University of Nebraska - Lincoln
DigitalCommons@University of Nebraska - Lincoln

Library Philosophy and Practice (e-journal) | Libraries at University of Nebraska-Lincoln

Summer 4-15-2019

Mapping of Research Productivity on Nanotechnology in Canada: A Scientometric Profile

Chandran Velmurugan
Research Scholar, Periyar University, Salem, murugan73@gmail.com

Follow this and additional works at: https://digitalcommons.unl.edu/libphilprac

Part of the Library and Information Science Commons

Velmurugan, Chandran, "Mapping of Research Productivity on Nanotechnology in Canada: A Scientometric Profile" (2019). *Library Philosophy and Practice (e-journal)*. 2450.
https://digitalcommons.unl.edu/libphilprac/2450

Mapping of Research Productivity on Nanotechnology in Canada: A Scientometric Profile

Dr. Chandran Velmurugan*

***Researcher**
Department of Library and Information Science, Periyar University,
Salem- 636 011, Tamilnadu, India
Email: murugan73@gmail.com

Abstract

A scientometric assessment of the scientific publications has been considered in this analysis by examining annual growth rate of publications, collaborative countries and territories, preferred subject areas and research work, prolific organizations and institutions and top ranked journals and highly productive papers etc. This paper focus on the literature growth and development in Nanotechnology in Canada as reflected in web of science data database. During the period between 1994 and 2014, a total 576 scientific research papers along with cited references are 34955 were published in the field in Canada. The average number of literature output were published per year was 33.88 and the greatest number of publications were published in 2013 and 2014 respectively a total number of authors 2213 were identified and the maximum number of authors i.e. 364 and the mean value of 4.77 were in the year 2014. Out of 15804 citations, the greatest number of 2791 citations in the year 2008 (52 papers, 23 h-index) and highest average citation per paper were 60.74 in the year 2007. From this study, researchers, scientists, subject specialists, students, administrators, policy makers, academicians, Library and Information Science professionals and faculty members will be benefited due to the scientific and effective investigation.

Keywords: Nanotechnology, publication analysis, bibliometrics, *citation analysis, RGR, DT, DC, collaborative research, Canadian research.*

Introduction

Nanotechnology is an emerging thrust area in the research world and it is a growing interdisciplinary technology. Nanotechnology is progressively enticing universal attention on account of its wide range of end-uses. In the last two decades, the publication analysis has been drastically expanded as researchers and eminent scholars have experienced with significant growth and development of nanotechnology research in Canada. A number of studies have been carried out by scientists and identified that Canada is listed one of the top ranked countries publishing nanotechnology peer-reviewed journal articles (Rosei, 2008; Yegul; Yavuz & Guild 2008; Beaudry & Schiffauerova 2011).

This study tries to investigate the growth pattern of publication in terms of articles, review, editorial material, proceedings paper, meeting abstract, review as book chapter, letter, and article as book chapter, book review and note etc. in other words, it also analyses the various factors such as authors and co- authorship pattern, collaborative research trends, single authors as well as joint authors relationship, citation based analysis, institution and geographical wise production, subject wise and research area based study and funding agency. This present study is aimed to explore the research gap by mapping the scientific publications in the developing field of nanotechnology in Canada. It is anticipated that this study will support and help to user community to understand the amount of technology transfer between Canada and other countries in the discipline of nanotechnology.

Based on the below table Canada has ranked in global wise in terms of scientific productivity in different phases. In first phase, Canada ranked 6th place in the world output of nanotechnology and it shows the nanotechnology publication growth rate is upward trend whereas in the second phase, Canada has in the downward trend as placed in the 11th rank during the period of 1998-2002 and 5th position during the period between 2005 and 2009 among the highly productive countries in nanotechnology. But in this present study, based on the research output as reflected in web of science database Canada is ranked in the eleventh position. The results reveal that the growth rate of nanotechnology research output is in the fluctuation trend compare with previous study.

Rank based nanotechnology research in Canada during 1990-2014

	1990-1994	**1998-2002**	**2005-2009**	**1990-2014**
Rank	Country (Global %)	Country (Global %)	Country (Global %)	Country (Global %)
1	USA (40%)	USA (27%)	USA (26%)	USA (34%)
2	Japan (12%)	Japan (14%)	China (17%)	China (10%)
3	Germany (10%)	Germany	Japan (10%)	Germany (6%)
4	UK (8%)	China (17%)	Germany (9%)	England (5%)
5	France (8%)	France (7%)	**Canada (8%)**	Japan (5%)
6	**Canada (4%)**	UK (7%)	France (6%)	India (4%)
7	Italy (4%)	Russia (5%)	UK (5%)	Italy (4%)
8	China (3%)	Italy (4%)	South Korea (5%)	France (3%)
9	Russia (3%)	South Korea (4%)	Italy (3%)	South Korea (3%)
10	Switzerland (2%)	Spain (3%)	India (3%)	Spain (2%)
11	Netherlands (2%)	**Canada (2%)**	Russia (3%)	**Canada (2%)**
12	Spain (2%)	India (2%)	Spain (3%)	Australia (2%)
13	Sweden (2%)	Switzerland (2%)	Taiwan (3%)	Switzerland (2%)
14	India (2%)	Netherlands (2%)	Poland (2%)	Netherlands (2%)
15	Australia (2%)	Sweden (2%)	Australia (2%)	Russia (1%)

Related work

A huge number of research works have been done in the field of scientometric study in the last few decades. For the present study, we have selected few of them and presented here. Tang and Shapira (2012) examined the bibliometric analysis in terms of on international

collaboration and knowledge moderation on China's nanotechnology, Heinze, et al (2007) carried out and identified the research results on nanotechnology and human genetics, Kostoff, et al (2006) found the structure and infrastructure of the global nanotechnology research output, Lee (2006) investigated the nanotechnology patent and followed by Youtie; Shapira and Porter (2008) analyzed the research papers and citations on nanotechnology. Aytac (2010) studied with G7 countries such as franc, Germany, Italy, Japan, UK, USA, and Canada and the results show that based on the scientific collaboration in terms of scientific publications the co-authorship relationship growth rate was progressively increased during the period of 1990-2006. Hu; Carley & Tang (2012) described the study based on the publication activity on nanotechnology during 1990-2009. Garousi & Varma (2012) have identified the top ranked institutions such as University of Waterloo by two metrics and Queen's University's by one metric on Canadian Electrical and Computer Engineering Institutions based on IEEE Journal Publications during the period 1996 -2006.

To add strength of this paper, we have taken into account few of the authors' previous studies in various discipline as well as individual journal of scientometric analysis in different period of study for the present analysis such as Research analysis on Biotechnology by Velmurugan and Radhakrishnan (2015), Journal of Information Literacy by Velmurugan and Radhakrishnan (2015), Quantitative Analysis of Scientific Publications Output on Engineering Journal by Velmurugan and Radhakrishnan (2015), Literature output of Supply Chain Management by Velmurugan and Radhakrishnan (2015), Authorship trends and collaborative research work on Library Herald by Velmurugan and Radhakrishnan (2015), Scientometric Analysis of Research Papers on Pharmacognosy as reflected in the Web of Science by Velmurugan and Radhakrishnan (2015), Journal of Intellectual Property rights by Velmurugan (2013, 2014), Annals of Library and Information Studies for the year 2007-2012 by Velmurugan (2013) Indian Journal of Pure and Applied Physics for the Year 2009 – 2012 by Velmurugan (2014), Technical Review Journal by Velmurugan (2014).

Objectives

The main purpose of the scientometric analysis on nanotechnology in Canada is to evaluate the growth pattern of Nanotechnology in terms of year wise, citation wise and author wise publications with mean value and the other objectives are as follows:

- To know different types of document during the period
- To identify the highly cited Institutions with h-index
- To trace the country wise highly cited production
- To depict the highly cited papers and rank based cited references
- To illustrate the top ranked authors with h-index
- To examine the top ranked research areas, subject and source wise distribution
- To measure the degree of collaboration (DC), relative growth rate (RGR) and doubling time (DT) in nanotechnology research

Materials and Methods

To retrieve the appropriate source data, given a select keyword i.e. nanotechnology, and then the documents were identified in Science Citation Index- Expanded, social science Citation Index, Arts & Humanities Citation Index and ESCI by dint of Web of Science. The research has limited by searching the term 'Nanotechnology' as the topic and refined by countries /territories as Canada via WoS. A total number of 576 scientific publications with 245 total local citation score and 15804 total global citation score for the period between 1989 and 2014. The data include articles, review, editorial material, proceedings paper, meeting abstract, and review as book chapter, letter, and article as book chapter, book review and note. This scientometric study is carried out in the month of November 2015. The download data was transferred to Excel spreadsheet for further statistical analysis and also used the vos viewer visualization software to screenshot the publication. Further, to evaluate the research output, the relative growth rate and the doubling time and K. Subramanyam's degree of collaboration have been used to determine and extent the growth of publication trend during the study period.

Relative growth rate (RGR)

The relative growth rate (RGR) is the increase in the number of research publications/pages per unit of time. The relative growth rate and the doubling time models have developed by Garg and Padhi in the year 1999 to measure the publications. The growth rate of total research output published by faculty members from Periyar University has been evaluated as per the following equation.

$$R\,(a) = \frac{(W2 - W1)}{(T2 - T1)}$$

Where, R (a) = Relative Growth Rate over the specific period of interval, w1= logw1 (Natural log of initial number of publications), w2= log w2 (Natural log of final number of publications), T2- T1 = Unit difference between the initial and final time R (a) = per unit of publications per unit of time (Year).

Doubling Time (DT)

There exists a direct equivalence between the relative growth rate and the doubling time. If the number of research output or pages of a subject doubles during a given period then the difference between the logarithms of numbers at the beginning and end of this period must be logarithm of the number 2. If natural logarithm is used this difference has a value of 0.693. Thus, the corresponding doubling time for each specific period of interval and for both articles and pages can be calculated based on the given formula.

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

K. Subramanyam's degree of collaboration

The degree of collaboration is defined as the ratio of the number of collaborative research papers to the total number of research papers in the discipline during a certain period of time. The formula is suggested by K.Subramanyam has been used for the present study and expressed as given below.

The formula is $C = \frac{Nm}{Nm+Ns}$

Where, C – denotes the degree of collaboration; NM – indicates number of multi-authored research output in the discipline published during a year; NS – represents number of single authored research output in the discipline published during the same year.

Results and Discussion

Growth Pattern of Nanotechnology

Computing growth rate is essential in every walks of life and it is mandatory to publication growth too. Publication is evaluated based on the growth and development in each field of study. The nanotechnology literature output is 20825 in worldwide during the period of 1990 – 2014 as reflected in the web of science database and the Canada is in the eleventh position among the 88 countries. In this context, table 1 and figure 1-3 shows that out of 576 literature output, the highest number of 77 (13.4%) articles was published in the year 2013 and 2014 respectively whereas the least number of research papers were published in the year 2000 is only one article (0.2%).Out of 15804 citations, the greatest number of 2791 citations in the year 2008 (52 papers, 23 h-index) and highest average citation per paper is 60.74 in the year 2007 while the small number of average citation per paper is 5.11 in the year 2014.But, an overall publication, the average citation per paper is 27.44. We have calculated (figure 4) the year wise cited references and mean value in the nanotechnology research in which the huge number of cited references (5329) in the year 2013 and the highest mean value of cited references is 73.62 in the year 2007 and the least number of mean values of cited references is 18.67 in the year 2001. We have also measured the year wise authorship pattern and out of 2213 authors, the maximum number of367 authors (77 papers, 09 h-index) in the year 2014 and followed by 314 authors (77 papers, 14 h-index) in the year 2013 and the minimum number of 4 authors (one paper) in the 2000. It is found from the analysis that the majority of scholarly publications were written by the authors in the year 2013 and 2014 respectively. The average citation per article in the overall publications is 27.44 and the highest author productivity in the year 2014.

Table 1: scientific publications of Nanotechnology in Canada during 1994-2014

#	PY	TP	TC	ACPP	CR	CRM	NA	NAM	h-index
1	1994	2	173	86.5	80	40.0	5	2.50	2
2	1999	3	129	43.0	93	31.0	10	3.33	2
3	2000	1	30	30.0	31	31.0	4	4.00	1
4	2001	3	31	10.33	56	18.67	12	4.00	3
5	2002	2	15	7.5	71	35.50	5	2.50	2

6	2003	13	786	60.46	532	40.92	49	3.77	10
7	2004	13	444	34.15	890	68.46	38	2.92	8
8	2005	20	1054	52.7	1135	56.75	60	3.00	15
9	2006	40	2289	57.23	1666	41.65	133	3.33	21
10	2007	42	2551	60.74	3092	73.62	149	3.55	23
11	2008	52	2791	53.67	2861	55.2	181	3.48	23
12	2009	46	965	20.98	2260	49.13	188	4.09	16
13	2010	53	1224	23.09	3094	58.38	196	3.70	20
14	2011	73	1501	20.56	4912	67.29	290	3.97	20
15	2012	59	686	11.63	3747	63.51	212	3.59	15
16	2013	77	741	9.62	5329	69.21	314	4.08	14
17	2014	77	394	5.11	5106	66.31	367	4.77	09
		576	15804	27.44	34955	866.6	2213	60.58	204

PY- Publication year, TP- Total papers, TC- Total citations, Cited references, Mean value of Cited references, NA- Number of authors, Mean value of Number of authors.

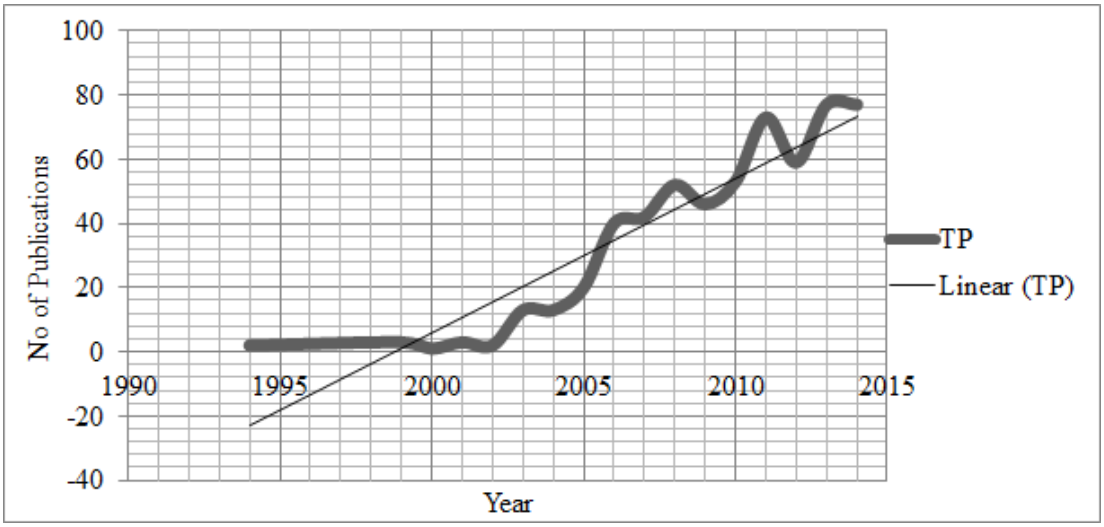


Figure 1: Growth of Publications

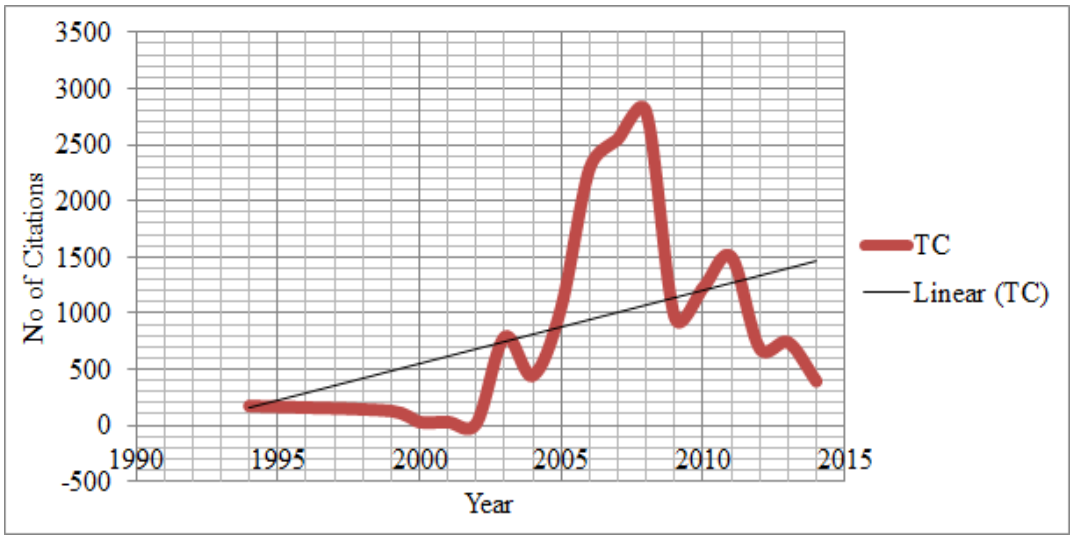


Figure 2: Citation wise publications

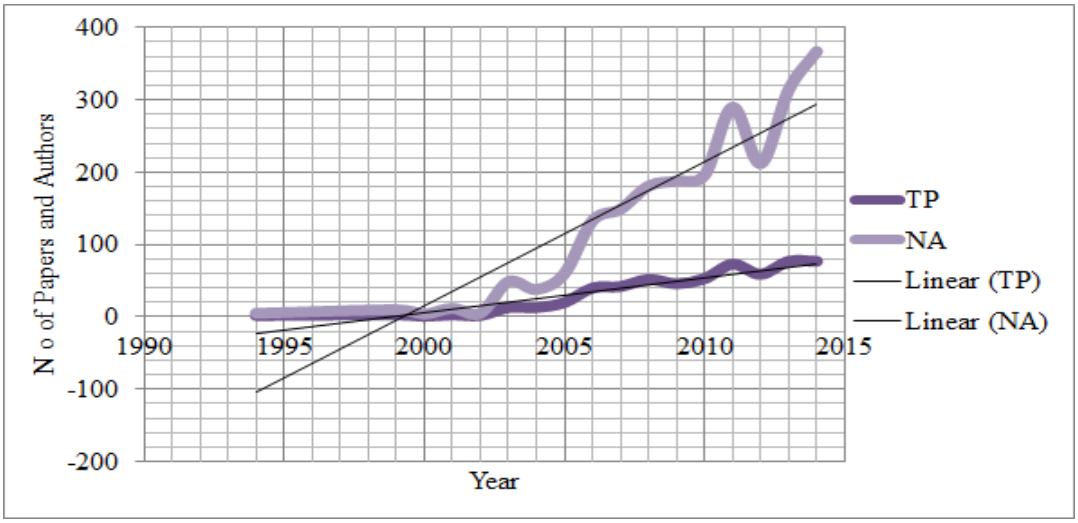


Figure 3: Author wise publications

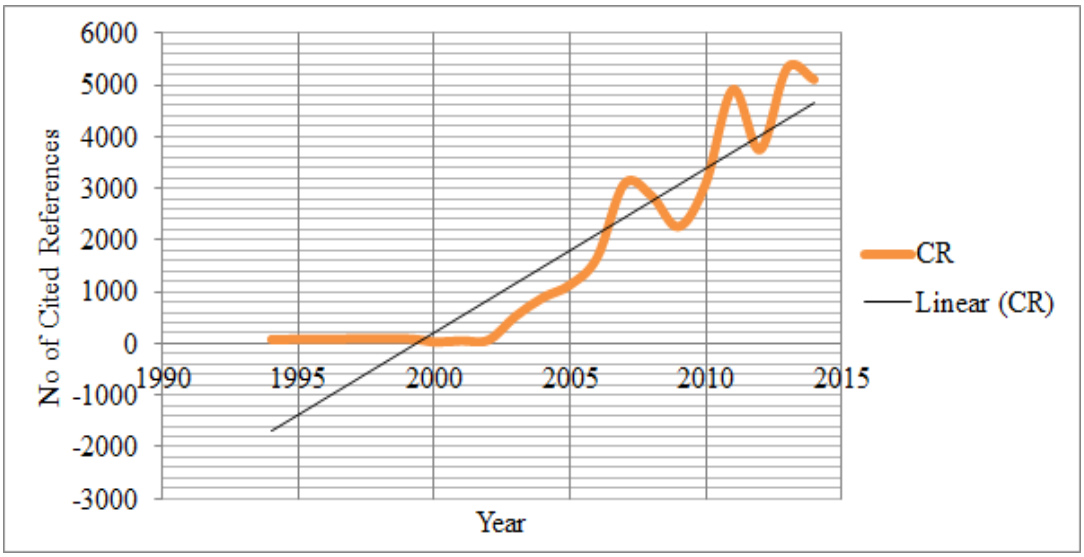


Figure 4: Year wise Cited references

Table 2: RGR and DT on Nanotechnology research in Canada

PY	TP	Percent	CP	Percent	Log1	Log 2	RGR	Mean RGR	DT	Mean DT
1994	2	0.3	2	0.3	0.69	-	-		-	
1999	3	0.5	5	0.8	1.098	1.61	0.51		1.36	
2000	1	0.2	6	1.00	0	1.79	0		0	
2001	3	0.5	9	1.80	1.098	2.19	1.09		0.64	
2002	2	0.3	11	2.10	0.69	2.40	1.71		0.41	
2003	13	2.3	24	4.40	2.56	3.18	0.62	0.655	0.64	0.51
2004	13	2.3	37	6.70	2.56	3.61	1.05		0.41	
2005	20	3.5	57	10.2	2.99	4.04	1.05		0.64	
2006	40	6.9	97	17.10	3.69	4.57	0.88		0.41	
2007	42	7.3	139	24.4	3.74	4.93	1.19		0.64	
2008	52	9.0	191	33.4	3.95	5.25	1.3		0.41	
2009	46	8.0	237	41.4	3.82	5.47	1.65	1.187	0.64	0.52
2010	53	9.2	290	50.5	3.97	5.67	1.7		0.41	
2011	73	12.7	363	63.3	4.29	5.89	1.6		0.64	
2012	59	10.2	422	73.4	4.08	6.04	1.96		0.41	
2013	77	13.4	499	86.8	4.34	6.21	1.87		0.64	
2014	77	13.4	576	100	4.34	6.36	2.02	1.83	0.41	0.49
Total	576	100						1.224		0.51

PY- Publication year, TP- Total publications, CP- Cumulative publications

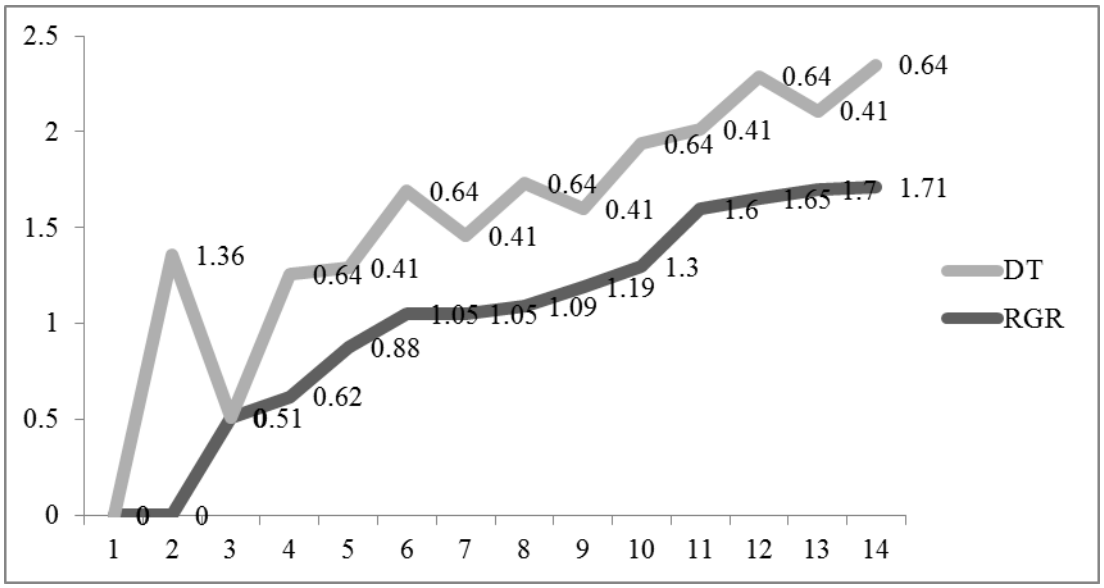


Figure 5: RGR and DT on Nanotechnology research in Canada

It can be seen from the above table 2 figure 5 indicates that the statistical analysis of relative growth rate and doubling time in nanotechnology research trends in Canada during the period of study. As per the formula, RGR is the measure to analyze the increase in terms of number of literature output of a particular period of time whereas DT is the period of time required for a quantity to double in size of value. It is therefore, from the present study the results reveal that the RGR range in the nanotechnology output is from 0.51 to 1.71. The mean RGR during the first quarter of the period of study is 0.655 and 1.187 is in the second quarter and 1.83 in the third quarter and the overall mean RGR is 1.224. DT is inversely proportionate to RGR. When RGR decreases DT is increases proportionately at the rate of 0.693. The DT rage is from 1.36 to 0.64 which is demonstrated in Figure 4.

Author Productivity on Nanotechnology in Canada

Table 3 and Figure 6 indicate that the data in connection with author productivity and represents that the total average number of authors per paper is 3.84. The maximum number of average number of authors per author is 4.76 in the year 2014 whereas the minimum number of average number of authors per author is 2.5 in the years 1994 and 2002. The total average productivity per author is 0.26. The highest number of average productivity per author is 0.4 in the years 1994 and 2002 while the least number of average productivity per author is 0.21 in the year 2014.

Table 3: Author Productivity

#	Year	Total Papers	Total Authors	AAPP	APPA
1	1994	2	5	2.5	0.4
2	1999	3	10	3.33	0.3
3	2000	1	4	4.0	0.25
4	2001	3	12	4.0	0.25
5	2002	2	5	2.5	0.4
6	2003	13	49	3.77	0.27

7	2004	13	38	2.92	0.34
8	2005	20	60	3.0	0.33
9	2006	40	133	3.33	0.30
10	2007	42	149	3.55	0.28
11	2008	52	181	3.48	0.29
12	2009	46	188	4.09	0.24
13	2010	53	196	3.70	0.27
14	2011	73	290	3.97	0.25
15	2012	59	212	3.59	0.28
16	2013	77	314	4.07	0.25
17	2014	77	367	4.76	0.21
	Total	576	2213	3.84	0.26

Average Authors per Paper (AAPP) = Number of authors/ Number of papers, Average Productivity per author= Number of papers/ Number of authors.

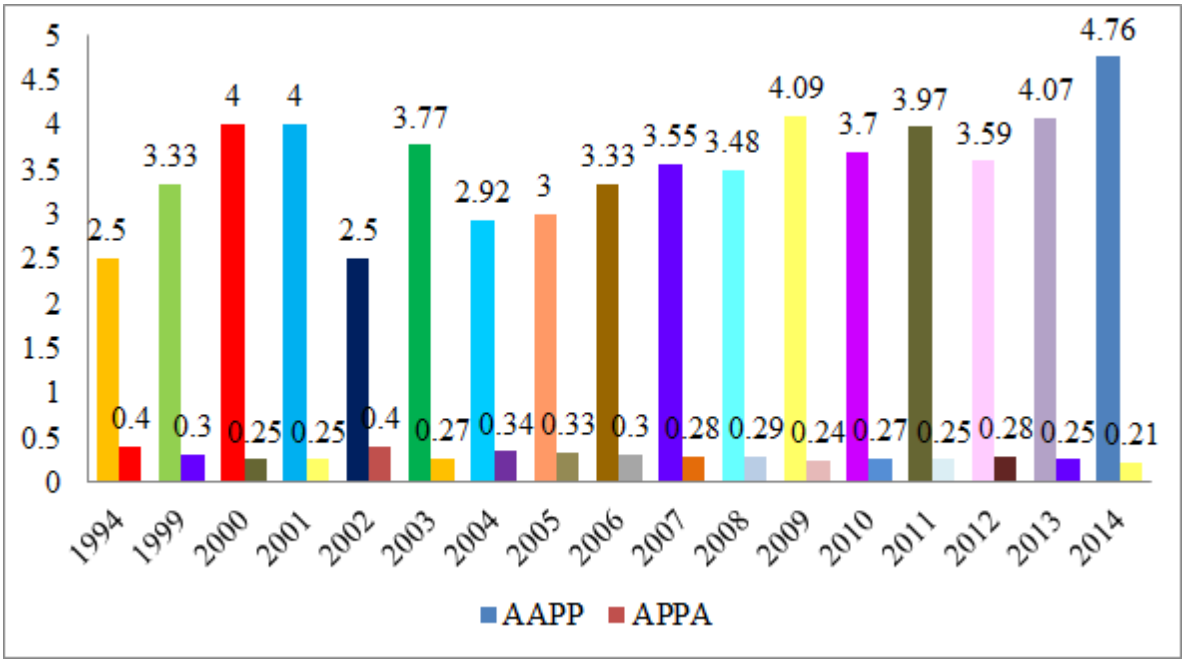


Figure 6: Author Productivity

Degree of Collaboration on Nanotechnology research in Canada

Table 4 and figure 7 represents the strength of Degree of Collaboration on Nanotechnology research in Canada the given formula suggested by Subramanyam K has been employed. It has been identified that the degree of collaboration was so high i.e. 2152 (0.97) in terms of collaborated contributors whereas the solo researchers were very small amount i.e. 61 only compare with multi-authors during the period of study.

Table 4: Degree of Collaboration on Nanotechnology in Canada

TY	SAP	MAP	DC

1994	1	4	0.8
1999	0	10	0
2000	0	4	0
2001	2	10	0.83
2002	0	5	1.00
2003	1	48	0.97
2004	3	35	0.92
2005	5	55	0.92
2006	6	127	0.95
2007	6	143	0.96
2008	8	173	0.95
2009	3	185	0.98
2010	6	190	0.97
2011	4	286	0.99
2012	9	203	0.96
2013	5	309	0.98
2014	2	365	0.99
Total	61	2152	0.97

Total Years, Single Authored papers, Multi-Authored papers, DC- degree of collaboration

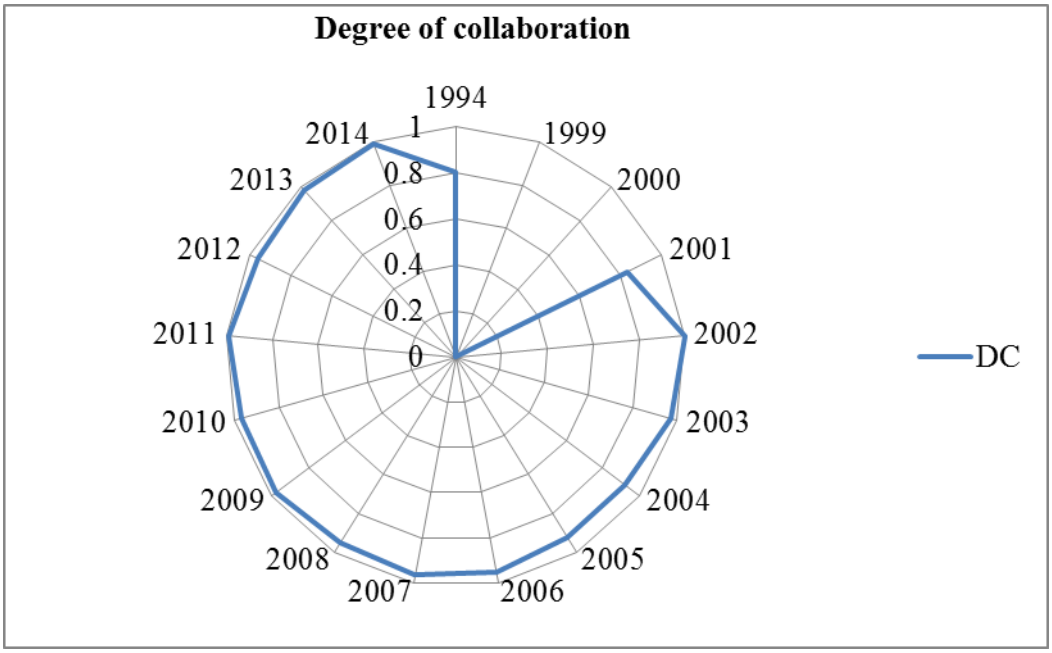


Figure 7: Degree of Collaboration on Nanotechnology research in Canada

Highly Productive Authors in Nanotechnology

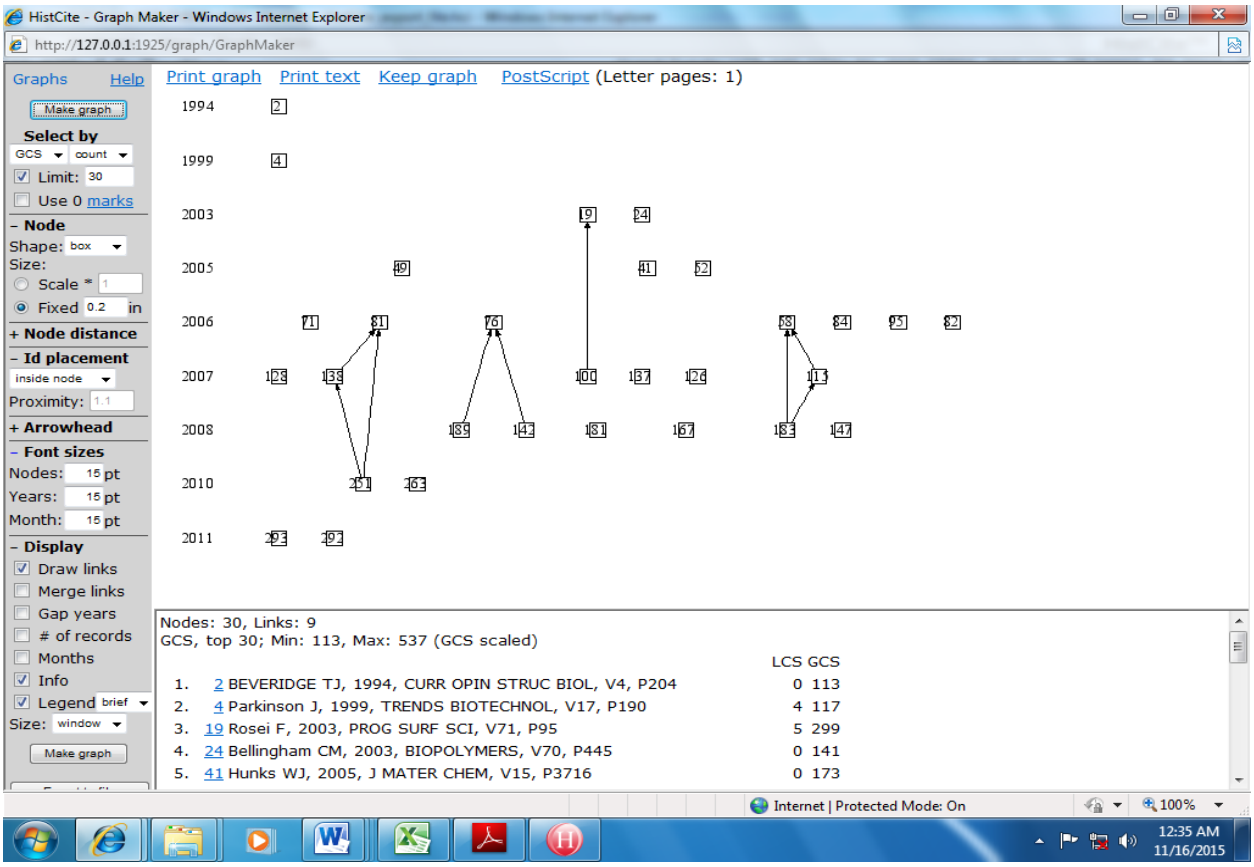
Table 5 depicts the highly cited authors with high citations on nanotechnology in Canada during the research. Out of 2213 total authors, researchers have selected only top ranked authors

for the present study. Out of top 25authors, ‘Chan WCW’ has placed in the top position with 11 research papers along with 1103 citations with 11 h-index and followed by ‘Sleiman HF’ has ranked in the second place with 14 scientific papers and 1018 citations with 10 h-index. The third position has got by ‘Li YF’ with 8 papers with 1004 citations and 8 h-index. The least number of which is single article published by many authors among the top 25 authors with high citations during the study.

Table 5: Highly Cited Authors with h-index

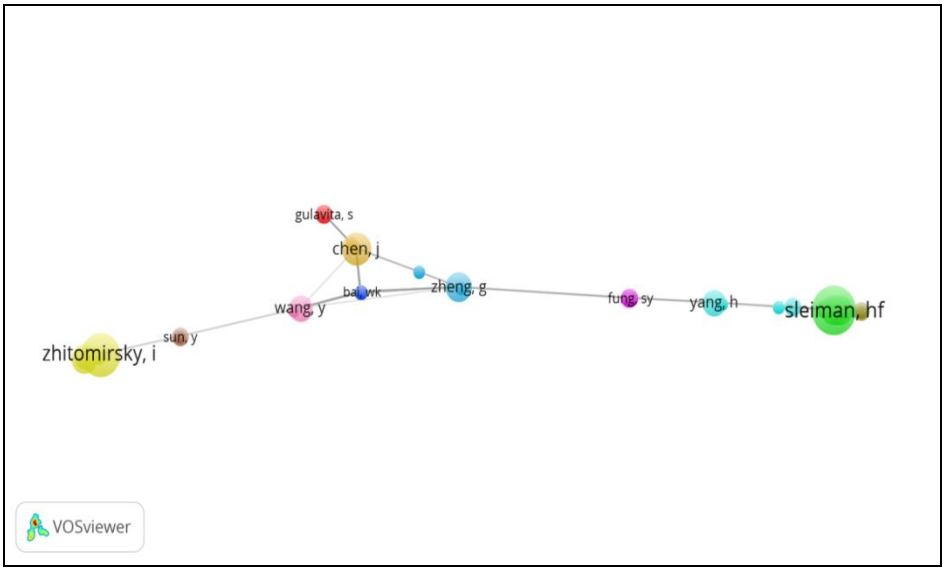
S. No	Author	TP	Percent	TC	h-index
1	Chan WCW	11	1.9	1103	11
2	Sleiman HF	14	2.4	1018	10
3	Li YF	8	1.4	1004	8
4	Aldaye FA	5	0.9	822	5
5	Brook MA	5	0.9	692	5
6	Fischer HC	3	0.5	676	3
7	Rosei F	7	1.2	606	5
8	Barth JV	2	0.3	595	2
9	Palmer AL	1	0.2	498	1
10	Zhao WA	5	0.9	494	5
11	Buzea C	2	0.3	408	2
12	Gordon R	8	1.4	405	7
13	Pacheco II	1	0.2	396	1
14	Robbie K	1	0.2	396	1
15	Besenbacher F	2	0.3	385	2
16	Zhao W	1	0.2	340	1
17	Ozin GA	7	1.2	308	6
18	Birch D	1	0.2	302	1
19	Czeisler C	1	0.2	302	1
20	Fehlings MG	1	0.2	302	1
21	Kessler JA	1	0.2	302	1
22	Niece KL	1	0.2	302	1
23	Sahni V	1	0.2	302	1
24	Stupp SI	1	0.2	302	1
25	Tysseling-Mattiace VM	1	0.2	302	1

TP- Total Papers, TC- Total Citations

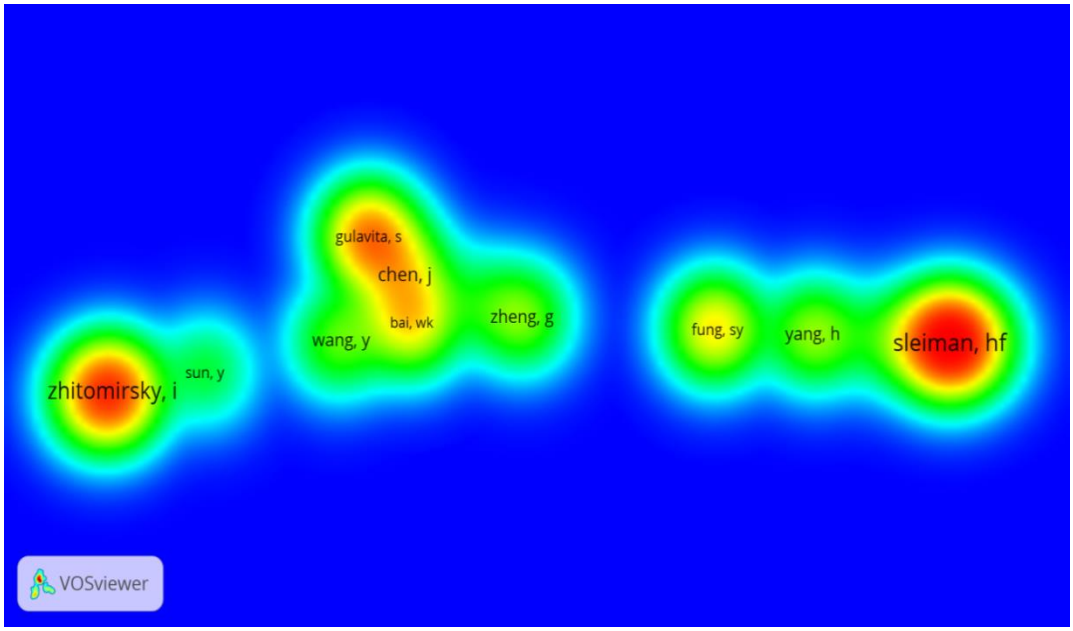


Graph 1: citation using HistCite software

The graph 1 has been made of using HistCite software with measuring 30 nodes and 9 links, top 30 GCS scales with minimum number 113 and maximum number 537.



Map 1: Label view of highly cited authors



Map 2: Density view of highly cited authors

Types of document on Nanotechnology

It is seen from the table 6 and figure 8 that the collected information for the analysis have different types in terms of article (390,67.7%), review (115, 20.0%), editorial material 29, 5.0%), article from proceedings paper (23, 4.%), meeting abstract (6, 1.0%); review from book chapter (5, 0.9%), Letter (3, 0.6%), article from book chapter (2, 0.3%), book review (2, 0.3%) and Note (1, 0.2%). It is observed from the analysis in terms of documents that the highest number of documents comes under articles and 7776 citations which occupies the top rank and followed by review papers with 5858 citations is in the second position and the small amount of citations i.e. only 2 by article from book chapter and none of the citation has meeting abstract. The almost all the documents (except one) have been written by English language (575, 99.8%) and the least only one number of document was by French language (1, 0.2%). It is indicated that the English Language is the predominant (figure 9).

Table 6: Types of Document

Rank	Document Type	items	Share of %	Total Citations
1	Article	390	67.7	7776
2	Review	115	20.0	5858
3	Editorial Material	29	5.0	406
4	Article; Proceedings Paper	23	4.0	948
5	Meeting Abstract	6	1.0	0
6	Review; Book Chapter	5	0.9	703
7	Letter	3	0.6	51
8	Article; Book Chapter	2	0.3	2
9	Book Review	2	0.3	0
10	Note	1	0.2	60
	Total	576	100	15804

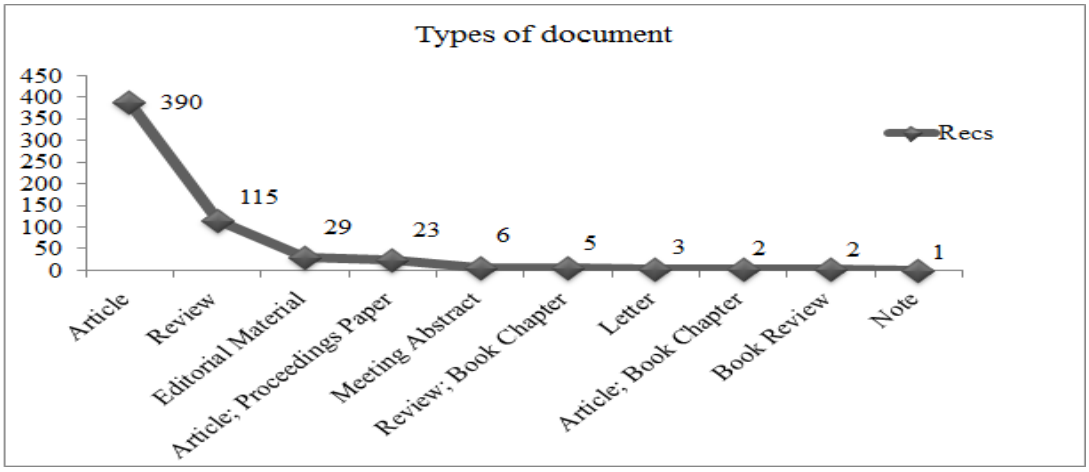


Figure 8: Types of document

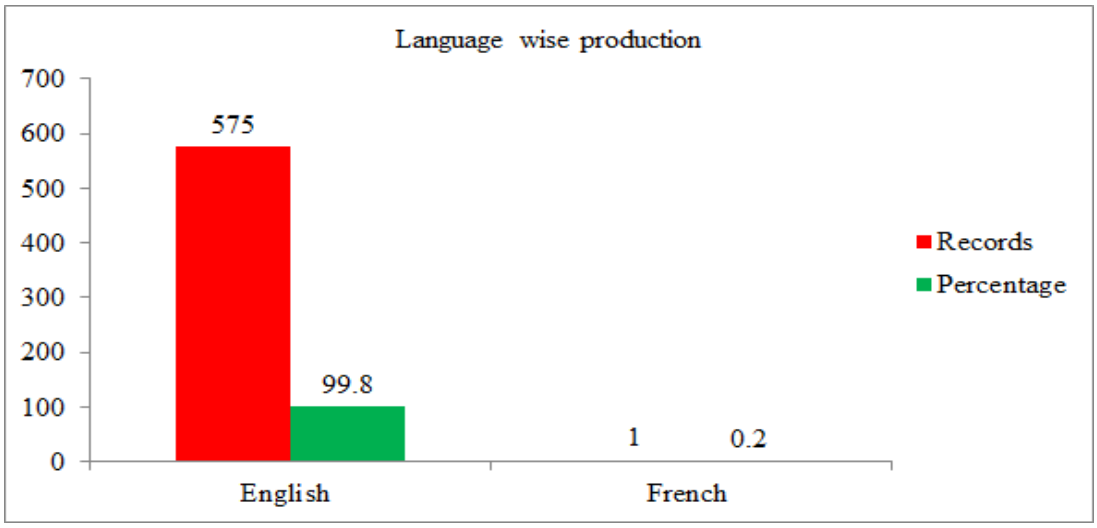


Figure 9: Language wise production

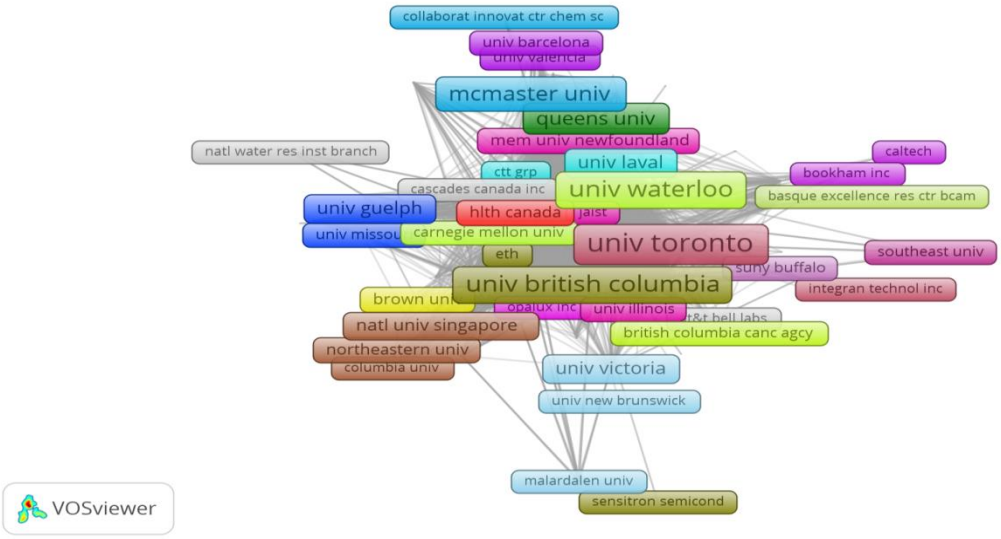
Most productive Institutions on Nanotechnology in Canada

It can be seen that from the table is more than 300 highly cited institutions were taken into account out of 15804 citations on nanotechnology. In this context, the highest number of cited institution with in the top 20 institutions is University of Toronto is in the top position with 2867 citations and the average citation per paper is 42.79 and the h-index is 26 with 67 total records during the study period and followed by McGill University is in the second rank with 1911 citations and average citation per paper is 37.47 and h-index is 21 with 51 articles. University of British Columbia (= 1850 citations with 46 articles), McMaster University (= 1278 citations, 28 articles) and the minimum number of citations (= 302 citations with only one article) is in the 20th position in nanotechnology research in Canada. It seems that the University of Toronto is the top ranked and have good relationship with other institutions to produce the publications in the field of nanotechnology. The same study had already done by Hui-Zhen and Yuh-Shan and found that the University of Toronto was the most productive institution in the highly cited Canadian articles during the year 1900-2011.

Table 7: Highly cited Institutions with h-index

#	Institution	TP	Percent	TC	CPP	h-index
1	University of Toronto	67	11.6	2867	42.79	26
2	McGill University	51	8.9	1911	37.47	21
3	University of British Columbia	46	8.0	1850	40.22	20
4	McMaster University	28	4.9	1278	45.64	13
5	University of Alberta	57	9.9	937	16.44	17
6	University of Waterloo	45	7.8	751	16.69	15
7	University of Manitoba	14	2.4	702	50.14	11
8	Queens University	12	2.1	663	55.25	9
9	Tech University of Munich	2	0.3	547	27.35	2
10	University of Quebec	15	2.6	535	35.67	9
11	Canadian InstAdv Res	1	0.2	498	498.0	1
12	Natl Res Council Canada	16	2.8	457	28.56	11
13	EcolePolytech	12	2.1	439	36.58	8
14	University of Calgary	28	4.9	434	15.5	9
15	MIT	11	1.9	405	36.82	8
16	Aarhus University	2	0.3	385	192.5	2
17	University of Western Ontario	20	3.5	350	17.5	10
18	Hosp Sick Children	4	0.7	348	87.0	4
19	University of Montreal	17	3.0	309	18.18	9
20	Northwestern University	1	0.2	302	302.0	1

Total Papers, TC- Total citations, CPP – Citation per paper



Map 3: Label view of highly cited Institutions

International collaboration

It can be observed from the table 8and figure 10 that Canada has collaborated with other countries in terms of publications during the study period. Of the 44 collaborative countries, we select only top ranked countries based on the citation wise for the study. It is seen that USA (108 articles with 3150 citations) is the top country to collaborate with Canada which has got the first position and followed by France (806 citations with 17 articles) is in the second rank, Germany (644 citations with 10 articles) has occupied the third place, UK (528 citations with 21 records) has placed in the fourth rank, Denmark (433 citations with 4 records) is the fifth rank, Peoples R China (353 citations with 22 records) is in the sixth place and India (190 citations with 8 articles) is achieved in the eight place. Further, we have calculated in terms of h-index, in this context, the huge number of h-index (=32) is achieved by USA and ranked in the first position and followed by UK (=11) is in the second rank, France (=10) has got the place in the third rank and Peoples R China (=9) is in the four tank and followed by Japan and Italy (=7) have occupied in the fifth position and India (=6) is in the sixth rank among the top 20 country wise highly cited production in nanotechnology.

Table 8: Country wise highly cited production in nanotechnology

Rank	Country	TP	Percent	TC	CPP	CR	NA	h-index
1	USA	108	18.8	3150	29.17	7629	564	32
2	France	17	3.0	806	47.41	846	92	10
3	Germany	10	1.7	644	64.4	617	52	5
4	UK	21	3.6	528	25.14	1342	104	11
5	Denmark	4	0.7	433	108.25	282	42	4
6	Peoples R China	22	3.8	353	16.05	1366	129	9
7	Switzerland	5	0.9	318	63.6	219	28	5
8	Spain	8	1.4	293	36.63	621	51	5
9	Japan	9	1.6	232	25.78	685	41	7
10	Australia	8	1.4	210	26.25	722	42	5
11	India	8	1.4	190	23.75	816	41	6
12	Italy	9	1.6	174	19.33	695	56	7
13	Israel	3	0.5	142	47.33	331	25	3
14	Netherlands	5	0.9	138	27.6	172	28	4
15	Portugal	5	0.9	113	22.6	339	25	3
16	Brazil	4	0.7	74	18.5	362	23	2
17	South Korea	2	0.3	68	34.0	149	8	2
18	Singapore	6	1.0	66	11.0	270	36	4

19	New Zealand	3	0.5	66	22.0	266	11	2
20	Ireland	2	0.3	46	23.0	84	23	2

Total Papers, TC- Total citations, CPP – Citation per paper, TCR- Total cited references, NA- number of authors

It is seen from the Table 8 deals with the cited references in which the huge number of cited references (=7629) is achieved by USA which is placed in the first rank and followed by Peoples R China (=1366) is got in the second position and United Kingdom (= 1342) is placed in the third place, France (=846) and India (=816) fourth and fifth position. The researchers have also evaluated the authors based on the country and found that the maximum number of authors (=564) are collaborated with Canada is USA and followed by Peoples R China (=129) and UK (=104). It shows that the USA, Peoples R China and UK have the good relationship with Canada in terms of publishing research output among the top 20 countries. The chart has been plotted the trend line and equation of exponential growth is $y = 2383.1e^{-0.21x,}$ and R^2 square value on chart is 0.3106.

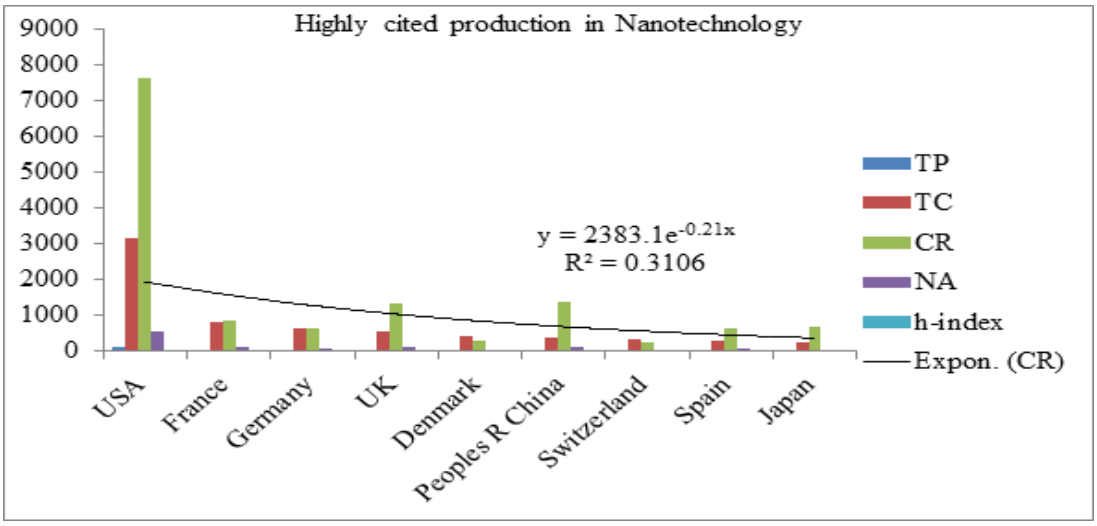


Figure 10: International collaboration (top 10)

Top ranked Research Areas on Nanotechnology

Selecting research areas is most important and it is the one of the major work for researchers and scientists. Table 9 indicates that out of 70 research areas in the field of nanotechnology in Canada, we have selected only top ranked research areas such as Materials Science (= 170 literature output and 29.514%) has got in the first rank, Chemistry (= 168 records and 29.167%) is placed in the second rank, Science Technology Other Topics (= 157 with 27.257%) has ranked in the third position, Engineering (= 96 with 16.667%) and Physics (93 with 16.146%) is in the fifth rank etc.

Table 9: Research Areas on Nanotechnology in Canada

S. No	Research Areas	Total Record	Percent

1	Materials Science	170	29.514
2	Chemistry	168	29.167
3	Science Technology Other Topics	157	27.257
4	Engineering	96	16.667
5	Physics	93	16.146
6	Pharmacology Pharmacy	61	10.590
7	Biochemistry Molecular Biology	29	5.035
8	Business Economics	29	5.035
9	Biotechnology Applied Microbiology	22	3.819
10	Polymer Science	20	3.472

Top ranked Subject wise distribution

It is inferred in the table 10 that out of 112 subject wise productions in the field of nanotechnology, only top 10 subjects has been taken into account for the analysis. The results reveal that the highest number of 140 records with 24.306 percent has occupied in the subject of 'Materials Science Multidisciplinary' and placed in the first rank and followed by in the next place has got by the subject of 'Nanoscience Nanotechnology' with 138 research output and 23.958 percent. The subject 'Chemistry Multidisciplinary' is in the third rank with 113 publications and 19.618 percent. Within top 10 subject areas, the minimum number of subject in Canada is Biotechnology Applied Microbiology with 22 records and 3.819 percent.

Table 10: Subject wise distribution on Nanotechnology in Canada

S. No	Subject	Record Count	%
1	Materials Science Multidisciplinary	140	24.306
2	Nanoscience Nanotechnology	138	23.958
3	Chemistry Multidisciplinary	113	19.618
4	Physics Applied	75	13.021
5	Chemistry Physical	66	11.458
6	Pharmacology Pharmacy	55	9.549
7	Engineering Electrical Electronic	39	6.771
8	Physics Condensed Matter	29	5.035
9	Biochemistry Molecular Biology	22	3.819
10	Biotechnology Applied Microbiology	22	3.819

Top ranked Source Journals

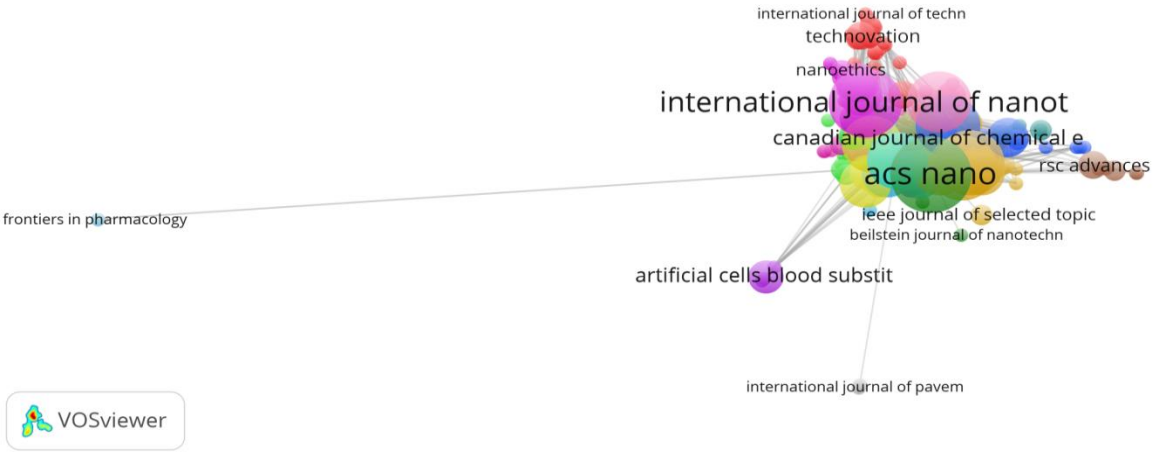
It is shown in the table 11 that out of 338source journals, researchers have carefully chosen only leading and top ranked journals such as ACS NANO, International Journal of Nanotechnology, Angewandte Chemie International Edition, Journal of the American Chemical Society, and IEEE Transactions on Nanotechnology and Nanotechnology etc. Out of top 15 productivity source journals, ACS NANO (167 h-index) is ranked first place with 14 records along with 355 total citation score and the average citation per paper is 25.36, and followed by the second rank is occupied by International Journal of Nanotechnology (25 h-index) with 12 and

43 citations and average citation per paper is 3.58.AngewandteChemie-International Edition is in the third rank with 11 records (675 citations), and the average citation per paper is 61.36 and the next position is got by Journal of the American Chemical Society (412 h-index) with 11 articles and the citations are439 with average citation per paper is 39.91.

Table 11: Source Journals on Nanotechnology in Canada

#	Journal	TR	TC	ACPP	h-index
1	ACS Nano	14	355	25.36	167
2	International Journal of Nanotechnology	12	43	3.58	25
3	Angewandte Chemie-International Edition	11	675	61.36	-
4	Journal of the American Chemical Society	11	439	39.91	412
5	IEEE Transactions on Nanotechnology	10	216	21.6	56
6	Nanotechnology	10	276	27.6	128
7	International Journal of Nanomedicine	9	210	23.33	53
8	Journal of Pharmaceutical Sciences	9	88	9.78	121
9	Small	8	356	44.5	135
10	Advanced Drug Delivery Reviews	7	328	46.86	205
11	Langmuir	7	50	7.14	241
12	Nanomedicine-Nanotechnology Biology and Medicine	7	221	31.57	66
13	ACS Applied Materials & Interfaces	6	36	6.0	-
14	Journal of Nanoscience and Nanotechnology	6	151	25.17	74
15	Canadian Journal of Chemical Engineering	5	156	31.2	43

Totla recors, Total citations, ACPP- Avarage citaion per paper



Map 4: Label view of the source Journals on Nanotechnology

Findings and Conclusion

We can conclude in the present study of nanotechnology research in Canada during the period of 17 years from 1994- 2014. The findings of the results reveal that based on the manuscripts, out of 576 literature output, the highest number of (13.4%) articles was published in the year 2013 and 2014 respectively. The most productive authors are measured in which the maximum number of authors (77 papers, 09 h-index) in the year 2014 and the minimum number of authors (one paper) in the 2000. Researchers analyzed and evaluated the cited references and the huge number of cited references in the year 2013 and the highest mean value of cited references are 73.62 in the year 2007 and the least number of mean values of cited references is 18.67 in the year 2001. The scientometric indicators such as RGR, DT, and DC have been used to measure the literature out during the study period in this context, The RGR range in the nanotechnology output is from 0.51 to 1.71. The mean RGR during the first quarter of the period of study is 0.655 and 1.187 is in the second quarter and 1.83 in the third quarter and the overall mean RGR is 1.224 and DT is increases proportionately at the rate of 0.693. The degree of collaboration was so high (0.97) in terms of multi-authored contributors.

References

Aytac, S. (2010). Scientific International Collaboration of Turkey, Greece, Poland, and Portugal: a Bibliometric analysis. ASIST, 22-27.

Beaudry, C., & Schiffauerova, A. (2011). Is Canadian intellectual property leaving Canada? A study of nanotechnology patenting. Journal of Technology Transfer. doi:10.1007/s10961-011-9211-1.

Garg,K.C & Padhi,P. Scientometrics of Laser Research Literature as viewed through the Journal of CurrentLaserAbstracts.*Scientometrics,*1999, 45(2),251 – 268.

Garousi, V & Varma, T. (2012). A Bibliometrics Analysis of Canadian Electrical and Computer Engineering Institutions (1996-2006) Based on IEEE Journal Publications, Computer and Information Science, 5 (4), 1-24.

Heinze, T., Shapira, P., Senker, J., & Kuhlmann, S. (2007). Identifying creative research accomplishments: Methodology and results for nanotechnology and human genetics. Scientometrics, 70 (1), 125–152.

Hu., G; Carley, S & Tang, L (2012). Visualizing Nanotechnology Research in Canada: Evidence from Publication Activities, 1990-2009. Journal of Technology Transfer, 37, 550-562.

Hui-Zhen, F and Yuh-Shan, H. (2015). Highly cited Canada articles in Science Citation Index Expanded: a bibliometric analysis. Canadian Social Science, 11 (3), 50-62.

Kostoff, R. N., Stump, J. A., Johnson, D., Murday, J. S., Lau, C. G. Y., & Tolles, W. M. (2006). The structure and infrastructure of the global nanotechnology literature. Journal of Nanoparticle Research, 8(3–4), 301–321.

Lee, L. L., Chan, C. K., Ngiam, M., & Ramakrishna, S. (2006). Nanotechnology patent landscape 2006. NANO, 1(2), 101–113.

Rosei, F. (2008). Special issue: On nanotechnology in Canada. International Journal of Nanotechnology, 5 (9–12), 897–899.

Subramanyam, K. (1993). "Bibliometric Study of Research Collaboration: A Review." Journal of Information Science, 6 (1): 33-38.

Tang, L., Shapira., P. (2012). Effects of international collaboration and knowledge moderation on China's nanotechnology research impacts, Journal of Technology Management in China, 7 (1), 94-110. www.emeraldinsight.com/1746-8779.htm

Velmurugan, C & Radhakrishnan, N. (2015). Research analysis by means of Scientometric techniques on Biotechnology, International Journal of Multidisciplinary Consortium (IJMC), 2(1), 256-265.

Velmurugan, C & Radhakrishnan, N. (2015). A Scientometric Analysis of Research Papers Published on Pharmacognosy as reflected in the Web of Science. *Advances in Pharmacognosy and Phytomedicine,* 1(1), 27-40.

Velmurugan, C & Radhakrishnan, N. (2015). Journal of Information Literacy: A Scientometric Profile, *Journal of Information Sciences and Application,* 3 (1), 1-9.

Velmurugan, C & Radhakrishnan, N. (2015). Quantitative Analysis of Scientific Publications Output on Engineering Journal: A Scientometric Study, *Journal of Information Sciences and Application,* 3 (1), 19-30.

Velmurugan, C & Radhakrishnan, N. (2015). Literature output of Supply Chain Management: A Scientometric approach, *Journal of Organizational Behaviour,* 3(2), 31-44.

Velmurugan, C & Radhakrishnan, N. (2015). Authorship trends and collaborative research work on Library Herald: a Scientometric analysis, In Information Science and Digital Libraries, edited by Somvir, International Research Publication House, Delhi, 183-197.

Velmurugan, C. (2013). Research Trends in Journal of Intellectual Property Rights (JIPR): A Bibliometric Study, Library Philosophy and Practice (e-journal), Paper 1043. Retrieved 6 March from: http://digitalcommons.unl.edu/libphilprac/1043.

Velmurugan, C. (2013). Scientometric analysis: Annals of Library and Information Studies Publications Output during 2007-2012, International Journal of Library and Information Studies, 3 (3), 58-65.

Velmurugan, C. (2013). Bibliometric analysis with special reference to Authorship Pattern and Collaborative Research Output of Annals of Library and Information Studies for the Year 2007 – 2012. International Journal of Digital Library Services, 3 (3), 13-21.

Velmurugan, C. (2014). Research Trends in Indian Journal of Pure and Applied Physics (IJPAP) for the Year 2009 – 2012, Asian Review of Social Sciences, 3 (1), 24-28.

Velmurugan, C & Radhakrishnan, N. (2014). Publication Research Trends on Technical Review Journal: A Scientometric Study, International Journal of Digital Library Services (IJDLS), 4 (3), 45-55.

Yegul, M. F., Yavuz, M., & Guild, P. (2008). Nanotechnology: Canada's position in scientific publications and patents. PICMET 2008 Proceedings, 27–31 July. Cape Town, South Africa.

Youtie, J., Shapira, P., & Porter, A. L. (2008). Nanotechnology publications and citations by leading countries and blocs. Journal of Nanoparticle Research, 10(6), 981–986.