutional collaboration[6].

Agriculture is the base of Indian economy. Indian Council of Agricultural Research (ICAR) is a country's top institution which plays a vital role in agricultural research and education. The four of its institutions were recognized as Deemed Universities namely Indian Agricultural Research Institute (IARI), National Dairy Research Institute (NDRI), Indian Veterinary Research Institute (IVRI) and Central Institute on Fisheries Education (CIFE).[7]The researcher intends to analyze the co-authorship and pattern of collaboration of ICAR-Deemed University publication based on the Web of Science database. The scientometric study based on a particular institution will be beneficial for the institution to understand the current research works and to plan for future scientific development. To analyze and visualize co-authorship and collaboration several software packages are available such as R packages, Bibexcel, Pajek, Ucinet, VOSviewer, HistCite etc. The researcher utilizes the three packages, R, Bibexcel and VOSviewer for the present study.

2. RELATED WORKS

Comparatively less number of scientometric studies have conducted in the field of agriculture recently. Hence the researcher have reviewed some of the relevant studies which concentrated on co-authorship pattern of publications and institution productivity. Khalil and Sreekumar[8] have analyzed the co-authorship in the Corona virus publications published in the Web of Science database. The researchers used VOS viewer and UCINET 6 software to construct a co-authorship network. Collaborative works dominated in the Corona Virus research and the USA had co-authorship with most of the country. Zowj and others[9] have done mapping, visualizing and determining subject trends in the field of information retrieval using an author co-citation network based on articles indexed in Scopus from 2005- 2018. The highly productive and highly cited journals have the articles with high numbers of citations. In the study of Yadav and others [10] the research output of Mizoram University was found to have indeed progressed during the study period of 2004-2017 in terms of scholarly literature. The co-authorship pattern dominated than single authored papers. The 3263 research publications of eight fisheries institutions under ICAR was analyzed by Bhoomaiah and others[11] found that the number of publications of these institutes and their quality showed a steady increase over the years. A total 24,253 citations received by the publications and the Indian Journal of Fisheries (408 papers; 12.5%) published by ICAR, New Delhi found the most productive journal. The different aspects of research productivity, such as year-wise growth of publications, most preferred sources for the publications, authorship pattern, subject-wise distribution of papers, etc of National Institute of Technology, Rourkela was analyzed by Pradhan and others[12]. A total of 102692 citations for all publications during 2000-2019, with an average of 11.12 citations per paper. Two authorship patterns dominated with the degree of collaboration and collaborative coefficient are apparent with a total of 0.97 and 0.61, respectively. Ramkumar[13] made an attempt to understand the extent of doctoral guidance in Sanskrit universities in India. For the study the researcher studied the 1016 doctoral thesis from two Sanskrit Universities spanning 2002-2016. In terms of topics, Sahitya was the most popular topic followed by Shikshashastra and Vyakarana. The coverage of topics and research productivity of the guides varied between the single and multiple campus Universities. Shanmugam and Ulaganathan[14] studied the research articles of Indian

Agricultural Research Institute based on Indian Citation Index. The study found that among the 22.008 Citations density, maximum of 2.870 citations density in 2004 and minimum number of citations density 0.023 in 2019. Lipeng Fan and others [15] attempted to find out the relationship between institutional research performance with the productivity trends and citation impact. The results showed that the relationship between number of authors and citations may differ from discipline to discipline. Amanullah and others[16] examined the research publication of Sher-e-Kashmir University of Agricultural Science and Technology, Kashmir based on Indian Citation Index. The performance of the institution was measured by publishing trends and citation trends. The study found that more citations were received by older publications than newer ones. Dhage and Vaishali[17] analysed the research output of ICAR- Central Institute of Dryland Agriculture (CRIDA) during 1994 to 2018 appeared in the web of science database. The study mainly focused on productive journals, prolific authors and productive research areas.

3. OBJECTIVES

The study carried out with the aim to analyses the research output of four Deemed Universities of Indian Council of Agricultural Research based on scientometrics tools to understand the research characteristics of these institutions. In order to obtain the main objective, the following specific objectives are considered.

- To identify the impact of highly productive authors based on citation metrics such as h-index, g-index and hg-index.
- To find out the authorship pattern with citation received.
- To calculate different collaborative measures such as Degree of Collaboration, Collaborative Coefficient and Modified Collaborative Coefficient.
- To visualize the Co-authorship network of authors and countries.
- To identify the most productive research areas, productive journals and trend topics.
- To explore the trend among collaborative countries.
- To study and visualize the co-citation network of authors.

4. DATA AND METHODS

The publication output of ICAR Deemed Universities (Indian Agricultural Research Institute, National Dairy Research Institute, Indian Veterinary Research Institute and Central Institute on Fisheries Education) published between 1989-2020 were considered for the study. A Total of 19990 records were downloaded from the Web of Science Database in January 2021. The search string used for study was: Organization Enhanced= (ICAR - Central Institute of Fisheries Education OR ICAR - Indian Agricultural Research Institute OR ICAR - Indian Veterinary Research Institute OR ICAR - National Dairy Research Institute) Timespan= 1989-2020. Through the Web of Science database we can download 500 records at a time so the researcher downloaded 42 Plain text files for Bibexcel analysis and 42 Tab-delimited (Win) text files for VOS Viewer visualization. Then combine these text files using Command Prompt into a single text file for analysis. For other calculations researchers used MS Excel also.

5. RESULTS AND DISCUSSION

5.1 Author Impact

The author impact was analyzed based on the three indices such as h-index, g-index and hg-index. H-index was framed by Jorge E Hirsch in 2005 as a tool to measure both the productivity and citation impact of an author or group of authors or institution or country[18]. The g-index is an improvement of the h-index. The g-index g is the largest rank (where papers are arranged in decreasing order of the number of citations they received) such that the

first g papers have (together) at least g^2 citations[19]. The hg-index of a researcher is computed as the geometric mean of h and g-indices[20]. The relationship between these three indices can be written as h ≤hg ≤g.

Kumar S is the most productive author with 1059 publications, 42 h-index, 59 g-index and 49.77 hg-index followed by Kumar A with 961 publications, 39 h-index, 63 g-index and 49.56 hg-index and Kumar R with 591 publications, 34 h-index, 71-g-index and 49.13 hg-index (Table 1). Based on the citation metrics, Singh A K (43 h-index, 66 g-index and 53.27 hg-index) found the author with more impact followed by Singh A (30 h-index, 86 g-index and 50.79 hg-index).

Table 1: Author Impact

Author	No. of Documents	h-index	g-index	hg-index
Kumar S	1059	42	59	49.77
Kumar A	961	39	63	49.56
Kumar R	591	34	71	49.13
Singh A K	563	43	66	53.27
Singh R	538	37	61	47.50
Kumar P	405	26	41	32.64
Singh S	378	33	49	40.21
Singh B	376	34	61	45.54
Singh A	360	30	86	50.79
Singh R K	327	28	41	33.88

5.2 Authorship Pattern V/s Citations

There is a general impression that the citation increases with increasing collaboration. The number of citations received by authors are tabulated based on their authorship in Table 2 and Figure 1. The number of single authored papers are 458 (2.29%) and receives 2739 citations and the number of multiple authored papers is 19532 (97.7%) and received 205383 total citations. Among the multiple authored papers three authorship pattern is dominating with 3605 publications (18.03%) and high number of citation, 34790 followed by four authorship pattern (16.87%) with 32067 citations and two authorship pattern (16.58%) with 30382 citations. The highest number of authors collaborated in a work is 322 (Title: The tomato genome sequence provides insights into fleshy fruit evolution) and that article receives 1695 citations.

Table 2: Authorship Pattern V/s Citations

Authorship Pattern	No. of Documents	% of 19990	No. of Citations
1 Author	458	2.29	2739
2 Authors	3314	16.58	30382
3 Authors	3605	18.03	34790
4 Authors	3373	16.87	32067
5 Authors	2793	13.97	29975
6 Authors	2041	10.21	20073
7 Authors	1457	7.29	14662
8 Authors	1002	5.01	9169
9 Authors	666	3.33	7614
10 and more Authors	1281	6.41	37383

Fig 1: Authorship Pattern v/s Citation

5.3 Collaborative Measures

5.3.1 Degree of Collaboration

To find out the degree of collaboration, the formula suggested by Subramanyam[21] has been applied in the study.

The degree of collaboration can be calculated using the formula;

$DC = N_m / N_m + N_s$

Where, DC= Degree of Collaboration

N_m = Number of Multiple Authored Paper

N_s = Number of Single Authored Paper

$$DC = \frac{19532}{458 + 19532}$$

$$= \frac{19532}{19990}$$

$$= 0.977$$

5.3.2 Collaborative Co-efficient

Collaborative Co-efficient (CC) can be calculated using the formula,

$$CC = 1 - \frac{\sum_{j=1}^{i} (\frac{1}{j}) f_j}{N}$$

Where

j = the number of the author(s),

f_j = the number of j-authored research papers published in the discipline during a certain period,

N= the total number of research papers published in the discipline during a certain period and

K= the greatest number of collaborated authors per paper in a discipline.

5.3.3 Modified Collaborative Co-efficient

Modified Collaborative Co-efficient (MCC) can be calculated based on the formula,

$$MCC = \frac{A}{A-1} \left\{ 1 - \frac{\sum_{j=1}^{A} (\frac{1}{j}) f_j}{N} \right\}$$

Where A represents the number of all authors.

Table 3: Collaborative Measures

Single Authored Publications	Multi Authored Publications	DC	CC	MCC
458	19532	0.98	0.669	0.671

In the study (Table 3) the Degree of Collaboration is 0.98, the mean Collaborative Co-efficient is 0.669 and the mean Modified Collaborative Co-efficient is 0.671.

5.4 Co-authorship network of authors

In the co-authorship network of authors 4290 authors who have a minimum 5 or more documents are considered among the total of 27335 authors. Among the total authors from ICAR Deemed Universities, Singh A K has the highest number of publications (265 publications) with 2710 citations and highest link strength (Table 4). Dhama Kuldeep has 201 publications but higher citation (3688) than the most prolific author with 992 total link strength. The authors Kumar Dinesh and Kumar, S have the same number of documents though the total link strength varies more. Those authors who have less publications also show higher citation and total link strength.

Table 4: Co-authorship of Authors

Author	No. of Documents	Citations	Citation per Document	Total Link Strength
Singh, A. K.	265	2710	10.23	1061
Dhama, Kuldeep	201	3688	18.35	992
Kumar, Dinesh	160	1857	11.61	713
Kumar, S	160	1635	10.22	366
Kumar, Amit	156	1633	10.47	723
Singh, S. K.	154	801	5.20	518
Amarpal	146	793	5.43	581
Singh, R. K.	133	1099	8.26	613
Singh, G R	131	352	2.69	340
Nain, Lata	130	2194	16.88	446

In the density visualization networking of authors (Figure 2), the yellow region represents the authors who have more number of documents. A total of 4290 authors represented in 38 clusters with 44339 links and 103512 total link strength.
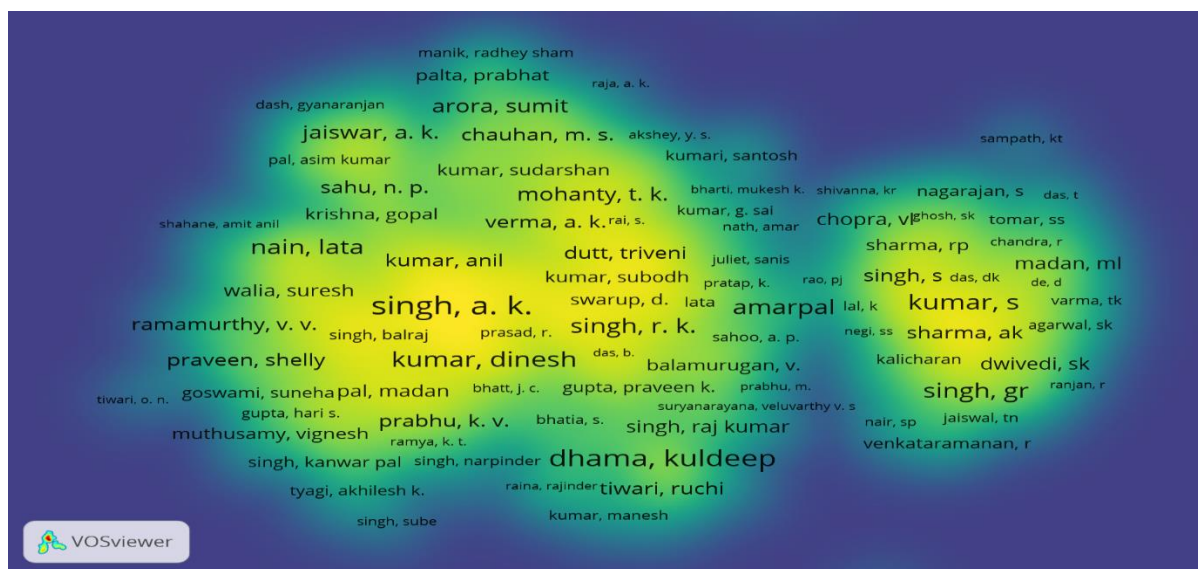

Fig 2: Density visualization of Co-authorship Network of 4290 authors

5.5 Trend among Research Area

The research area in which the scientists of ICAR-Deemed Universities have been most productive are tabulated in Table 5. Agriculture with 8580 publications (42.92%) is the most active research area. Veterinary Sciences with 2031 publications (10.16%) and Plant Sciences with 2007 publications (10.04%) are the second and third productive disciplines. The number of publications in every research area is increasing by decade; it shows the active research works by the ICAR-Deemed Universities.

Table 5: Highly Productive Research Area

Rank	Research Area	1989-1998	1999-2008	2009-2020	Total
1	Agriculture	1453	2192	4935	8580
2	Veterinary Sciences	464	608	959	2031
3	Plant Sciences	240	403	1364	2007
4	Food Science & Technology	222	353	1020	1595
5	Biotechnology & Applied Microbiology	84	205	961	1250
6	Biochemistry & Molecular Biology	126	263	758	1147
7	Environmental Sciences & Ecology	70	186	703	959
8	Science & Technology - Other Topics	116	168	551	835
9	Genetics & Heredity	49	113	647	809
10	Microbiology	69	132	512	713

5.6 Trend among Collaborative Countries

Among the total of 111 countries collaborated in research works with ICAR- Deemed Universities top 10 collaborated countries with citation are shown in Table 6. USA with 1052 publications, 8820 total citations and 40.091 average article citations found the most collaborative country. UK and Germany ranked second and third collaborative countries with 394 and 297 publications respectively.

Table 6: Collaborated Countries

Rank	Country	Publications	Total Citations	Average Article Citations
1	USA	1052	8820	40.091
2	UK	394	2735	31.08
3	Germany	297	2104	45.739
4	China	294	1301	27.104
5	Australia	280	2052	28.901
6	Japan	205	5127	142.417
7	France	165	841	49.471
8	Italy	143	92	7.077
9	Iran	131	392	11.529
10	Canada	130	905	28.281

5.7 Co-authorship Network of Countries

The co-authorship network of countries consist of 65 countries which have a minimum of 5 documents represented in Figure 3. This network has a total of 6 clusters with 1045 links and 4707 total link strength. Red color represent Cluster 1 having 24 items, Green color represent Cluster 2 with 14 items, Rose color represent Cluster 3 with 13 items, Yellow color represent Cluster 4 with 5 items, Violet color represent Cluster 5 with 5 items and Blue color represent Cluster 6 with 4 items. The USA has a high number of documents (605 publications) with 64 links and 774

total link strength. England with 185 publications, 58 links and 513 total link strengths ranked second and Australia with publications, links and total link strength.
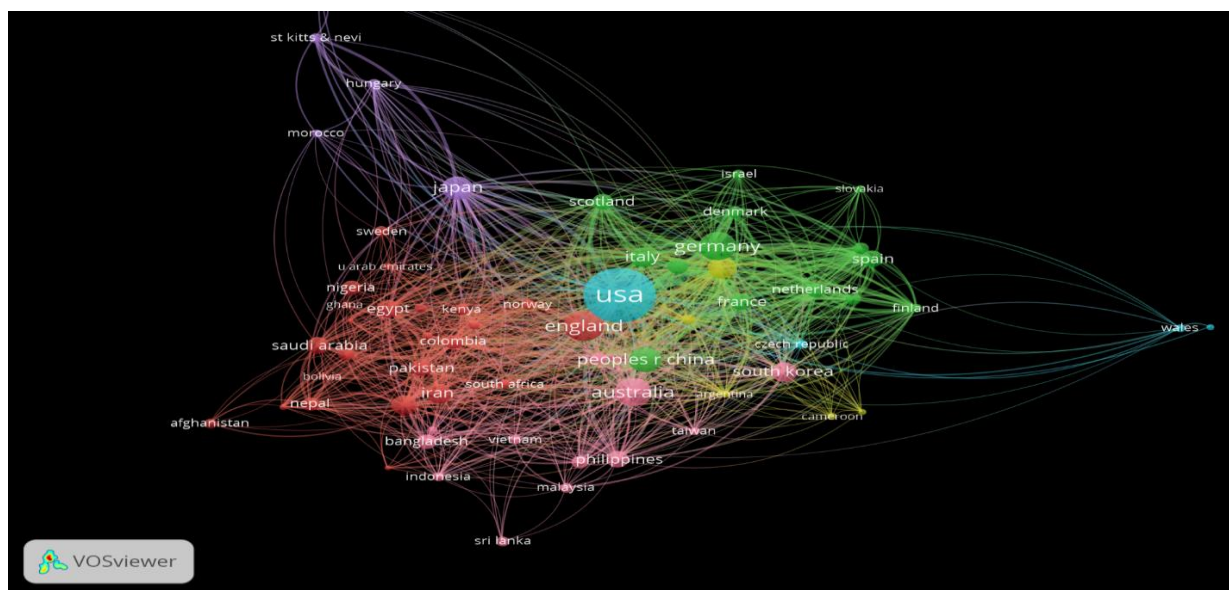

Fig 3: Co-authorship network of Countries

5.8 Trend Journals

The scientists of ICAR- Deemed Universities published their research works in 1564 journals. Among those 10 most productive journals are listed in Table 7. Indian Journal of Animal Sciences with 2511 article and total local citation score 4347 is at the top position followed by Indian Journal of Agricultural Sciences with 1302 articles and 1859 total local citation score and Indian Veterinary Journal with 556 articles and 605 total local citation score. In case of total global citation score, Current Science secured the highest citation score than the most productive journals.

Table 7: Top Journals

Sources	Articles	TLCS	TGCS	PY-start
Indian Journal of Animal Sciences	2511	4347	4205	1989
Indian Journal of Agricultural Sciences	1302	1859	2346	1989
Indian Veterinary Journal	556	1529	605	1989
Journal of Food Science and Technology-Mysore	502	1440	4099	1989
Current Science	423	1804	5161	1989
Indian Journal of Animal Research	387	92	431	2008
Indian Journal of Horticulture	308	2	415	2007
Indian Journal of Genetics and Plant Breeding	290	190	797	2008
Asian-Australasian Journal of Animal Sciences	273	1925	2284	1997
Indian Journal of Agronomy	242	670	632	1989

5.9 Co-Word Network Visualizations

Table 8 shows the Top 10 keywords in Author Keywords, Keyword Plus and All Keywords. The network visualization of Keywords generated using VOS Viewer is shown in Figure 4 and top keywords occurs in each clusters is tabulated in Table 9. The network of keywords consist of a total of 1000 keywords which have a minimum five occurrences. It includes both author keywords and keyword plus. The network consists of 7 clusters with 72250 links and 173197 total link strength. The total link strength indicates the number of publications in which two keywords occurred together[8]. Growth (1044 occurrences and 5227 total link strength), Identification (827

occurrences and 3943 total link strength) and Cattle (780 occurrences and 3759 total link strength) are the most occurring keywords.

Table 8: Top 10 Keywords in Author Keywords, Keyword Plus and All Keywords

Rank	Author keywords	Occurrences	Keyword Plus	Occurrences	All Keywords	Occurrences
1	Buffalo	596	Identification	810	Growth	1044
2	Wheat	390	Growth	791	Identification	827
3	India	301	Expression	699	Cattle	780
4	Growth	279	Cattle	543	Expression	743
5	Rice	259	Yield	502	Yield	662
6	Cattle	255	Protein	446	Buffalo	641
7	Goat	214	Quality	400	Wheat	633
8	Genetic Diversity	192	Infection	392	India	521
9	Yield	181	Resistance	369	Protein	507
10	Oxidative Stress	176	Gene	338	Quality	472

Table 9: Top Keywords occurs in each Clusters

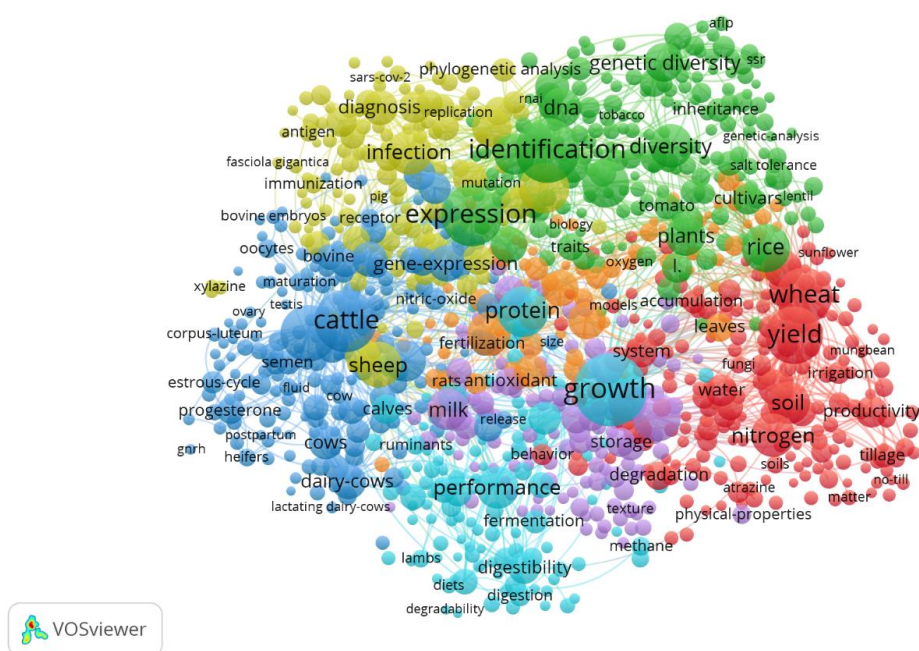| Clusters	Total Items	Keyword	Occurrences	Total Link Strength
1	197	Yield	662	3218
2	188	Identification	827	3943
3	183	Cattle	780	3759
4	126	India	521	1900
5	117	Quality	472	2033
6	112	Growth	1044	5227
7	77	Oxidative Stress	384	2562

Fig 4: Co-word network

5.10 Author Co-citation Network Analysis

According to Small, Co-citation is a linkage between a pair of documents concurrently cited by a third document[22]. The visualization of author co-citation represents the prevalence of citations by two authors (together) by other authors. Figure visualizes the co-citation network of 1000 authors who received minimum 5 citations. Each circle represents one author and the size of the circle represents the co-citation that means the bigger the circle the higher the co-citation. Figure 6 includes cluster 1-13 except cluster 12 and figure 7 represent Cluster 12 alone.
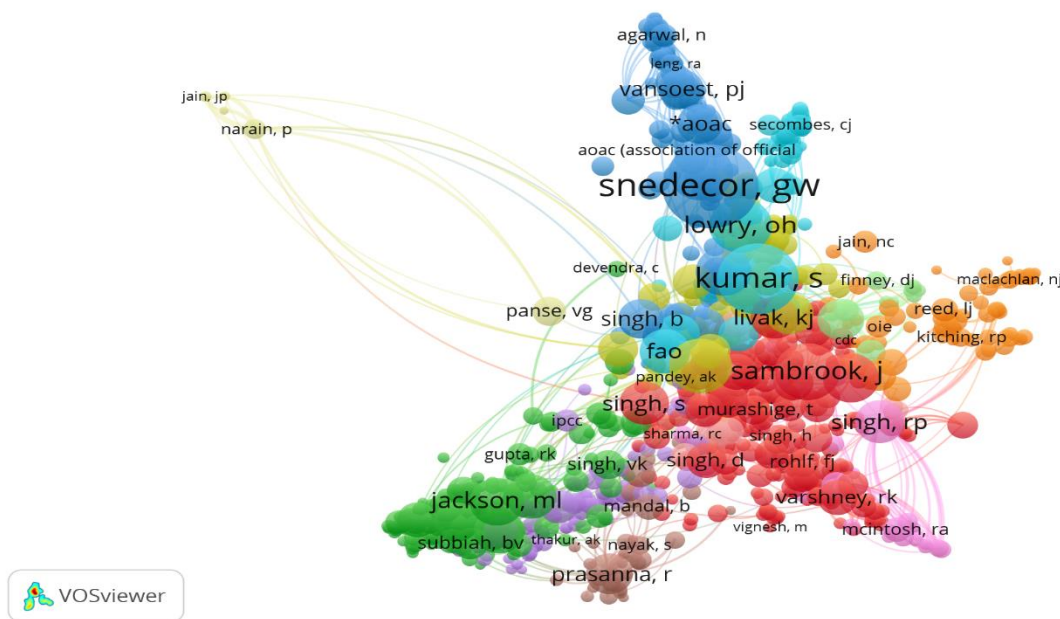

Fig 5: Co-citation network of authors

This network has 13 clusters and each cluster indicated by different colors. The top co-cited authors in each cluster are listed in Table

Table 10: Top authors in each cluster

Clusters	Total Items	Authors	Citations	Total Link Strength
1	257	Sambrook, J	811	2348
2	151	Jackson, ML	563	5484
3	117	Snedecor, GW	1730	7370
4	110	Prakash, BS	148	607
5	81	Aggarwal, PK	286	3119
6	72	Kumar, S	1245	9746
7	68	Thompson, JD	253	1543
8	38	Prasanna, R	417	7661
9	25	Singh, RP	464	5757
10	22	Sairam, RK	179	1648
11	16	Ghosh, S	409	3806
12	8	Faust, J	50	2626
13	13	Panse, VG	220	1410

Fig 6: Cluster 12 of author co-citation network

CONCLUSION

Indian Agricultural Research Institute (ICAR) is the prominent institution in the field of agriculture in India. The study investigated the co-authorship and collaboration pattern of ICAR-Deemed Universities' publications indexed in the Web of Science database. During the study period 1989-2020 the four deemed universities of ICAR published 19990 research works in which 19978 publications in English language and 12 in German languages. A study based on scientometric methods on thirty two years of publications is enough to understand the performance of an institution. The most productive authors have h-index 26 or more means each of the author have at least 26 or more citation which indicates the good quality of research work. Increase in the number of citation with collaboration is not visible in the research output. Here the results shows that the co-authorship in the agriculture field among authors and countries are sufficient to produce quality research works with more expertise from different fields. Most of the productive journals are Indian journals so the institutions should encourage their researchers to publish in international journals to get global reach of their research works and it also helps in developing a career as purposeful scientists.

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