Indian Journal of Animal Sciences **93** (9): 928–935, September 2023/Article
https://doi.org/10.56093/ijans.v93i9.115679

Mapping the research publication trends among ICAR-Animal Sciences Research Institutes in India: Web of Science-based scientometric study

P KRISHNAN[1, 2✉], M HEMALATHA[1], SUREKHA AGARWAL[1], P GIREESH-BABU[3], B M NAVEENA[3] and CH SRINIVASA RAO[1]

ICAR-National Academy of Agricultural Research Management (NAARM), Rajendranagar, Hyderabad 500 030 India

Received: 20 September 2021; Accepted: 9 August 2023

ABSTRACT

In the current study we have undertaken the scientometric analysis to map research publications from 19 different animal science research institutions under the Indian Council of Agricultural Research (ICAR), for a period of two decades (1998 to 2020), using the Web of Science (WoS) platform of Clarivate Analytics. We analyzed different scientometric parameters like year-wise citation records, institute-wise publication output, authorship pattern, publication types, top collaborating countries, research areas and journals, and relative growth rate and doubling time. Current analysis revealed that the maximum number of research articles were published in 2017 and ICAR-Indian Veterinary Research Institute contributed to the highest number of research papers and citations during the study period. Multi-authorship papers were significantly higher than single and double-authored papers. The study showed that in the field of animal sciences, the USA is the top collaborator with India resulting in 417 collaborative research papers. The Indian Journal of Animal Sciences carried the maximum number of research papers published by researchers from ICAR-Animal Science Research Institutes (ASRI) during 1998-2020. Relative Growth Rate (RGR) showed a decreasing trend in research publications while the doubling time increased during this period. The paper provides a comprehensive account of the research trends in animal sciences research and also insights for strengthening research focus in India.

Keywords: Animal science, Citations, ICAR, Publication analysis, Relative growth rate

Scientometrics is a tool used to determine publication trends in different fields of science and to characterize the quantitative aspects of science, technology, and innovation (Nalimov and Mulchenko 1971). It aims to understand the behaviour of scientific citations as a means of scholarly communication and map the intellectual landscape of science. The assessment of research publication productivity by scientometric techniques will help researchers identify and assess stronger and weaker areas of research productivity in various scientific fields including agriculture and allied subjects.

Initially, research in animal science departments began with a distinct focus on applied nutrition to enhance food, animal and poultry productivity. However, the major focus remained strongly on applied research until the early 1960s, subsequent to which the focus shifted towards discovery and fundamental research (Britt *et al.* 2008). Today, the emphasis on molecular research, health, diseases, and vaccine discovery is even stronger.

Research output mainly comprising scholarly research articles based on animal science come from a number of institutions and the Indian Council of Agricultural Research (ICAR) has a major share among them. The ICAR has 19 animal science institutions working on all the major food animals and these institutions conduct research in emerging areas of livestock and poultry sector to drive an increase in productivity, reduce the gap between potential and actual yield, ensuring food and nutritional security and to prepare the country to meet the challenges of globalization and sustainable development. Quantification of the research output from these institutions in terms of scholarly publications will provide an idea of the research capacity *vis-à-vis* other research institutions across India and globally. As per the earlier study by Garg *et al*. (2006) for a period between 1993 and 2002, among ICAR institutions, veterinary sciences had the highest output with about one-fourth of the total publications followed by dairy and animal science. These two sectors together constituted about half (49%) of the total output. The publication output in Indian agricultural and biological sciences during 1996-2011 has been evaluated by Gupta *et al.* (2013) under

Present address: [1]ICAR-National Academy of Agricultural Research Management (NAARM), Rajendranagar, Hyderabad, Telangana. [2]Bay of Bengal Programme Inter-Governmental Organization (BOBP-IGO), Chennai, Tamil Nadu. [3]ICAR-National Research Centre on Meat, Chengicherla, Hyderabad, Telangana. ✉Corresponding author email: krishnanars@naarm.org.in ; krishnanars@yahoo.com

11 sub-fields. These researchers reported that, during the period animal science and zoology fields have contributed 11024 papers accounting for 15.58% share relative to soil science (5.56%), horticulture (5.06%), aquatic science (4.80%) and others.

Analyzing the research output in specific fields through the assessment of their research publications will provide insight to prioritize the funding, policies and further strengthening of the Institutions. Hence, the present study was undertaken to explore the research publication performance of ICAR animal science research institutions individually and cumulatively during 1998-2020 (23 years) in terms of India's global share in research publication, productivity rate, citation impact, international collaborative linkages, top research areas, Relative Growth Rate (RGR) and Doubling Time (DT) of publications, using the Web of Science-based scientometric analysis.

MATERIALS AND METHODS

Data collection: The bibliometric data pertaining to 19 animal science institutes functioning under ICAR were retrieved from the Web of Science (WoS) hosted by Clarivate Analytics, for the period 1998–2020, in which three databases, viz. Science Citation Index Expanded (SCIE), Conference Proceedings Citation Index- Science (CPCI-S), and Emerging Sources Citation Index (ESCI) were considered.

To retrieve the appropriate records, an 'Advanced Search' was performed by applying query in the 'Organization-Enhanced' mode as follows; (NAME OF THE INSTITUTE_1 OR NAME OF THE INSTITUTE_2 OR NAME OF THE INSTITUTE_19) (Accessed on 24th January 2021). The search yielded 13,342 records. The data pertaining to the temporal trends in the number of scientists of each institute was collected from the annual reports of respective research institutions for the study period, using which the publications per scientist was estimated. The cumulative research productivity data for ICAR was retrieved from WoS by combining all the institution names through the 'Organization- Enhanced' search.

Data analysis and visualization

Research publication productivity assessment: The year-wise research publication productivity of ICAR-animal sciences institutes was assessed in terms of publication trend (no. of papers and relative growth rate), citations (total citations and average citation per paper) and *h-index*. The Relative Growth Rate (RGR) determines the increase in number of articles per unit of time. The mean RGR over the specific time interval was calculated using the following equation:

$$1\text{–}2\overline{R} = \frac{Log_{e2}W - Log_{e1}W}{2^T - 1^T}$$

Where, 1-2R, mean relative growth rate over the specific time period; $Log_{e1}W$, log of the initial number of articles/pages; $Log_{e2}W$, log of the final number of articles/pages after a specific period of interval; $2^T - 1^T$, the unit difference between the initial time and the final time, 'Year' can be taken here as the unit of time. The RGR for both articles and pages can be calculated separately. Therefore, $1\text{-}2\ R^{(aa\text{-}1Year\text{-}1)}$ represents the mean relative growth rate per unit of articles per year and $1\text{-}2\ R^{(pp\text{-}1Year\text{-}1)}$ represents the mean relative growth rate per unit of pages per year.

Doubling time (DT) is the time required for research papers to get double in number and is directly related to RGR. If the number of articles in a subject doubles in a defined time period, then the difference between the logarithms of numbers at the beginning and end of this time period must be logarithm of the number 2. If Napier Logarithm is used, the value of Loge2 is 0.693. Therefore, once the average growth rate is calculated then it is important to analyze that by what interval do the Napier Logarithm of numbers increased by 0.693. Thus, the corresponding doubling time (DT) of publications and citations was calculated as follows:

$$\text{Doubling Time (DT)} = 0.693/\text{RGR}$$

Publication characteristics assessment: The publication and citation-based indicators such as Total Number of Papers (TP), Total Citations (TC), Average Citations per Paper (ACPP) and *h*-index were used to determine the research publication performance and impact (Li and Ho 2008; Carpenter *et al.* 2014). The *h*-index quantifies the scientific research output of an author, institute or journal based on the most cited papers and the number of citations received (Hirsch 2005, Baldock *et al.* 2009). Apart from this, top journals that published research papers of ICAR-animal sciences institutes were also identified and impact factors of those journals mentioned in the present study were retrieved from Journal Citation Report from the Web of science platform (JCR 2019). The details pertaining to the funding sources (names of funding agencies) were also extracted using the WoS platform based on the research paper's 'Funding Text' information.

Co-authorship network mapping: VOS viewer software tool (version 1.6.14) was used for analyzing the co-authorship network between and among the ICAR-animal sciences institutes based on the domestic collaborative publications following Van Eck and Waltman (2020). The size of balls in the network map is proportionate to the quantum of unit taken for analysis (documents), while the weight of edges between balls is proportional to the collaboration volume.

RESULTS AND DISCUSSION

Research publication productivity

Trend of research publication productivity: The ICAR-animal science institutions published a total of 13,342 scholarly articles with 1,04,347 citations during the study period, 1998-2020 (Supplementary Table 1). There has been a significant temporal rise in the annual number of total publications with the maximum number of publications (973) recorded in the year 2017 and the lowest (274) in 2003. Decadal analysis of research output during the study

period shows that out of the total publications, 26.1% of the publications were recorded during 1998-2007 and 53.9% of the publications were recorded from 2008 to 2017, while the recent three alone (2018-20), accounted for 20% of the total publications.

In the current study, the number of publications was increasing over time; however, there was a dip in the number of publications between 2009 and 2011, which could possibly be due to the withdrawal of one of the important journals chosen by the Indian animal science researchers, i.e. Indian Veterinary Journal (IVJ) from the list of journals indexed by the Web of Science (Rathinasabapathy and Kopperundevi 2020). An increase in the number of publications over the years can be explained by the expansion in database coverage. As a result of this, and other additions, the relative number of articles that appear in the WoS database has increased substantially (Aksnes and Browman 2016). It is worth mentioning here that the study results of Fanelli and Lariviere (2016) reported no increase in researchers' individual publication rate throughout the century by only counting papers published as the first author.

The *h-index* is a measurement which evaluates the total impact of an author's research performance and publications. The highest average citations per paper (ACPP) value of 13.16 was reported during the year 2009. The maximum number of citations (7791) was recorded for 2014 while highest *h*-index (37) was observed for 2008 and 2014. However, the high values for *h*-index (>30) for the publications were reported only for papers published during the mid of study period, i.e. 2004-2016. A decreasing trend was observed for the Relative Growth Rate (RGR) of publications during the study period, while the Doubling Time (DT) of publications has increased gradually from 0.91 (1999) to 10.13 (2020) (Supplementary Fig. 1). A similar trend for RGR and DT was reported in the scientometric analysis of the research trend and productivity (2000-2017) in the field of mechatronics using the Web of Science database (Anandhalli and Achha 2018).

Publication metrics: The highest number of publications was recorded from ICAR-Indian Veterinary Research Institute, IVRI (5770) followed by ICAR-National Dairy Research Institute, NDRI (3809). The highest number of citations (48,185) was received by ICAR-IVRI while ICAR-National Research Centre on Meat (NRCM) recorded the highest number of average citations per paper (10.29) on its papers (n=150) published during the study period (Fig. 1).

An analysis on the pattern of number of research papers per scientist in different ASRIs showed that, the average publications per scientist in case of eight institutions was higher than that of all ICAR ASRIs, considered cumulatively. The top five animal science institutions based on the number of papers per scientist were ICAR-NRC Yak (25.95) with 7 scientific staff, ICAR-IVRI (25.33), ICAR-NDRI (24.55), ICAR-NBAGR (20.71) and ICAR-NRC on Mithun (19.27) (Fig. 1). The ACPP for overall ICAR ASRIs was 7.65 and eight institutes, viz. ICAR-NRC

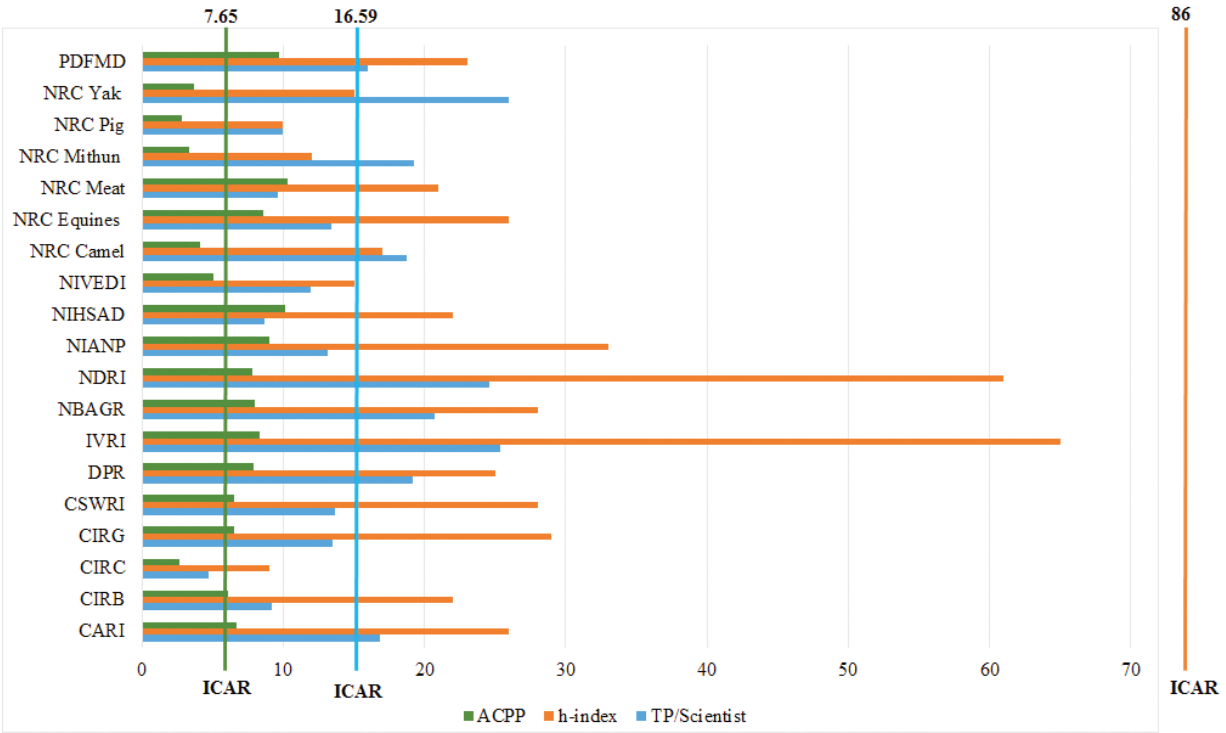

Fig. 1. Institute-wise publication characteristics of the research papers from ICAR-Animal Sciences Research Institutes during 1998-2020.

*Source: Number of scientists from annual reports, *NRC Pig- Number of scientists taken from ASTI, 2018.*

Note: ICAR comprises of all the animal science institutions data.

Meat (10.29), ICAR-NIHSAD (10.15), ICAR-PDFMD (9.72), ICAR-NIANP (9.02), ICAR-NRC Equines (8.59), ICAR-IVRI (8.35), ICAR-DPR (7.92) and ICAR-NDRI (7.85) recorded higher ACPP than the ICAR ASRIs considered cumulatively, which suggest the significant research impact of these institutions in terms of influencing further research in the respective sector.

Publication metrics in the block period of 5 years: The total publication metrics of animal sciences institutions under ICAR for five-year block periods are presented in Table 1. ICAR-IVRI, ICAR-NRC on Camel and ICAR-NRC on Yak have more publications per scientist when compared to the publications per scientists of ICAR ASRIs considered cumulatively, in all the block periods of 5 years. The ACPP of ICAR-NIHSAD was higher than that of ICAR ASRIs during all the 5-year block periods studied. The ICAR-PDFMD , ICAR-NIHSAD , ICAR-NRC on Meat , ICAR-NIANP and ICAR-NIANP recorded higher ACPP than ICAR during the block periods 1998-2002, 2003-2007, 2008-2012, 2013-2017 and 2018-2020, respectively.

Authorship-based collaboration analysis

Characteristics of collaborative research papers: The year-wise pattern of bibliometric indicators was analyzed for the ICAR ASRI's collaborative research publications (Supplementary Table 2). More than 2-fold increase in the number of national co-authorship papers was observed during 2020 compared to that in the base year (1998), while it was ~40-fold higher for the papers with at least one author from institutions outside India. During the study period, ICAR-ASRIs had published 12,155 papers (91.1% of the total publications) with all authors from India and 1,187 papers (7.65% of the total publications) with at least one international collaborator, which have received a total of 85,632 and 18,970 citations, respectively. There is an increase in the number of international collaborative papers after 2004, while the maximum number of papers with international collaboration was recorded in the year 2020. The *h*-index values were higher for national collaboration papers during the entire study period except for last three years 2018-2020, while the ACPP values were predominantly higher for papers with international collaboration.

An institute-wise analysis of national and international collaborative papers of ICAR ASRIs (Supplementary Table 3) showed that ICAR-IVRI had the highest national collaborative papers followed by ICAR-NDRI and ICAR-CSWRI. The highest number of publications with international collaboration was also recorded by ICAR-IVRI followed by ICAR-NDRI. ICAR-IVRI and ICAR-NDRI have the deemed university status in animal sciences, hence the network formed by the research scholars during their study programmes and abroad visits for higher education might have resulted in the generation of more papers in collaboration with national and international authors. The citation impact (total citations and *h-index*) of papers with national as well as international collaboration was found to be highest for the papers published by ICAR-IVRI and ICAR-NDRI (45 and 34, respectively). The ACPP for national collaborative papers was highest for ICAR-NRC on Meat, while ICAR-NBAGR recorded the highest ACPP (24.29) in case of international collaborative papers.

Collaboration type affects the citation count such as domestic collaboration increases the citations by 0.75 citations annually while international collaboration increases citation by 1.6 citations annually (Katz and Hick 1997). It has been confirmed that collaborative research increases the quality of research (Oliveira Junior *et al.* 2016). It was also observed that collaboration also results in an increase in personal productivity (Marmolejo-Leyva *et al.* 2015, Katz and Martin 1997).

Authorship pattern: The present study analyzed the authorship pattern of animal science institutions in producing scientific papers. The major proportion, i.e. 2379 publications (17.83%) was contributed by papers with four authors, followed by 2128 (15.95%) publications with five authors, and 2118 (15.87%) publications with three authors (Supplementary Table 4). Whereas, 1.45% of the research papers (193) were contributed by a single author while 4.15% publications (554) were with more than ten authors. Collaboration is essentially a critical component in research and development (Lee and Bozeman 2005, Jirotka *et al.* 2013, Wang *et al*. 2017, Qi *et al.* 2017). Due to the information explosion, the authors do not hesitate to do research in collaboration with each other and hence the higher number of papers contributed were collaborative in nature (Kumbhar *et al.* 2004).

International collaboration: The study showed that only 8.90% of the total research papers from the ICAR ASRIs were published in collaboration with other countries. India is one of the countries with less (<20%) international collaborative papers (Gazni *et al.* 2012). The top collaborating countries with India are USA (3.13%; 417 papers) followed by Germany, Japan, and England (Supplementary Table 5). The *h-index* was highest (41) for papers collaborated with USA. It was also observed that there was a gradual increase in international collaborative papers from 2004. However, the increase in international collaboration has been reported for more than a decade by several scientometric studies (Schmoch 2005, Wagner and Leydesdorff 2005, Hayati and Didegah 2010). USA is the major collaborating country of India in case of fisheries research (Bhoomaiah *et al.* 2020a) and pulses research (Krishnan *et al.* 2021). Several factors were identified for the increased collaboration e.g., to bring special expertise and knowledge not otherwise available but crucial to research outcome (Thornsteinsdottir 2000), for prestige and wide visibility; and prospects to achieve higher productivity (Lee and Bozeman 2005).

Research focus of ICAR-Animal sciences institutes

Research areas provided by WoS aid in identifying the research strengths of an institution. The WoS comprises

Table 1. Publication metrics in the block period of 5 years

Institution	1998-2002			2003-2007			2008-2012			2013-2017			2018-2020		
	TP/ Scientist	*h-index*	ACPP	TP/ Scientist	*h-index*	ACPP	TP/ Scientist	*h-index*	ACPP	TP/ Scientist	*h-index*	ACPP	TP/ Scientist	*h-index*	ACPP
CARI	2.30	11	11.57	2.55	17	10.05	3.75	17	7.52	5.49	17	5.63	2.94	6	1.36
CIRB	0.95	7	4.29	0.73	11	13.73	1.27	13	7.25	3.88	15	6.85	3.07	6	2.89
CIRC										2.51	8	3.56	1.72	4	1.19
CIRG	1.97	11	5.13	2.35	19	9.91	3.25	20	8.65	3.42	17	6.36	3.03	7	1.42
CSWRI	3.41	16	6.28	1.62	19	11.28	3.02	21	8.52	2.94	14	5.72	2.61	6	1.7
DPR	1.23	10	22.05	2.22	12	11.45	4.82	17	11.5	5.88	14	6.68	5.12	5	1.07
IVRI	3.82	38	8.41	4.09	48	12.11	5.89	44	10.35	7.42	41	7.82	4.38	21	3.16
NBAGR	0.88	8	8.12	3.08	18	11.29	6.00	21	12.48	6.55	17	6.18	4.14	6	1.32
NDRI	1.96	28	12.48	2.23	28	12.58	4.78	44	12.48	9.35	41	7.54	6.12	13	1.68
NIANP	1.47	14	9.22	1.81	15	9.11	3.00	20	11.81	3.47	20	11.24	3.55	11	3.85
NIHSAD	0.21	3	12.75	0.83	10	23.09	2.63	13	10.9	3.28	15	10.2	1.79	6	2.74
NIVEDI										5.23	15	8.49	5.84	6	2.13
NRC Camel	2.31	7	5.53	3.60	9	6.11	4.23	10	4.12	5.53	9	3.83	4.27	4	1.19
NRC Equines	1.26	6	9.67	1.98	11	9.33	2.94	20	13.75	4.74	17	7.34	2.44	7	2.59
NRC Meat	0.07	1	1	0.98	10	23.07	2.57	14	20.72	2.68	11	7.95	3.48	5	1.85
NRC Mithun	0.90	3	2.4	6.47	10	4.19	3.80	8	6.11	5.96	6	1.82	2.31	3	1.23
NRC Pig*	0.33	2	2.6	0.47	1	0.71	2.00	7	4.7	4.00	8	3.43	3.13	4	1.19
NRC Yak	3.14	4	1.62	4.43	9	6.25	5.59	9	3.69	5.50	7	3.67	3.82	2	0.57
PDFMD	0.66	6	35	2.07	10	12.77	2.87	13	14.52	8.09	11	7.62	2.64	4	1.34
ICAR	2.15	48	8.83	2.43	58	11.49	3.81	61	10.6	5.24	51	7.37	3.43	25	2.33

*Source: Number of scientists from annual reports, *NRC Pig- Number of scientists taken from ASTI, 2018.*

Note: ICAR comprises of all the animal science institutions data; TP/Scientist=Total Publications per Scientist, ACPP- Average Citations per Paper.

Table 2. Top fifteen research areas of publications during 1998-2020

Research areas	TP	% of 13342	*h-index*	ACPP	TC	WSC
Agriculture	6881	51.57	52	4.72	32587	24758
Veterinary Sciences	2656	19.91	48	7.74	20698	18579
Food Science Technology	1138	8.53	56	14.68	16747	15469
Biotechnology Applied Microbiology	747	5.60	39	11.19	8382	7992
Reproductive Biology	591	4.43	38	11.41	6744	5818
Biochemistry Molecular Biology	576	4.32	38	12.67	7297	7034
Microbiology	531	3.98	42	16.65	8856	8480
Pharmacology Pharmacy	370	2.77	35	15.7	5809	5598
Immunology	343	2.57	32	13.59	4661	4472
Virology	326	2.44	27	10.51	3436	3081
Genetics Heredity	306	2.29	26	9.69	2965	2790
Science Technology Other Topics	277	2.08	27	12.33	3440	3389
Life Sciences Biomedicine Other Topics	271	2.03	18	5	1360	1260
Cell Biology	240	1.80	25	10.27	2465	2275
Infectious Diseases	206	1.54	25	13.25	2742	2638

TP, Total Publications; ACPP, Average Citations per Paper; TC ,Total Citations; WSC, Without Self-Citation.

more than 250 subject areas in sciences, social sciences, and arts and humanities.

The results revealed 'Agriculture' to be the top research category with 6,881 total publications followed by 'Veterinary Sciences' , 'Food Science Technology', 'Biotechnology Applied Microbiology' and 'Reproductive Biology' (Table 2). The research area of 'Agriculture' produced a greater number of publications and had maximum citations. The *h-index* was the highest for the 'Food Science Technology' area and the subject area of 'Microbiology' had the highest ACPP . This shows the high interest among the researchers from ASRIs in these specific fields. The scientometric analysis on the Indian agricultural research output by Indian scientists during 1993–2002 comprising 16,891 publications showed that 'Dairy, Animal and Veterinary Sciences' had the largest share of publications (Garg *et al*. 2006).

Journals which carried most papers on animal sciences

'Indian Journal of Animal Science' is the most preferred journal (n=2954) by the faculty and researchers of animal science institutions under ICAR. The analysis was performed in terms of 5-year block periods (Supplementary Table 6; Supplementary Fig. 2). Out of the top 5 journals (block-wise), the Indian Journal of Animal Sciences remained on the top of the list, however, the average number of publications in that journal decreased over time. This might be due to increase in the number of other journals over the years. Indian Veterinary Journal occupied the second place in the top 5 journals list for the first three blocks, from 1998-2012 only. This trend could be attributed to the increase in the number of journals with greater influence and reach over the years, institutional guidelines mandating the researchers to publish in high-impact factor journals, online tools enabling better journal choices and enhanced awareness among the researchers on the research metrics. An earlier study conducted on research paper trends in Indian agriculture for 15 years showed that, most articles (6.23%) are published in Indian Journal of Animal Sciences (Peter and Devi 2018).

The top 10 journals carried 45% of the total publications during 1998-2020 (Table 3). Six of the top ten journals carrying the majority of the publications from the researchers of ICAR ASRIs were published in India. The preference for national journals by the researchers could be due to the fact that national journals have a vast local reader base and thus the researchers can communicate their findings to the relevant stakeholders. It could also be attributed to the scope of the majority of the research undertaken by the researchers having specific relevance to India. Indian Veterinary Journal has been reported to be the top journal which carried about 50% of the research publications from Tamil Nadu Veterinary and Animal Sciences University (TANUVAS), Chennai followed by Indian Journal of Animal Science (27.34%), and Indian Journal of Animal Research (7.20%) (Rathinasabapathy

Table 3. Top 10 journals published the ICAR-Animal sciences research during 1998-2020

Journals	TP*	Percentage
Indian Journal of Animal Sciences	2954	22.14
Indian Veterinary Journal	467	3.5
Indian Journal of Animal Research	466	3.49
Asian Australasian Journal of Animal Sciences	365	2.74
Veterinary World	359	2.70
Journal of Food Science and Technology Mysore	325	2.44
Indian Journal of Dairy Science	290	2.2
Tropical Animal Health and Production	255	1.90
Small Ruminant Research	246	1.84
Journal of Applied Animal Research	203	1.52

***** *TP = Total Publications.*

and Kopperundevi 2020). Many Indian journals are not indexed by the Web of Science, thus the numbers presented here do not represent the research work of the researchers from ASRIs, in entirety.

Funding sources for animal sciences research

Top funding agencies that supported Indian animal sciences research are the Indian Council of Agricultural Research, New Delhi (10.08%); Department of Biotechnology, New Delhi (4.2%); and Department of Science and Technology, New Delhi (1.35%). The present study also reports financial support from international funding sources namely US National Institute of Health (NIH); United States Department of Health and Human Services; United States Department of Agriculture (USDA); Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan (Table 4). Similar results were also observed for the fisheries research institutions (Vinitha *et al.* 2018). The results suggest that only 10.08% of the total publications from ICAR-animal sciences research institutes were supported by ICAR, which is a gross under-representation. This is due to the existing practice among the researchers from ICAR, who generally do not specify ICAR as a funding source in the case of in-house research projects and student research (Bhoomaiah *et al.* 2020b). Similarly, another study also found that the researchers do not mention the employer as the funding source (Nicola *et al.* 2016). The acknowledgement rates and practices may vary among countries. The Chinese authors acknowledge their funding source in 65% of their publications, while it is only 40% in the case of Indian authors (Costas and van Leeuwen 2012). This highlights the need for institutionalizing specific guidelines for writing acknowledgements in research articles.

Table 4. Top 10 funding agencies supported the ICAR-Animal sciences research during 1998-2020

Funding Agency	TP*	Percentage
Indian Council of Agricultural Research (ICAR)	1345	10.08
Department of Biotechnology (DBT), India	561	4.20
Department of Science Technology (DST), India	180	1.35
Council of Scientific Industrial Research (CSIR), India	115	0.86
University Grants Commission (UGC), India	105	0.80
Ministry of Science and Technology, Government of India	93	0.70
Indian Council of Medical Research (ICMR), India	91	0.68
National Dairy Research Institute (NDRI), Karnal, India	56	0.42
Indian Veterinary Research Institute (IVRI), Izatnagar, India	47	0.35
Biotechnology and Biological Sciences Research Council (BBSRC), India	46	0.34

**TP, Total Publications.*

The present study results indicate that all the ICAR-animal sciences institutions over a period, have indeed progressed in terms of the quantity and quality of scholarly literature. ICAR-IVRI contributed the maximum number of research papers and citations followed by ICAR-NDRI. ICAR-NRC on Yak with only 7 scientific staff, has the highest papers produced per scientist while ICAR-NRC on Meat has demonstrated highest ACPP. 'Agriculture', 'Veterinary Sciences' and 'Food Science Technology' are the top three research areas while 'Indian Journal of Animal Science', 'Indian Journal of Animal Research,' and 'Indian Veterinary Journal' are the most preferred journals. USA has contributed the maximum number of research papers in collaboration with India. There is an increasing trend in team work as indicated by the increase in the average number of authors in the research papers. The results of the present scientometric analysis highlight the progress and impact of ICAR-animal science institutions in terms of research productivity and provide clear direction on the strong areas of research. Though the focus of the current study was only to investigate the research trends of ICAR ASRIs, further studies including all other state agricultural universities and traditional universities which are involved in animal sciences research would provide a broader picture of the national research base in the sector.

ACKNOWLEDGEMENTS

The authors thank Dr. R. Soundararajan, Retd. Principal Scientist, ICAR-National Bureau of Fish Genetic Resources (NBFGR), Lucknow and Dr. R.C. Bhatta, Adjunct Faculty, ICAR-NAARM for reviewing and improving the content.

REFERENCES

Aksnes D W and Browman H I. 2015. An overview of global research effort in fisheries science. *ICES Journal of Marine Science* **73**(4): 1004–11.

Anandhali G and Achha L. 2018. Research trend and productivity in the field of mechatronics: A scientometric study. *International Journal of Current Research* **10**(11): 75789–94.

Baldock C, Ruimin M S and Colin G. 2009. The *h-index* is the best measure of a scientist's research productivity. *Medical Physics* **36**(4): 1043–45.

Britt J, Aberle E, Esbenshade K and Males J. 2008. Invited Review: Animal science departments of the future. *Journal of Animal Science* **86**: 3235–44.

Bhoomaiah D, Krishnan P, Kantharajan G, Rajendran K V, Ponniah A G and Ch. Srinivasa Rao. 2020a. Scientometric assessment of research publications from fisheries institutes under Indian Council of Agricultural Research (ICAR) during 2009-2018. *Indian Journal of Fisheries* **67**(4): 1–12.

Bhoomaiah D, Krishnan P, Kantharajan G, Sangeeta B and Rajendran K V. 2020b. A scientometric assessment of research on white spot syndrome virus (WSSV) in India *vis-a-vis* the world (1998–2017). *Aquaculture* **520**: 734672.

Carpenter C R, Cone D C and Sarli C C. 2014. Using publication metrics to highlight academic productivity and research impact. *Academic Emergency Medicine* **21**(10): 1160–72.

Costas R and van Leeuwen T N. 2012. Approaching the

reward triangle: General analysis of the presence of funding acknowledgements and peer interactive communication in scientific publications. *Journal of the American Society for Information Science and Technology* **63**(8): 1647–61.

Eck N K and Waltman L. 2020. VOS viewer version 1.6.14. Manual for VOS viewer version 1 .6.14. University Leiden https://www.vosviewer.com/

Fanelli D and Lariviere V. 2016. Researchers' individual publication rate has not increased in a century. *PLoS ONE* **11**(3): e0149504.

Garg K C, Kumar S and Lal K. 2006. Scientometric profile of Indian agricultural research as seen through Science Citation Index Expanded. *Scientometrics* **68**(1): 151–66.

Gazni A, Sugimoto C R and Didegah F. 2012. Mapping world scientific collaboration: Authors, Institutions, and countries. *Journal of the Association for Information Science and Technology* **63**(2): 323–35.

Gupta B M, Bala A and Kshitig A. 2013. S&T publication output of India: A scientometric analysis of publications output, 1996-2011. Library Philosophy and Practice 921.

Hayati Z and Didegah F. 2010. International scientific collaboration among Iranian researchers during 1998-2007. *Library Hi Tech* **28**(3): 433–66.

Hirsch J E. 2005. An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences of United States of America* **102**(46): 16569–72.

Jirotka M, Lee C P and Olson G M. 2013. Supporting scientific collaboration: Methods, tools, and concepts. *Computer Supported Cooperative Work* **22**(4–6): 667–715.

Katz J S and Martin. 1997. What is research collaboration? *Research Policy* **26**(1): 1–18.

Katz J S and Hicks D. 1997. How much is a collaboration worth? A calibrated bibliometric model. *Scientometrics* **40**: 541–54.

Krishnan P, Praharaj C S, Kantharajan G, Bhoomaiah D, Sekar I, Soam S K and Rao C S. 2021. A scientometric analysis of research on pulses in India during 2000–2017. *Agricultural Research* 1–14.

Lee S and Bozeman B. 2005. The impact of research collaboration on scientific productivity. *Social Studies of Science* **35**(5): 673–702.

Li Z and Ho Y S. 2008. Use of citation per publication as an indicator to evaluate contingent valuation research. *Scientometrics* **75**(1): 97–110.

Mahapatra M. 1985. On the validity of the theory of exponential growth of scientific literature. *Proceedings of the 15th IASLIC Conference,* pp. 61-70.

Marmolejo-Leyva R, Perez-Angon M A and Russell J M. 2015. Mobility and international collaboration: Case of the Mexican Scientific Diaspora. *PLoS ONE* **10**(6): e0126720.

Nalimov V V and Mulchenko Z M. 1971. Scientometrics-Studying Science as an Information Process. US Air Force Systems Command, Foreign Technology Division, Washington DC.

Nicola G, Daniele R, Joshua M, Frédérique B and Michael H. 2016. Funding Data from Publication Acknowledgments: Coverage, Uses, and Limitations. Journal of the Association for Information Science and Technology 68.

Oliveira Junior J G C, Silva L P S, Malhado A C M, Batista V S, Fabre N N and Ladle R J. 2016. Artisanal fisheries research: A need for globalization? *PLoS ONE* **11**(3): e0150689.

Perianes-Rodriguez A, Waltman L and Eck N J V. 2016. Constructing bibliometric networks: A comparison between full and fractional counting. *Journal of Informetrics* **10**(4): 1178–95.

Peter A and Devi B. 2018. Scientometric sketch of Indian agriculture literature. *Knowledge Librarian* **5**(2): 132–38.

Price D J D. 1965. Networks of scientific papers. *Science* **149**(3683): 510–15.

Qi M, Zeng A, Li M, Fan Y and Di Z. 2017. Standing on the shoulders of giants: The effect of outstanding scientists on young collaborators' careers. *Scientometrics* **111**(3): 1839–50.

Rathinasabapathy G and Kopperundevi S. 2020. Publication Productivity of Tamil Nadu Veterinary and Animal Sciences University (TANUVAS) during 1999–2018: A Scientometric view based on Web of Science. *Indian Journal of Information, Library & Society* **33**: 59–73.

Schmoch U. 2005. The technological output of scientific Institutions, pp. 717–732. *Handbook of Quantitative Science and Technology Research*. (Eds) Moed H, Glänzel W and Schmoch U. Dordrecht, Kluwer.

Thorsteinsdottir H. Public-sector research in small countries: Does size matter? Science and Public Policy **27**(6): 433–42.

Vinitha K, Kumaresan R and Kannan K. 2018. Twenty-five years of fisheries research in India based on Web of Science. *Proceedings of the International Conference on Exploring the horizons of Library and Information Sciences: From Libraries to knowledge hub*. pp. 396-403. 7-9th August 2018. Indian Statistical Institute, Bangalore, India

Wagner C S and Leydesdorff L. 2005. Mapping the network of global science: Comparing international co-authorships from 1990 to 2000. *International Journal of Technology and Globalisation* **1**(2): 185–208.

Wang W, Yu S, Bekele T M, Kong X and Xia F. 2017. Scientific collaboration patterns vary with scholars' academic ages. *Scientometrics* **112**(1): 329–43.