# Power Structure in Co-Authorship Network among Iranian Researchers in the Filed of Biotechnology based on Centrality Measures

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## Abstract

Scientific collaboration gives the researchers of various disciplines the opportunity to combine their capabilities, which can't be done individually. According to the scientific cooperation importance, in particular, Co-Authorship, this study intends to investigate Co-Authorship articles in a branch of new disciplines and interdisciplinary science: biotechnology. In the present bibliometric study, Network analysis method is used to visualize Co-Authorship networks. There search community of this study includes 3796 article in the ISI database related to biotechnology area written by Iranian authors. Ucinet software and its complementary netdraw are applied for data analysis. Co-Authorship matrices were created by ravarmatrix software. General survey showed that the pattern of 4-writer Articles, with 1.22%, had the highest rate of Co-Authorship followed by three-author and five-author with 7/2% and 8/16% more than other patterns, respectively. Moreover, the cooperation level of 0/95 shows high tendency of this field researchers to scientific cooperation indicators. Based on these indicators, hossein Baharvand & Khosrow khajeh had the highest rank. In general, the process of authorship among researchers in the field of biotechnology has been rising during the studied period. The Co-Authorship was much more than single-Authorship in this area. The results also showed a significant relationship between the centrality of authors and their productivity. Also authors with higher centerality were more influential and powerful in the network.

Keywords: Social Network Analysis Measures, Centrality Metrics, Research Collaboration, Co-Authorship Networks, Efficiency, Biotechnology.

## Introduction

Over the past decades, cooperation between individuals, research organizations and different countries has increased dramatically in the production of science. A reliable and important activity, scientific cooperation has facilitated the provision and dissemination of knowledge and thus has attracted the attention of researchers in various fields (Ye, Li, & Law, 2013). Concerning research areas and academic cooperation, Co-Authorship is the most visible and available index used to assess and measure the academic cooperation (Tajedini, Ghazizade & Sadatmoosavi, 2018). Assessing Co-Authorship in scientific publications is easy theoretically and is significantly correlated with academic cooperation. Cooperation can be useful for several reasons: firstly, it provides large capital of existing ideas, methods and resources and secondly, it shares the costs and saves the time as a result of the division of labor (Day, Shih, Chang, 2011). According to Cheong and Corbit (Fuyuki, 2008), several studies have emphasized the positive correlation between scientific cooperation and Co-Authorship; thus, Co-Authorship can be considered one of the most tangible and reliable forms of research cooperation. Moreover, scientific cooperation causes the science not to be restricted to specific institutions and countries; that is, all countries including developing ones can get involved in this matter and can avoid being consumers of information generated by the developed countries (Wolfram, 2010). Generally speaking, studies have shown that centrality metrics have recently been used to assess researchers' scientific products and to detect Co-Authorship behavior. It reflects the importance and necessity of carrying out this research. These

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metrics are used to identify influential people in the Co-Authorship Network (Tahmasebi limoni et al. 2018). Owing to the nature of different disciplines and their differences, levels of scientific participation and cooperation vary in various fields. Biotechnology is one of the areas which needs more cooperation due to its complex and vast nature. In Iran's 20-year vision plan in 1404, great emphasis has been placed on scientific development in new fields, especially in biotechnology, nanotechnology and environment in order to develop countries (Cheong, Corbit, 2009). Due to its new subject, vast nature and interdisciplinary nature, biotechnology has been considered by researchers in different fields (Giuliani, De petris, Nico, 2010). The researchers have been working together to create a Biotechnology Co-Authorship Network. These networks created based on cooperation between researchers are examined and analyzed according to various metrics. One of the most appropriate and common metrics for these networks is the centrality metric (Asare, Soheili, Farajpahlou & Moarefzadeh, 2012). Centrality metric identifies the location of specific nodes within a network (Nooy, Marvar & Batagelj 2005). because people who are at the center of the network are more powerful than others, usually affect other members of the network, have access to almost all resources inside the network and are considered powerful people (Sadatmoosavi et al., 2015; 2018). The most important centrality metrics include betweenness, degree, closeness and eigenvector. Betweenness is an authors' structural feature used to understand how an author is placed, among other authors, in the shortest path in the network (Hassanzade, Khodadoust, Zandian, 2011). Concerning degree, it should be said that in a Co-Authorship Network people who have the most incoming links have the highest degree and are called high-degree people (Arunachalam, 2003). Closeness has been creased based on the concept of distance or path length. People who have the least distance to all other people in the network have higher closeness centrality (Alijani, 2014). Eigenvector centrality has been created based on the principle that all edges (links) of a graph don't have the same values, but rather the edges which are linked with the influential vertices (people) are of higher value compared to other edges. Therefore, vertices with higher specific values are the vertices that are linked with the influential vertices (Borgatti, 2007 & Newman, 2008). In this study, the eigenvector centrality means people who have links with influential individuals in the Co-Authorship Network. Several studies have been conducted on this field in different areas. Asadi, Aghamolaie & Malekoutikhah, (2015) examined the status of scientific cooperation among the seminary and academic people and studied the Co-Authorship of researchers at Tehran University and Qom Seminary between 2004 and 2013. Findings of their study revealed that although Co-Authorship had a generally increasing trend among researchers at Tehran University and Qom Seminary, it was not desirable. Moreover, it seemed that authors had higher tendency towards cooperation but it could be concluded that, due to dispersion and the limited number of scientific products, only a specific group of people had the highest number of scientific products and it didn't reflect a real cooperation between these two groups. Soheili et al. (2015) analyzed the Co-Authorship network between researchers in Iran Medical Sciences fields using the social network analysis approach. Results showed that there was a significant relationship between the variables "degree centrality, beta, eigenvector and closeness" and the variable "productivity criterion" (0.001). Results of regression analysis revealed that there was a positive direct relationship between scores of centrality metrics and efficiency of researchers in Iran Medical Sciences fields. That is, the more these variables increased, the more the efficiency increased. Moreover, they concluded that the Co-Authorship Network of the study journals had low centrality and there was little communication between the authors (Soheilifar, Cheshmesohrabi, Atashpeikar, 2015). In his study conducted in 2016, Koseoglu examined the co-authorship network of articles published in the Journal of Strategic Management between 1908 and 2014. He showed that Michell and Hitt were the most central authors in the strategic management field and that they would have the possibility of creating a stronger network in the future. Moreover, these people had a greater understanding of this field than other researchers (Koseoglu, 2016). In another study, Clemens et al. (2016) carried out a bibliometric study of Co-Authorship among industrial psychologist to understand if gender difference had a role in scientific cooperation. The statistical population consisted of 4234 psychologists and their articles. Results showed that there was no evidence that the lack of cooperation between women decreased their scientific success. It rejected the idea that men's scientific success was more than women's scientific success. In their study, Kumar and John, (2013) depicted a scientific cooperation map in the field of management and business management in Malaysia based on social science citation index data in the Science Web between 1980 and 2010. The results revealed that the scientific collaboration patterns of Malaysian institutions were mostly in the intra-institutional forms than in the inter-institutional forms. Concerning the most scientific products with scientific cooperation, Malaysian top university was the best institution in terms of received citations. In the field of business and management, Malaysia mostly cooperates with developed countries including the United States of America, Australia, Japan, England and Canada. Wang et al studied China's international scientific cooperation in three levels of partner countries, universities, institutions and authors. They showed that international cooperation was conducted with 20 countries, 60% of which was with three countries of America (42.2%), Japan (9.93%) and England (8.72%). At the university level, the highest scientific cooperation was found with Chejiang University, Peking University and Tesingo University. The results revealed that the immigrant Chinese researchers played an important role in international academic cooperation; scientific collaboration with English-speaking countries was more than that with countries like Japan and France (Wang, Xu, Wang, Peng & Wang, 2013).

In conclusion, literature reviews have shown that the Co-Authorship Network has been analyzed from different aspects in different fields; however, no study has been conducted on Iranian researchers' scientific cooperation in the field of biotechnology. Therefore, concerning the interdisciplinary nature of biotechnology and its significant importance, especially in everyday life, the aim of this research was to answer this question "to what extent was co-authorship which was based on centrality metrics considered in Iranian authors' scientific products in the field of biotechnology". Moreover, concerning the importance of network mapping and information visualization which provides users with the possibility of interpreting large amounts of information and creates better conditions to think

about and analyze information, scientific structure of biotechnology which helps a general understanding and an overview of a framework in this field, informs people of improvement and development of scientific publications and identifies top researchers in this field can be depicted.

#### Research questions:

- 1. How is the trend of Iranian researchers' scientific products in the field of biotechnology?
- 2. How is the trend of co-author articles and single-author articles?
- 3. Who are the highly productive Iranian authors in the field of biotechnology?
- 4. Who are Iran's top researchers in the field of biotechnology in terms of centrality metrics?

#### Research hypothesis:

There is a significant relationship between the scores of centrality metrics (degree, closeness, betweenness and eigenvector) and researchers' efficiency in the field of biotechnology.

#### Methodology:

This bibliometric study was conducted to visualize Co-Authorship Networks using the network analysis method. The statistical population consisted of 3796 articles published by Iranian researchers in the field of biotechnology. These articles were indexed in the science expanded citation index belonging to Thomson Reuters Web of Science. In this study, data was collected in two stages: First, to retrieve data from Thomson Reuters Web of Science, the following formula was used in the advanced search section:

WC= biotechnology and CU=Iran Doctype=All document; Language=All languages Indexes=Sci-Expanded; Timespan= All years

Therefore, some documents such as Article, Meeting Abstract, Proceedings Paper, Review and Software Review which were considered scientific products and were called "article title" in this research were recorded in two Plain Text and Tab-delimited formats in 500-digit records including bibliographic information of every record. It should be noted that this data selection method was based on valid ISI Classification System that covers all articles in the field of biotechnology. After extracting data from Thomson Reuters Web of Science, since some inconsistencies were found in the names of some authors and since first names and last names of some authors were written in different ways, full names of these authors were searched and the names which were repeated more and were more common were selected. Data was preprocessed and duplicates, mistakes and similar cases with different spellings were corrected. Authors' names were standardized because some authors had written their names differently in various articles. To prepare the authors' matrix, the final file was converted into RAVARMATRIX software format and was then entered the software. Thus, the weighted square matrix with 9067 columns and 9067 rows was obtained in this way. In this matrix, diagonal cells were considered zero. After that, the created matrix was uploaded using the UCINET software and was converted into UCINET (##H) format; centrality metrics (degree, betweenness, closeness and eigenvector) was obtained. Then, the authors' co-authorship network was depicted using NETDRAW and UCINET complementary version. It should be noted that although all measures were taken to reduce errors and data loss, some data might be lost that was not part of our population.

#### **Findings:**

#### 1. How is the trend of Iranian researchers' scientific products in the field of biotechnology?

Examining this trend showed that it was different in various periods and conditions. These conditions might include the importance of and researchers' needs to the field of biotechnology as well as the scientific contributions. The total number of scientific products in this period was 3796 articles indexed in the Web of Science database in the field of biotechnology (Fig. 1). As shown in this graph, the number of scientific products in the field of biotechnology was only 20 articles in the years before 1998. In 1998, the number of products was very low (only 5 articles). In 1999, it increased considerably and reached 14 articles. Between 1999 and 2011, there was a significant increase in these products; the highest number of scientific publications was observed in 2011 (665 articles) (17.26%) and the lowest number was observed in 1998 (5 articles) (0.13%). This fluctuation was shown in the following graph. Between 1998 and 2011, there was a slight increase in the field of biotechnology, while a decrease was found from 2011 to 2013. In 2014, there was a slight increase, but 2015 experienced a decrease in the scientific products.



Fig. 1: the trend of scientific products in the field of biotechnology from the beginning to 2015

## 2. How is the trend of co-author articles and single-author articles?

Research and scientific findings are conducted and published by either a single author or some authors. Undoubtedly, in single-author studies, the author must examine previous studies and establish a kind of mental connection with their creators. On the other hand, conducting group research and publishing collective findings requires mental and social interactions among the colleagues. Figure 2 and 3 showed the frequency distribution of single-author and co-author articles from the beginning up to 2015. As shown in this graph, the highest number of co-author articles was related to 2011 (625). The highest number of single-author articles was also observed in the same year (40, 23.39%). The lowest number of co-author articles was found in years prior to 1998 (from 1983 to 1997). No single-author article was found between 1998 and 2000.



Fig. 2: frequency of single-author articles in the field of biotechnology



Fig. 3: frequency of co-author articles in the field of biotechnology

In order to understand issues related to Co-Authorship, distribution of co-author articles were shown based on the number of co-authors (Fig. 3). The graph showed the frequency distribution of the number of co-author articles conducted by researchers of the co-authorship network in the field of biotechnology. As shown in this graph, the frequency of co-author articles was shown on the vertical columns, and the number of co-authors was depicted on the horizontal lines. The highest number was related to four-author articles (with the frequency of 840 articles). Three, five, two and six-author articles were ranked second to fifth with the frequencies of 786, 638, 469 and 422 articles respectively.



Fig. 4: frequency distribution of the number of co-authors in co-author articles in the field of biotechnology

## Degree of cooperation (DC)

To calculate the proportion of co-author articles (co-authorship), the degree of cooperation (DC) index was used. This index represented the proportion of co-author articles to total number of articles; single-author articles were given zero weight. Moreover, articles with higher numbers of authors had more weight (Hariri, Nikzad, 2011). The formula for calculating the degree of cooperation was shown as follows.

$$DC = 1 - \frac{F_i}{N} = 0.95$$

Fi is the number of single-author papers published in one field in a specified period. N is the total number of articles.

This value can be a number between zero and one. The closer the obtained number is to one, the more scientific cooperation can be found among researchers to produce science. Since the degree of cooperation in this area was 0.95, it could be concluded that the authors in the field of biotechnology were more willing to cooperate scientifically.

#### 3. Who are the highly productive Iranian authors in the field of biotechnology?

The frequency of the most productive authors was calculated using the ISI database and software Ravarmatrix; Table 1 briefly showed ranks 1 to 10. As shown in this table, Khosro Khaje (with the frequency of 70 articles) was considered the most productive author. Seyed Abbas Shoja Sadati, Younes Ghasemi, Masoud Soleimani and Keykhosro Karimi were ranked second to fifth with the frequencies of 58, 46, 37 and 35 articles respectively.

No.	Author	Frequency	%
1	Khaje, Khosro	70	1.81
2	Shoja Sadati, Seyed Abbas	58	1.5
3	Ghasemi, Younes	46	1.22
4	Soleymani, Masoud	37	0.93
5	Karimi, Keykhosro	35	0.9
6	Mousavi, Seyed Mohammad	33	0.85
7	Faramarzi, Mohammad Ali	32	0.83
8	Hossein Khani, Saman	31	0.83
9	Emtiazi, Giti	30	0.8
10	Mohammadi, Mehdi	30	0.77

Table 1: names of 10 highly productive authors in the field of biotechnology from the beginning up to 2015

To identify top researchers in the field of biotechnology, after the data was obtained from the Web of Science database and was entered into Ravarmatrix software, the authors' matrix (a 9067 by 9067 square matrix) was created and then data was analyzed using UCINET software; finally, centrality of authors was obtained.

#### 4. Who are Iran's top researchers in the field of biotechnology in terms of centrality metrics?

Degree centrality is only the number of direct relations which a node has with other nodes. To assess degree centrality in this research, a symmetric matrix was formed, data was entered into the UNICET software in the form of a matrix and their degree and betweenness centrality was evaluated. Table 2 showed the names and the degree and betweenness centrality of top ten authors in the co-authorship network. As shown in the table, the first four columns were related to the degree centrality metric; the third column represented the number of links between a researcher and other researchers, and the fourth column showed the percentage of the related links (normalized degree). According to this table, Hossein Baharvand has the highest degree among all other authors (normal degree centrality of 0.18). Khosro Khaje, Hamid Gouraie, Seyed Abbas Shoja Sadati and Younes Ghasemi were ranked second to fifth with centrality of 0.15, 0.11, 0.11 and 0.1 respectively. The next four columns were related to the betweenness centrality. Betweenness refers to the limit in which a node is placed between nodes of another network. This metric measures links or relationships between a node and its neighboring nodes and gives higher values to the nodes that connect clusters to each other (Ramezani & Mirzamohammadi, 2014). As shown in the table, Masoud Soleimani (with centrality of 2353307.75) had the highest betweenness centrality. Khosro Khaje, Hossein Baharvand, Seyed Abbas Shoja Sadati and Mehdi sadeghi were ranked second to fifth with centrality of 1780136.75, 1466071.75, 1443297.75 and 1443297.75 respectively.

Table 2: degree and betweenness centrality of the best authors of the co-authorship network in the field of biotechnology

No.	Author	Degree centrality	Normalized degree	No.	Author	Betweenness centrality	Normalized betweenness
1	Baharvand, Hossein	327	18.0	1	Soleymani, Masoud	75.2353307	72.5
2	Khaje, Khosro	276	15.0	2	Khaje, Khosro	75.1780136	33.4

3	Gouraie, Hamid	216	11.0	3	Baharvand, Hossein	75.1466071	56.3
4	Shoja Sadati, Seyed Abbas	204	11.0	4	Shoja Sadati, Seyed Abbas	75.1443297	51.3
5	Ghasemi, Younes	185	1.0	5	Sadeghi, Mehdi	62.1424557	46.3
6	Soleymani, Masoud	176	09.0	6	Yakhchali, Bagher	1337153	25.3
7	Salakde, Ghasem	175	09.0	7	Mohammadi, Mehdi	37.1135509	76.2
8	Faramarzi, Mohammad Ali	140	07.0	8	Soleymanian, Ali Hatef	37.943584	29.2
9	Mousavi-Movahedi, Ali Akbar	138	07.0	9	Brahimi, Mehdi	93.929546	26.2
10	Sadeghi Zade, Majid	136	07.0	10	Faramarzi, Mohammad Ali	823211313	2
Total		87190	08.48		Total	121163464	86.294
Average		616.9	005.0		Average	12.13363	03.0
Standard deviation		703.17	01.0		Standard deviation	4499001344	02.0

Closeness is another centrality index; it is created based on the concept of distance or path length. People with the least distance to other people in a network have higher closeness centrality. Table 3 showed the names and scores of distance, closeness and eigenvector centrality of top ten researchers. As shown in this table, the first four columns were related to the distance and closeness centrality of researchers in the field of biotechnology. According to this table, Khosro Khaje, Masoud Soleimani and Seyed Abbas Shoja Sadati had the lowest distance to other people in the network and thus had the highest closeness to other researchers. In other words, these people had higher chance and opportunity to develop a relationship with other researchers. The next four columns related to the eigenvector centrality represented the fact that the stronger the link between people was, the more effective people were. As shown in the table, Hossein Baharvand (with centrality of 0.12) had the highest centrality. Ghasem Salakde, Hamid Gouraie, Peter Adndruze and Paul G Gokhale were ranked second to fifth with centrality of 0.1, 0.1, 0.09 and 0.09 respectively. It should be noted that Peter Adndruze and Paul G Gokhale had the same centrality. Moreover, Katrin Amps, Gorj Anifantis, Leil Armestrang and Estowart Avry who were ranked seventh to tenth had the same eigenvector centrality (0.08).

Table 3: distance, closeness and eigenvector centrality of the best authors of the co-authorship network in the field of biotechnology

No.	Author	Distance centrality	Normalized closeness	No.	Author	Eigenvector centrality	Normalized eigenvector
1	Khaje, Khosro	14714108	0.062	1	Baharvand, Hossein	0.12	18.19
2	Soleymani, Masoud	14714186	0.062	2	Salakde, Ghasem	0.1	14.31
3	Shoja Sadati, Seyed Abbas	14714186	0.062	3	Gouraie, Hamid	0.1	14.16
4	Yakhchali, Bagher	14714810	0.062	4	Adndruze, Peter	0.09	13.07
5	Sadeghi, Mehdi	14714935	0.062	5	G. Gokhale, Paul.	0.09	13.07
6	Soleymanian, Ali Hatef	14714945	0.062	6	Fax, Victor	0.09	12.86
7	Hosseinkhani, Saman	14715185	0.062	7	Amps, Katrin	0.08	12.54
8	Noghabi, Kambiz	14715677	0.062	8	Anifantis, Gorj	0.08	12.54
9	Shafei, Abbas	14716200	0.062	9	Armstrong, Liel	0.08	12.54
10	Naderi Manesh, Hossein	14716346	0.062	10	Avry, Stewart	0.08	12.54
Total		242781831168	476.26	Total		11.59	1640

Average	26776424	0.053	Average	0.001	0.18
Standard deviation	25831196	0.019	Standard deviation	0.01	1.47

Information visualization techniques and methods is one of the ways to have access to relevant information. Having a higher understanding of the provided information, information visualization helps users increase information retrieval productivity (Ramezani & Mirzamohammadi, 2014). Depicting a scientific map is an information visualization method. Maps both show the structure of information and facilitate access to information. Figure 5 showed the map of main components of the co-authorship network in the field of biotechnology (including 9067 nodes (authors) and 77426 links (scientific cooperation). This figure indicated components or authors who worked together as a group and had at least one work conducted together. Therefore, it didn't include single-authorship. In these maps, the authors who had more scientific cooperation were shown in closer distances, while those who had less scientific cooperation were shown in farther distances. On the other hand, when an author was shown in the center of the map, it meant that this author was very important in the researchers' co-authorship network. In this figure, the size of the nodes indicated the authors' degree centrality. As shown in this figure, the authors with high degrees were shown in the center of the network. The larger the diameter of a circle which represented the researcher was, the more the links which he received and thus the more influential he was in the network.



Fig. 5: the map of main components of researchers' co-authorship network in the field of biology from the beginning up to 2015 in terms of degree centrality

#### Research hypothesis:

There is a significant relationship between the centrality metrics (degree, closeness, betweenness and eigenvector) and researchers' efficiency in the field of biotechnology. The research hypothesis was tested using Pearson correlation test and centrality scores; results of this analysis were separately calculated for each of the centrality indexes and were shown in the following table.

Table 4: results of Pearson correlation test between centrality indexes and researchers' efficiency in the field of biotechnology

	Authors'	efficiency		Type of	
Centrality type	Pearson cor	relation test	Relationship		
	Correlation (r)	Р	Р		
Betweenness	0.73**	.000	Yes	Positive	
Eigenvector	0.41	-0.009	No		
Degree	$0.4^{**}$	0.00	Yes	Positive	
Closeness	**-0.11	0.000	Yes	Reverse	

Results of the Pearson correlation test revealed a positive, direct and significant relationship between the betweenness centrality and researchers' efficiency (P=0.000, r=0.73). In other words, the higher the betweenness centrality was, the higher the efficiency of authors

and researchers was. Results of Pearson correlation coefficient between eigenvector centrality and researchers' efficiency revealed that there was no statistically significant relationship (P=-0.009, r=0.41). Pearson correlation test between degree centrality and researchers' efficiency represented a positive, direct and significant relationship (P=0.000, r=0.4). In other words, the higher the degree centrality was, the higher the efficiency of authors and researchers was. This test showed a significant inverse relationship between closeness centrality and researchers' efficiency (P=0.000, r=-0.11). In other words, the higher the efficiency of authors and researchers was. Based on these findings, the research hypothesis was confirmed.

## **Discussion and Conclusions:**

Results of this research showed that 3796 articles in the field of biotechnology were indexed by 9067 authors up to 2015. The findings revealed that the scientific products of Iranian researchers have fluctuated in the field of biotechnology in the Web of Science. These fluctuations occur due to various reasons including lack of research facilities, undermining the importance of science and scientific collaboration by managers or researchers and lack of complementary disciplines. From the beginning to 2015, 2011 was a turning point in scientific products in the field of biotechnology; it showed the researchers' willingness to conduct group studies. After 2011, a decreasing trend was found. Concerning the number of initial products compared to 2015, it could be concluded that this trend was positive and significant. Results of this study were in line with the results of a study conducted by Asadi et al. (2015) on co-authorship of researchers at Tehran University and Qom Seminary between 2004 and 2013. In their study, the scientific cooperation had an increasing trend from 2004 to 2012; it decreased in 2013. Generally speaking, they found an increasing trend. Moreover, the highest number of single-author and co-author articles was found in 2011. Findings of this research showed that the number of co-author articles was more than that of single-author ones in the field of biotechnology; that is, researchers in this field were more willing to cooperate due to different reasons including the interdisciplinary, applied and laboratory nature of this field. In addition, researchers in this field incurred high costs to provide and use laboratory equipment. To achieve scientific progress, collaboration among authors is necessary and important in this field. A significant increase in scientific products in recent years has suggested that scientific cooperation has been taken into huge consideration by most researchers. One of the tangible results of such works is the increased quality of the published works due to the involvement of some researchers and the presence of some expertise in the research group. Examining the number of articles in the field of biotechnology showed that the highest number was related to the four-author articles (22.1%); three- and fiveauthor articles were ranked second and third respectively (20.7 and 16.8%). The degree of cooperation among researchers in the field of biotechnology revealed the high willingness of researchers to cooperate with other researchers scientifically. Results of this research were in line with the results of studies conducted by (GeliniMoghaddam and Taheri, 2014). Individual performance of each of the researchers in the co-authorship network in the field of biotechnology was examined using the production index and centrality. In the production index, Khosro Khaje, Seyed Abbas Shoja Sadati and Younes Ghasemi had the highest ranks. Concerning degree centrality, Hossein Baharvand, Khosro Khaje and Hamid Gouraie had the highest ranks. Masoud Soleimani, Khosro Khaje and Hossein Baharvand were the best authors in the betweenness index. The best authors in the closeness index were Khosro Khaje, Masoud Soleimani and Seyed Abbas Shoja Sadati. Concerning the eigenvector index, Hossein Baharvand, Ghasem Salakde and Hamid Gouraie were ranked first to third. Concerning all indexes, it could be stated that Khosro Khaje and Hossein Baharvand had the best ranks in the researchers' co-authorship network. Therefore, they had more power and ability to have greater influence on the flow of knowledge. Moreover, people who have higher centrality have a very important role in developing and completing co-authorship networks, attracting newcomers and encouraging them to work on their network. Accordingly, Soheili and Mansouri (2014) reported that the main reasons of obtaining high ranks among authors were having maximum relationship with other members of the network, having the ability to create collaborative team, controlling the flow and dissemination of knowledge in the network and the willingness of other people to have relationships with this group of authors . Razi et al. (2016) stated that one of the reasons which might affect the scientific creation of some authors was their interests in their academic fields and in having scientific activities in their fields; they could be considered internal factors. In addition, having subject knowledge and skills, perseverance, experience and enough time, managerial ability and conducting various research simultaneously were some of the other factors in this regard. Results of analysis of the relationship between the centrality score and efficiency of Iranian biotechnology researchers showed that there was a positive relationship between the centrality and efficiency (the higher the centrality score was, the higher the efficiency was). As mentioned earlier, people who are at the center of a network have more authority, power and influence. Therefore, they can have more efficiency and effectiveness in the network. Results of this study confirmed the results of a study conducted by Hill, (2008). His results showed that there was a positive relationship between efficiency and the centrality score in computer science in America. Results of this study were also in line with the results of a study by Badar, Hitt & Badir, (2013). Their results revealed that there was a relationship between degree and closeness centrality and Pakistani researchers' efficiency in the field of chemistry.

Generally, results of this study showed that centrality of co-authorship network of the researchers in the field of biotechnology was high and there was an appropriate relationship among the authors in this field.

Scientific cooperation and co-authorship was very high among researchers in this field. People who had high centrality scores had more opportunities and alternatives compared to other factors. These factors had more nodes and more opportunities because they had more

options (Asare, Soheili, Farajpahlou & Moarefzade, 2012). Moreover, creating team spirit, forming research teams and making use of different specialties in writing scientific outputs would cause greater success; these criteria would be part of the best researchers' criteria in choosing research teams. Identifying top authors in the field of biotechnology will result in strengthening, expanding and developing this field. Top researchers in this field have certainly higher understanding of the subject compared to other researchers.

#### References

- Alijani, R (2014). Examining scientific products of Iranian Association of Surgeons based on articles indexed in the ISI. *Iranian Journal of Surgery*, 22 (4), 65-73.
- Arunachalam, S. (2003). Information for research in developing countries—Information technology, a friend or foe?. *The International Information & Library Review*, 35(2-4), 133-147.
- Asare, F; Soheili, F; Farajpahlou, A; Moarefzade, A (2012). Examining centrality metrics in the co-authorship network of articles in Information Science Journals. *Information and Library Journal*, 2 (2), 181
- Badar, K; Hite, J.M; Badir, Y.F. (2013). Examining the relationship of co-authorship network centrality and gender on academic research performance: the case of chemistry researchers in Pakistan. *Scientometrics*, 94(2),755-775.
- Borgatti, P. (2007). Centrality and Network Flow'. Social Networks, 27, 55-71
- Cheong, F., & Corbitt, B. J. (2009). A social network analysis of the co-authorship network of the Pacific Asia Conference on Information Systems from 1993 to 2008. *PACIS 2009 Proceedings*, 23.
- Clemens, B; Fell Cornelius, J; Ko'nig, I. (2016). Is there a gender difference in scientific collaboration? A scientometric examination of co-authorshipsamong industrial–organizational psychologists, *Scientometrics*, 108,113–141.
- Day, M. Y., Shih, S. P., & Chang, W. (2011, August). Social network analysis of research collaboration in information reuse and integration. In *Information Reuse and Integration (IRI)*, 2011 IEEE International Conference on (pp. 551-556). IEEE.
- Fuyuki, Y. (2008). An analysis of the correlation among research productivity and collaboration network indices. *Research on academic degrees and university evaluation*, 8(1), 45-56.
- Gelinimoghaddam, G; Taheri, C. (2014). Depicting co-authorship network and scientific cooperation coefficient of Iranian researchers in the field of aerospace in the Science Citation Index up to 2014. *Knowledge Studies*, 3, 23-42S.
- Giuliani, F; De petris, M.P; Nico, G. (2010). Assessing scientific collaboration through co-authorship and content sharing. *Scientometrics*, 85(1), 13-28.
- Hariri, N; Nikzad, M. (2011). Co-authorship networks in Iranian papers in the fields of library and information science, management psychology and economics in the ISI database between 2000 and 2009. *Journal of Information Processing and Management*. 26 (4), 844-825.
- Hassanzade, M; Khodadoust, R; Zandian, F (2011). examining the co-authorship indexes, betweenness centrality and structural pits of Iranian Nanotechnology researchers indexed in Science Citation Index (1991-2011). *Journal of Information Processing and Management*, 28 (1), 224-249.
- Hill, V. A. (2008). Collaboration in an academic setting: Does the network structure matter. Center for the Computational Analysis of Social and Organizational Systems (CASOS) technical report. Retrieved from www. casos.cs.cmu.Edu/publications/papers/CMU-ISR-08-128. pdf.
- Koseoglu, M.A. (2016). Growth and structure of authorship and co-authorship network in the strategic management realm: Evidence from the strategic management journal. *business research quarterly*, 19, 153-170.
- Kumar, S & Jan, J.M. (2013). Mapping Research Collaborations in the Business and Management Field in Malaysia, 1980–2010. *Scientometrics*, 97, 491–517.
- Newman, M. E. (2008). The mathematics of networks. The new palgrave encyclopedia of economics, 2(2008), 1-12.
- Nooy, W., Mrvar, A., & Batagelj, V. (2005). Exploratory social network analysis with Pajek. Cambridge University Press.
- Ramezani, A; Mirzamohammadi, A. (2014). Analyzing social networks and teaching ucinet software. Sociologists, Thran.
- Razi, M; Hashemzadeh, C; Asare, F; Mohammadi ostani, M. (2016). Explaining citation behavior model and determining the level of researchers' scientific cooperation in Iranian scientific-research journals of Geology. *Journal of Library and Information Science* of Shahid Chamran University of Ahvaz, 17, 62-41.
- Sadatmoosavi, A., F. Nooshinfard, N. Hariri and S. Mohamadesmaeil (2015). The Co-Authorship social network structure of countries in the field of nuclear science and technology analysis: the micro and macro level indicators. *Journal of Academic Librarianship* and Information Research, 49(3), 339-353.
- Sadatmoosavi, A., Nooshinfard, F., Hariri and S. Mohamadesmaeil (2018). Does the superior position of countries in co-authorship networks lead to their high citation performance?. *Malaysian Journal of Library & Information Science*, 23(1), 51-65.
- Soheilifar, F; Cheshmesohrabi, M; Atashpeikar, S. (2015). Analyzing researchers' co-authorship network in the field of Medical Sciences, Iran: A study using social network analysis approach. *Journal of Caspian Sscientometrics of Babol University of Medical Sciences*, 1, 24-32.
- Soheilifar, F; Mansouri, A. (2014). Analyzing co-authorship network of Iranian researchers in the field of chemistry using centrality metrics. Journal of Library and Information Science of Shahid Chamran University of Ahvaz, 13, 89-106.

- Tahmasebi limoni, S.; Tajedini, O., & Sadatmoosavi, A. (2018). Establishing and Analyzing the Pattern of Relationships in Coauthorship Networks: the Case Study of Scientific Productions of Researchers at Kerman University of Medical Sciences. *Library Philosophy and Practice, 1714. Available at:* http://digitalcommons.unl.edu/libphilprac/1714.
- Tajedini, O., Ghazizade, A., & Sadatmoosavi, A. (2018). Identifying the Effects of Co-authorship Strategies on the Citation-based Performance of Scholars: A Social Networks Analysis. *Journal of Scientometric Research*, 7(1), 19-28.
- Tajedini, O., Soheili, F., & Sadatmoosavi, A. (2018). The Centrality Measures in Co-authorship Networks: Synergy or Antagonism in Researchers' Research Performance. Iranian Journal of Information Processing & Management Quarterly. Available at: http://jipm.irandoc.ac.ir/browse.php?a\_code=A-10-154-8&sid=1&slc\_lang=en.
- Wang, X; Xu, SH; Wang, Zhi; Peng, L & Wang, C. (2013). International Scientific Collaboration of China: Collaborating Countries, Institutions and Individuals. *Scientometrics*, 95(3), 885–894.
- Wolfram, D. (2010). Geographic characteristics of the growth of informetrics literature 1987-2008. *Journal of informetrics*, 4(4), 591-601.
- Ye, Q., Li, T., & Law, R. (2013). A coauthorship network analysis of tourism and hospitality research collaboration. *Journal of Hospitality & Tourism Research*, 37(1), 51-76.