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ASSESSMENT OF COLLABORATION PATTERNS IN THE FIELD OF BIOLOGY IN ARMENIA DURING 2007-2020: A BIBLIOMETRIC OVERVIEW

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Bibliometric analysis is widely used for the assessment of collaboration both at the domestic and international levels, which has been known as one of the essential parts of academic performance and enhancement of scientific productivity and visibility. Evaluation of national and international cooperation in the framework of jointly published papers in biology underlies the core of present study. This research provides insight into the nature of scientific productivity and international scientific cooperation. The study aims to give a bibliometric overview via scientometric indicators based on a bibliometric database of published articles in the Biological Journal of Armenia during 2007-2020. The main indicators used for the evaluation of co-authorship patterns include the degree of collaboration, collaboration index, and the collaboration coefficient. The visualization of landscapes for both institution-wise and country-wise distributions within the international cooperation has also been performed.

Bibliometrics – collaboration – bibliometric indicators – collaboration indexes

Մատենագիտական վերլուծությունը լայնորեն օգտագործվում է ինչպես ազգային, այնպես էլ միջազգային մակարդակում գիտական համագործակցությունը գնահատելու համար, որը հայտնի է որպես ակադեմիական արտադրողականության, վերջինիս ընդլայնման և տեսանելիության բարձրացման կարևորագույն տարրերից մեկը: Սույն ուսումնասիրության հիմքում ընկած է կենսաբանության վերաբերյալ համատեղ հրապարակված հոդվածների միջոցով տեղական և միջազգային համագործակցության գնահատումը: Այս հետազոտությունը պատկերացում կարող է տալ գիտական արտադրողականության և միջազգային գիտական համագործակցության բնույթի մասին: Հետազոտության նպատակն է՝ գիտաչափական ցուցանիշներով իրականացնել մատենագիտական վերլուծություն՝ հիմնվելով Հայաստանի կենսաբանական հանդեսում 2007-2020թթ.-ի ընթացքում տպագրված հոդվածների մատենագիտական տվյալների բազայի վրա: Համահեղինակության օրինաչափությունների գնահատման համար օգտագործվող հիմնական ցուցանիշները ներառում են համագործակցության աստիճանը, համագործակցության ինդեքսը և համագործակցության գործակիցը: Տրվել է նաև միջազգային համագործակցության շրջանակներում համագործակցող ինստիտուտների և երկրների բաշխման պատկերը:

Մատենագիտություն – համագործակցություն – մատենաչափական ցուցիչներ – համագործակցության ինդեքսներ

Библиографический анализ широко используется для оценки научного сотрудничества как на национальном, так и на международном уровнях, которое, как известно, является одним из ключевых элементов повышения академической производительности,

повышения научной продуктивности и видимости. Оценка национального и международного сотрудничества в рамках совместно опубликованных статей по биологии лежит в основе этого исследования. Настоящее исследование может дать представление о природе научной продуктивности и международного научного сотрудничества. Цель исследования – дать библиометрический обзор с помощью наукометрических показателей на основе библиометрической базы данных статей, опубликованных в Биологическом журнале Армении за 2007-2020 годы. Основные показатели, используемые для оценки паттернов соавторства, включают степень сотрудничества, индекс сотрудничества и коэффициент сотрудничества. Также была проведена визуализация как для институциональных, так и для национальных распределений в рамках международного сотрудничества.

Библиометрия – сотрудничество – библиометрические показатели – индексы сотрудничества

Collaboration is a vehicle for transferring knowledge that leads to economic development and growth [10, 16]. Collaboration, on both national and international levels, has been identified in a series of studies as a crucial factor in bringing together the expertise that resides in different sectors and institutions to enhance research productivity [11]. However, it is now commonly expected that the network of collaborations should be well developed to at least the continental level [1].

Collaboration may result in cross-fertilization of ideas and clash of views which may, in turn, generate new perspectives in science suggesting that internationally co-authored articles represent a more important segment of the world science [2]. Bibliometric analysis of the impact or visibility of scientific publications as a result of scientific collaboration seems to support the idea that it pays to cooperate [7]. By collaboration, scientists can share and pass knowledge, set up a network of academic communication, and generate new academic thoughts, meanwhile, decreasing research costs and increasing research productivity [13].

There is an increasing demand for collaborative relationships among individuals, organizations, and countries. International collaboration in scientific research has increased rapidly in recent decades [4], particularly in the biological sciences [15]. It is worth mentioning, that the collaboration in biology has increased substantially and takes different shapes in field and laboratory work. Teamwork in biology has increased due to a combination of increasing research funding, greater attention to research into life, and transformations in how biologists position their research [14].

In many important areas of biological research, the scientific process increasingly involves catalyzing collaborative efforts that bring together investigators with diverse scientific backgrounds and perspectives to solve complex problems that benefit from an interdisciplinary or multidisciplinary approach [3]. Besides the mutuality of interests in taking the benefits of collaboration, economic exchanges, educational exchanges, and foreign policy plays a dominant and significant role in deciding the collaboration ties among scientists [6]. Although, studies of collaboration across sectors are preferably studied in their national context [5].

A growing science policy interest in international scientific collaboration has brought about a multitude of studies which attempt to measure the extent of international scientific collaboration between countries and to explore intercountry collaborative networks [8]. Research methods that are used to measure scientific collaboration include bibliometrics and scientometrics [12].

The current study aims to evaluate the co-authorship and scientific collaboration patterns in biology based on a bibliometric database of the Biological Journal of Armenia from 2007 to 2020.

Materials and methods. The data required for bibliometric analysis was gathered from the Biological Journal of Armenia 2007-2019 period. Collected data were analyzed with the help of Ms. Excel. The current article is focused on co-authorship patterns by the evaluation of the Degree of collaboration (DC) by Neelamma G. [9].

$$\text{Degree of collaboration (DC)} = \frac{Nm}{Nm+Ns} \qquad (1)$$

where, Nm = number of multi authors during a specific period in a discipline, Ns = number of single authors publications in a discipline during a given period. Additionally, for determining the strength of co-authorship the Collaborative coefficient has been also assessed by the given formula (2),

$$CC = \frac{\sum_{j=1}^{k}\left(\frac{1}{j}\right)Fj}{N}$$

Here F_j is the number of *j*-authored research papers, *N* is the total number of overall published research papers, and *k* is the maximum number of authors per paper. CC tends to zero as single-authored papers dominate and to *(1 – 1/j)* as *j*-authored papers dominate. This implies that the higher the value of CC, the higher the probability of multi-authored papers [4].

Results and Discussion. The total number of papers both single and multi-authored, also the number of authors for each year have been calculated and depicted in Table 1. The co-authorship patterns for the period 2007-2020 show that the input of single-authored papers is equal to 33.6% (347 papers), while multi-authored ones shared about 66.3% (673 papers) in the total quantity of articles (total 1020 papers). It was also observed that the total author per paper ratio is approximate 2.81, which was evaluated by the following procedure;

$$\text{Average author per paper} = \frac{\text{Total no. of authors}}{\text{Total number of papers}}$$

To calculate the collaborative index, the above-mentioned formula has been used according to Neelamma G. [9],

$$\sum_{f}^{A} = \frac{1/fi}{N}$$

which is a measure of the mean number of authors; *f1, f2, f3*…… = measures the number of authors, *N* = Number of publications in that year.

In the result, it was detected that, during the studied period, the Collaboration Index underwent significant changes. In particular, from 2007 the CI gradually increased, especially in 2020. The highest index was observed in 2008, 2010, and 2014. The importance of international collaboration and processing of cooperation networks are vital for sharing the academic expertise and increase of jointly published papers. Moreover, the induce of visibility for research output makes it possible for establishing scientific collaboration with scholars from various institutes, scientific centers, and universities. It is very important to use a collective unit in the evaluation of the

Table 1. Co-authorship patterns in biology based on Biological Journal of Armenia from 2007 to 2020

Years	Total Papers	Number of Papers		Total no. of multiple-authors	Total no. of single-authors	Total Authors
		Single-authored papers, (%)	Multi-authored papers, (%)			
2007	64	19 (29.7%)	45 (70.3%)	161	19	180
2008	54	16 (29.6%)	38 (70.4%)	152	16	168
2009	63	22 (34.9%)	41 (65.1%)	141	22	163
2010	71	20 (28.2%)	51 (71.8%)	194	20	214
2011	77	28 (36.4%)	49 (63.6%)	167	28	195
2012	85	30 (35.3%)	55 (64.7%)	200	30	230
2013	101	42 (41.6%)	59 (58.4%)	228	42	270
2014	89	28 (31.5%)	61 (68.5%)	232	38	270
2015	69	28 (40.6%)	41 (59.4%)	153	32	185
2016	65	18 (27.7%)	47 (72.3%)	173	18	191
2017	104	31 (29.8%)	73 (70.2%)	259	31	290
2018	67	23 (34.3%)	44 (65.7%)	155	23	178
2019	60	21 (35.0%)	39 (65.0%)	158	18	176
2020	54	21 (38.8%)	35 (64.8%)	141	19	160

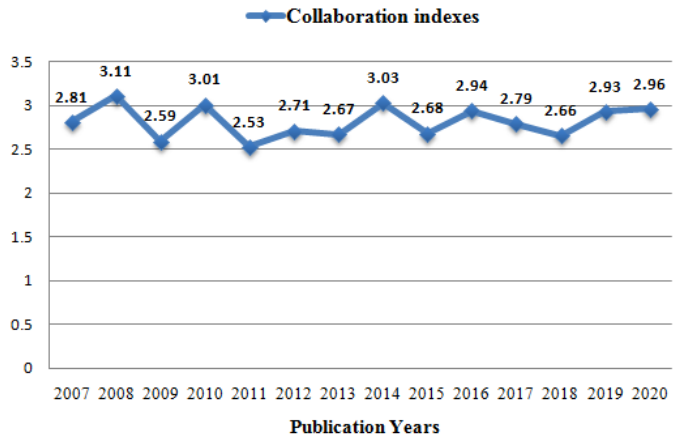

Fig. 1. Distribution and the dynamic changes of Collaboration Index during 2007-2020

collaboration, which will include the number and share of jointly published papers of different scientific units, the strength of the co-authors' links, and the impact indicators of the co-author's publications.

During this study, the overall degree of collaboration (DC) has been evaluated. The distribution of DCs is shown in Figure 2.

According to Figure 2, the degree of collaboration was changed during the study period. Intriguingly, as in the case of the collaboration index, the highest index for DC was indicated in 2010 and also in 2016 as well. After 2016 DC was reduced. In particular, the decrease of DC in 2020 was probably due to a possible impact of the Covid-19 pandemic on scientific productivity.

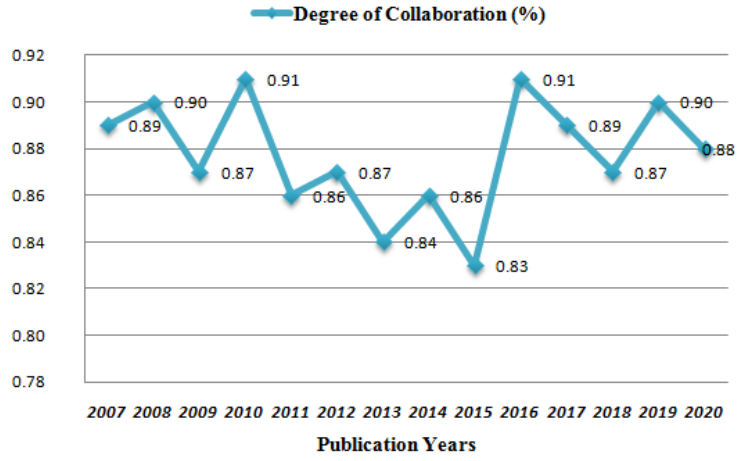

Fig. 2. Degree of Collaboration (%) for the studied period

Based on the data in Table 1, the Collaboration Coefficient from 2007 to 2020 has been calculated.

$$\textbf{Calculation: } CC = 1 - \frac{[f1 + (1/2)\,f2 + (1/3) + \ldots + (1/k)\,fk]}{N}$$

The results are shown in Table 2 and Figure 3. CC is calculated based on a collection of single-authored papers and distinguishes between single-authored, two-authored, etc., papers. It varies from 0 to 1. There is a robust decrease in CC from 2009 to 2015. The tendency of zero value is associated with the dominance of single-authored papers among publications. From Figure 3, we can consider that the Collaborative Coefficient has increased since 2017 from 0.07 to 0.57 indicating that the collaboration is quite high among biologists in recent years. The average CC is 0.31.

Table 2. Collaborative Coefficient (CC) distribution from 2007 to 2020

Years	Number of Authors									CC
	Single	Two	Three	Four	Five	Six	Seven	Eight	Nine	
2007	19	8	14	15	5	3	0	0	0	**0.49**
2008	16	15	12	3	3	3	2	1	0	**0.03**
2009	22	14	9	9	5	3	1	0	0	**0.44**
2010	20	10	16	10	10	10	1	0	3	**0.41**
2011	28	17	11	10	6	5	0	0	0	**0.31**
2012	30	11	12	24	4	3	0	1	0	**0.22**
2013	42	12	16	11	13	4	1	2	0	**0.03**
2014	42	12	16	11	13	4	1	2	0	**0.03**
2015	28	7	14	9	5	2	4	0	0	**0.38**
2016	18	10	16	8	10	1	0	1	1	**0.50**
2017	31	17	23	18	9	4	1	1	0	**0.07**
2018	23	11	16	7	6	3	0	0	1	**0.42**
2019	18	8	15	5	7	2	3	0	1	**0.53**
2020	19	3	9	8	7	3	1	2	0	**0.57**

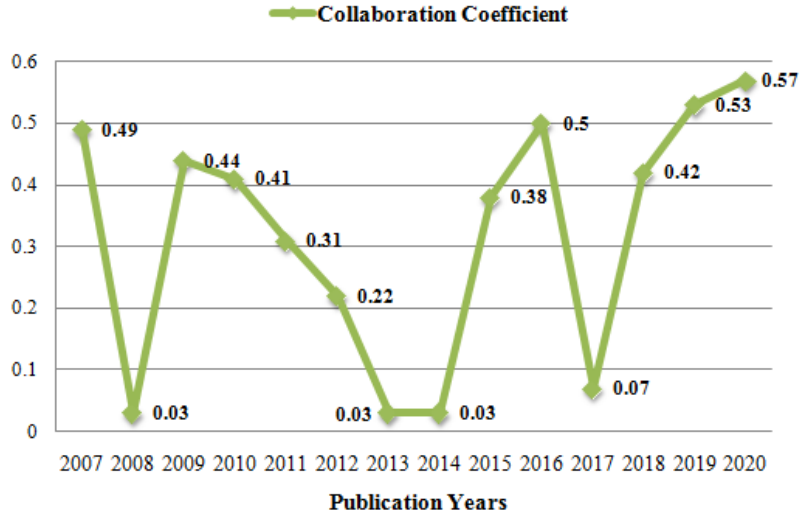

Fig. 3. Distribution of Collaboration Coefficient (CC) during 2007-2020

Institution-wise and country-wise distributions of jointly published papers are given in Table 3. The bibliometric data have been segregated by countries with several multi-authored publications. There were 55 affiliations and about 18 countries with scientific cooperation reported in the studied journal. The examination of scientific output with co-authored papers revealed that a total of 53 papers were published in the framework of international collaborations during 2007-2020.

Table 3. Country-wise distribution of jointly published papers from 2007 to 2020

No. of countries	Names of Countries	No. of jointly published papers, (%)	Publication Years
1	Belarus	5 (11.9%)	2012;2013
3	Croatia	1 (2.3%)	2020
4	Denmark	1 (2.3%)	2013
5	France	1 (2.3%)	2010
6	Georgia	1 (2.3%)	2020
7	Germany	5 (11.9%)	2008;2011;2013;2014;2020
8	Iran	7 (16.6%)	2008;2009;2010;2011;2013;2014
9	Italy	1 (2.3%)	2008
10	Malaysia	1 (2.3%)	2015
11	Norway	1 (2.3%)	2013
12	Poland	1 (2.3%)	2017
13	Switzerland	1 (2.3%)	2013
14	Russia	9 (21.4%)	2007;2008;2014;2016;2018
15	Syria	1 (2.3%)	2008
16	UK	1 (2.3%)	2010
17	Thailand	1(2.3%)	2014
18	Ukraine	2 (4.7%)	2014;2017
19	US	2 (4.7%)	2010;2016
Total	**42 papers**		

Russia has the highest share (approximately 21.4%) of publications followed by Iran (16.6%), Belarus (11.9%), and Germany (11.9%) with the same share of papers, UK and the US respectively binary publications (4.7%). The other 55 institutions from various countries shared about one paper in the collaboration with Armenian partners. It has been revealed that there are about 5 productive institutions (at least 2 jointly authored papers) within the international collaboration where the Russian scientific organizations were predominant (Table 4).

Table 4. Institution-wise distribution of jointly published papers during 2007-2020

	Name of Institutes	**Countries abbreviation**	**No. of papers**
1.	Institute of Bioorganic Chemistry, National Academy of Sciences of Belarus	BY	3
2.	Senkenberg Research Institute, Germany	DE	3
3.	University of Tehran	IR	2
4.	Scientific Research Institute of Physical and Chemical Biology named after A.N. Belozersky	RU	2
5.	Sukachev V.N. Institute of Forest SB RAS	RU	2
			Total 12 paper

There are a few scholars from foreign countries that were interested regarded to publishing in the Biological Journal of Armenia. The list of countries with the number of papers and years of publications is given below (Table 5).

Table 5. Country-wise distribution of papers published by foreign scholars from 2007 to 2020

No. of countries	**Names of Countries**	**No. of papers**	**Publication Years**
1.	China	1	2013
2.	Georgia	2	2009
3.	Germany	2	2009;2013
4.	Iran	4	2008;2011
5.	Oman	4	2011;2012
6.	Russia	8	2009;2012;2013;2014;2015;2017
7.	Ukraine	2	2014;2020
8.	Turkey	1	2015
		Total 24 paper	

This evidence suggests that the foreign scientists are quite interested in this journal, probably due to a collaborative effort of the Armenian biological society that makes the joint publications promising and possible and the fact that the Biological journal of Armenia was indexed in Scopus database.

Interestingly, the international collaboration is multidirectional from the point of geographical regions and continents in general, which includes not only the Caucasian region, but also Europe, Asia, and North America. This evidence supports the idea that the Armenian biological society is actively and efficiently collaborating with foreign scientists fostering academic productivity even in the framework of one specific scientific journal publishing in Armenia.

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