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Stem Cell Research: A Bibliometric Analysis from 1999-2008

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Introduction

Stem cell research is a vital area of study. It is of interest to scientists in India and all countries [1]. Bibliometrics is a truly interdisciplinary research field. Bibliometrics comprises mathematics, social science, natural sciences, engineering, and life sciences. Bibliometric studies such as a work on the research productivity in ophthalmic and vision research used both the number of publications and qualitative measures of journals.[2] This article is a bibliometric study of a part of the literature on stem cell research.

Bibliometrics

The terms bibliometrics and scientometrics were introduced by Pritchard and by Nalimov and Mulchenko in 1969. Pritchard explained the term bibliometrics as "the application of mathematical and statistical methods to books and other media of communication." There have been many bibliometric studies of the literature in the sciences in the last 40 years. In chemical information and computer sciences (CICS), a bibliometric approach was used to survey state-of-the-art of research. Journal of Chemical Information and Computer Sciences (JCICS) has been the leading journal in this area for the last 30 years. [3] One important element of bibliometrics is the author co-citation frequency matrix. It has been used to study Knowledge Management. Author co-citation frequencies were derived from the 1994-1998 academic literature and captured by the single search phrase of "Knowledge Management." [4] An economically and scientifically developing country like China has done research in the field of Neuroscience. A MEDLINE-based bibliometric analysis was done of the Chinese output in neuroscience for 1984 to 2001. [5] Research was done from the Inorganic Crystal Structure Database with the focus on growth rate, distribution of publications, productivity of authors, and multiple authorship patterns. [6] HIV/AIDS Research in India revealed the rapid growth of literature from 1992 onwards. The authorship distribution was examined using Lotka's Law. To identify the core journals Bradford's Law was used. The relative productivity of India was low and the focus was more on research and development. [7] Various aspects of nutrition research in Bangaladesh from 1972 to 2006 has been analyzed using bibliometrics. [8]

Materials and Methods

This study was confined to the published literature on the sub-discipline “Stem Cell” from the MEDLINE database. MEDLINE is the National Library of Medicine's (NLM) leading bibliographic database, which contains more than 18 million references to journal articles in the life sciences with a concentration on biomedicine. MEDLINE covers biomedicine, health, life sciences, biology,

environmental science, marine biology, plant, and animal science. The period chosen for the study was 1999 to 2008. The total number of records was 54,373.

Need for the Study

A stem cell is a cell that has the ability to divide (self-replicate) for unlimited periods, often throughout the life of the organism. Under the right conditions, stem cells can differentiate to the many different cell types that make up the organism. Many different studies have explored the efficacy of stem cell treatment. [9] [10] [11] [12 [13]

Limitations

The study is confined to literature from 1999 to 2008 that is covered in MEDLINE.

Methods

The MEDLINE database was searched using the the Medical Subject Heading (MeSH) "Stem cell research". This yielded ten years of records that were downloaded into separate text files.

Data Analysis

The data was investigated with Bibexcel. This was developed by Olle Persson of Umeå University in Sweden. This software is designed to analyse bibliographic data..

Objectives of the Study

- Observe authorship patterns
- Discover the degree of collabration
- Measure the quantum of research productivity in MEDLINE
- Study the linguistic distribution
- Study the geographical distribution
- Study the growth rate of production of literature
- Identify the most frequent journals

The yearwise distribution of data according to the number of authors is presented in Table 1. The table shows that nearly 12.6% of the contributors were only by single authors and 12.86% is two authors research output. It clearly collaboration in stem cell research.

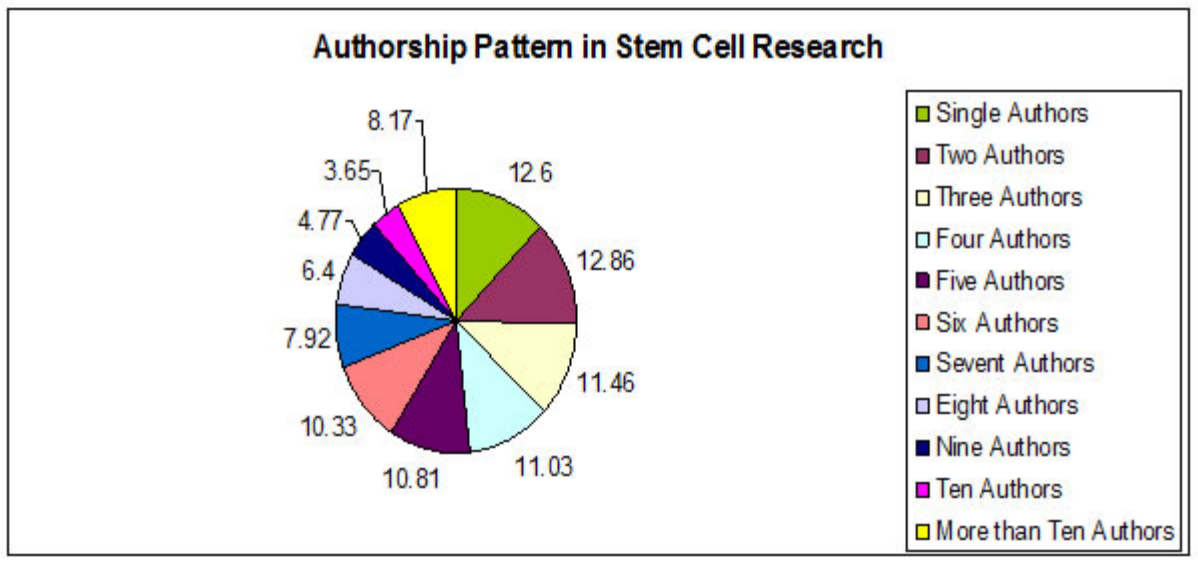
Table 1. Authorship pattern in Stem Cells

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total	%
Single Authors	328	434	676	708	604	759	875	896	768	808	6856	12.6
Two Authors	331	416	463	590	620	706	843	868	973	1180	6990	12.86
Three Authors	344	393	435	485	541	619	739	820	912	942	6230	11.46
Four Authors	394	398	439	487	530	594	651	708	914	885	6000	11.03
Five Authors	371	395	411	495	502	543	622	785	860	894	5878	10.81
Six Authors	364	341	376	399	471	546	621	795	842	861	5616	10.33

Seven Authors	252	269	291	293	357	429	486	589	642	699	4307	7.92
Eight Authors	217	220	218	251	254	320	409	450	533	609	3481	6.4
Nine Authors	126	161	156	164	227	258	286	354	383	476	2591	4.77
Ten Authors	87	91	110	135	168	202	220	298	302	366	1979	3.65
More than Ten Authors	224	235	240	296	327	392	507	631	741	852	4445	8.17
Total	3038	3353	3815	4303	4601	5368	6259	7194	7870	8572	54373	100

Diagram 1 depicts the authorship pattern in stem cell research from 1999 to 2008. Five or more authors are found on 41.24% of the records.

Diagram 1. Degree of Collaboration



The extent of the degree of collaboration was measured with the formula devised by K. Subramaniam.

The formula is

$$C = Nm / Nm + Ns$$

Where

C = Degree of Collaboration in a discipline

Nm = Number of multiple authored papers

Ns = Number of single authored papers

Accordingly, the Degree of Collaboration has been calculated for the year 1999 is as follows:

$$C = \frac{2710}{2710} = \frac{2710}{3038} = 0.89$$

$$2710 + 328$$

The yearwise degree of collaboration falls between 0.82 and 0.9. The degree of collaboration for any subject ranges from 0.01 to 0.99 and it is always below 1 which has been proved by Karisiddappa, Maheswarappa and Shirol in Psychology and Bandyopadhyay in different disciplines such as Mathematics, Physics, Philosophy, Political Science and Mechanical Engineering.

Table 2. Degree of Collaboration in Stem Cell Research

Years	Single	Two	Three	Four`	Five	Six	Seven	Eight	Nine	Ten	More than Ten	Total	More than One Authors	Degree of Collaboration
1999	328	331	344	394	371	364	252	217	126	87	224	3038	2710	0.89
2000	434	416	393	398	395	341	269	220	161	91	235	3353	2919	0.87
2001	676	463	435	439	411	376	291	218	156	110	240	3815	3139	0.82
2002	708	590	485	487	495	399	293	251	164	135	296	4303	3595	0.83
2003	604	620	541	530	502	471	357	254	227	168	327	4601	3997	0.87
2004	759	706	619	594	543	546	429	320	258	202	392	5368	4609	0.86
2005	875	843	739	651	622	621	486	409	286	220	507	6259	5384	0.86
2006	896	868	820	708	785	795	589	450	354	298	631	7194	6298	0.87
2007	768	973	912	914	860	842	642	533	383	302	741	7870	7102	0.9
2008	808	1180	942	885	894	861	699	609	476	366	852	8572	7764	0.9
Total	6856	6990	6230	6000	5878	5616	4307	3481	2591	1979	4445	54373	47517	0.87

Quantum of Stem Cell Research Activity

The research productivity in the source database and the quantum of records on stem cells covered is shown in the Table 3. Only 0.95% of the records in the MEDLINE database are on stem cells. The yearwise distribution of stem cell literature is shown in this table.

Table 3. Percentage of Literature Published from 1999 to 2008 in Stem Cell Research

Years	Total No. of Records	Records on Stem Cell	Percentage
1999	462148	3038	0.66
2000	489198	3353	0.69
2001	508109	3815	0.75
2002	523264	4303	0.82

2003	549977	4601	0.84
2004	579750	5368	0.93
2005	613406	6259	1.02
2006	637129	7194	1.13
2007	660193	7870	1.19
2008	676822	8572	1.27
Total	56,99,996	54373	0.95

Quantum of Stem Cell Research Productivity

The research productivity on 'Stem Cell' covered in the database is shown in Table 4.

Table 4. Quantum of Literature Published on Stem Cell from 1999 to 2008

Years	Records on Stem Cell	Percentage	Cumulative Percentage
1999	3038	5.58	
2000	3353	6.17	11.75
2001	3815	7.02	18.77
2002	4303	7.91	26.68
2003	4601	8.46	36.14
2004	5368	9.88	45.02
2005	6259	11.51	56.53
2006	7194	13.23	68.76
2007	7870	14.47	84.23
2008	8572	15.77	100
Total	54373	100	

The yearwise distribution of literature is shown in Table 4. The highest number of records (8,572) was published during 2008, followed by 7,870 in 2007, and 7,194 in 2006.

Distribution of Research Production by Language vs Year

The distribution of literature by language is presented in Table 5.

Table 5. Stem Cell Research Productivity by Language

S.No.	Languages	1999	2000	01	02	03	04	05	06	07	08	Total	%
1	English	2671	2901	3208	3758	3925	4785	5583	6507	7135	7655	48128	88.52
2	Japanese	40	40	31	38	58	49	59	59	55	80	509	0.94
3	Chinese	39	40	47	98	141	182	255	239	273	240	1554	2.86
4	Russian	25	8	29	20	36	29	38	30	45	46	306	0.56
5	French	23	27	31	19	45	33	46	37	81	48	390	0.72
6	Spanish	14	12	17	17	15	13	13	16	23	18	158	0.3
7	German	7	22	20	37	28	34	23	36	33	37	277	0.52
8	Polish	6	5	3	6	12	11	10	11	15	15	94	0.18
9	Czech	3	6	9	6	10	7	2	3	11	12	69	0.14
10	Italian	3	4	8	7	8	3	7	5	8	10	63	0.13
10	Norwegian	2	3	5	2	7	3	2	2	7	9	42	0.09
11	Other	155	285	407	295	316	219	221	249	184	402	2733	5.04
16		3038	3353	3815	4303	4601	5368	6259	7194	7870	8572	54373	100

Distribution of Stem Cell Research Productivity - Country Vs Year

Stem cell research by country and yearwise is presented in the Table 6. The USA has ranks first followed by the United Kingdom 11,397, and the Netherlands with 2,942 records. India is in 16th place with 203 records.

Table 6. Year vs. Country wise Distribution of Stem Cell Research

S No	Country	1999	2000	01	02	03	04	05	06	07	08	Total	%
1	United-States	1597	1714	2015	2284	2503	2902	3446	3874	4122	4513	28970	53.28
2	England	675	743	773	888	916	1103	1213	1509	1670	1907	11397	20.96
3	Netherlands	183	198	209	262	237	263	344	339	441	466	2942	5.41

4	China	48	44	61	116	177	234	315	312	384	342	2033	3.74
5	Germany	71	121	145	124	113	151	174	223	211	284	1617	2.97
6	Japan	59	69	70	71	101	100	128	130	146	176	1050	1.93
7	Switzerland	70	106	92	85	50	74	59	111	101	127	875	1.61
8	Ireland	30	52	81	81	57	57	64	55	99	98	674	1.24
9	France	53	49	60	62	66	78	69	80	98	81	696	1.28
10	Italy	61	45	58	51	56	55	66	88	68	68	616	1.13
11	Denmark	39	50	47	47	44	58	61	74	61	64	545	1
12	Scotland	6	16	19	26	14	15	26	40	52	53	267	0.49
13	Spain	19	7	21	31	24	47	36	35	41	45	306	0.56
14	Russia	20	8	30	23	37	32	31	27	44	44	296	0.55
15	Australia	7	8	13	16	22	14	24	24	37	38	203	0.38
16	India	4	6	3	5	10	8	6	14	9	6	71	0.13
17	Others	96	117	118	131	174	177	197	259	286	260	1815	3.34
18	Total	3038	3353	3815	4303	4601	5368	6259	7194	7870	8572	54373	100

Relative Growth Rate and Doubling Time for Stem Cell Research Output

The Relative Growth Rate (RGR) is the increase in number of articles/pages per unit of time. The mean Relative Growth Rate (R) over the specific period of interval can be calculated from the following equation:

$Log_{e\ 2}W - log_{e\ 1}W$

$1\text{-}2\text{`}R =$

$_2T - _1T$

Whereas

$1\text{-}2\text{`}R$ = mean relative growth rate over the specific period of interval

$log_{e\ 1}W$ = log of initial number of articles/pages

$log_{e\ 2}$W = log of final number of articles/pages after a specific period of interval

$_2T - _1T$ = the unit difference between the initial time and the final time

The year can be taken here as the unit of time. The RGR for both articles and pages can be calculated separately.

Therefore

$1 - 2^R$ (aa -1 year -1) can represent the mean relative growth rate per unit of articles per unit of year over a specific period of interval.

and

$1 - 2^R$ (pp -1 year -1) can represent the mean relative growth rate per unit of pages per unit of year over a specific period of interval.

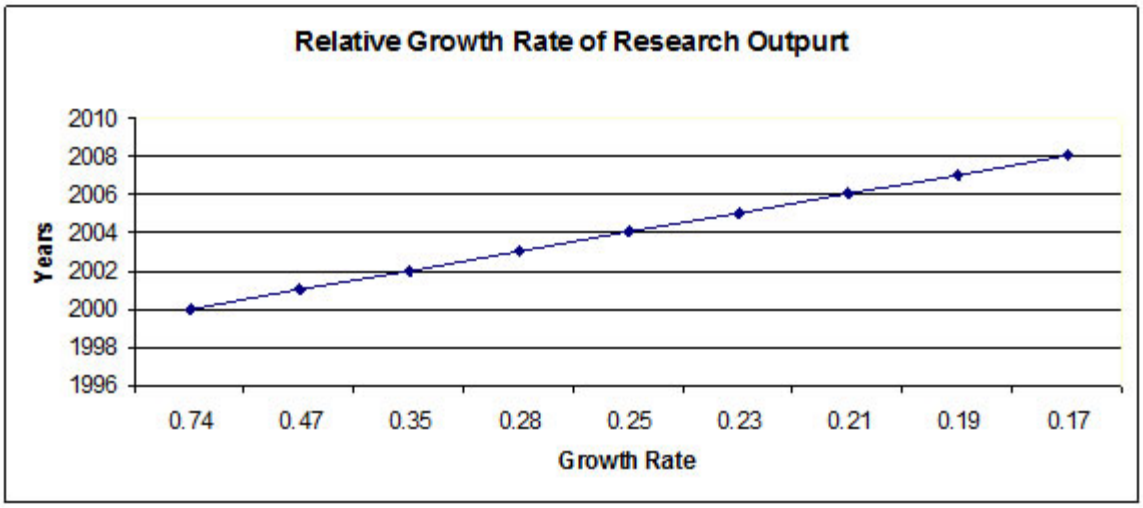
It is seen from rable that there is decrease in RGR by year.

Table 7. RGR and Dt for Stem Cell Research Output by Year-wise

Year	Quantum of Output	Cumulative Total of Output	W_1	W_2	RGR	Dt(a)
1999	3038	3038		8.018955		
2000	3353	6391	8.018955	8.762646	0.743691	0.931838
2001	3815	10206	8.762646	9.230731	0.468085	1.4805
2002	4303	14509	9.230731	9.582524	0.351793	1.969906
2003	4601	19110	9.582524	9.857967	0.275443	2.515951
2004	5368	24478	9.857967	10.10553	0.247563	2.799287
2005	6259	30737	10.10553	10.33322	0.227692	3.04358
2006	7194	37931	10.33322	10.54352	0.210302	3.295268
2007	7870	45801	10.54352	10.73206	0.188537	3.675667
2008	8572	54373	10.73206	10.90362	0.171562	4.039361

The RGR has decreased from 2000 (0.74) to 2008 (0.17) in the span of 10 years (Figure 1).The Doubling Time (Dt) has increased when calculated yearwise.The Doubling Time increases from 0.93 in 1999 to 4.03 in 2008 (Figure 2).

Figure 1



Doubling Time (Dt)

There exists a direct equivalence between the relative growth rate and the doubling time [17]. If the number of articles/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 logarithms of 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 by the formula:

0.693

Doubling time (Dt) =

`R

Therefore,

0.693

Doubling time for articles Dt (a) =

1 -2 `R (aa-1 year-1)

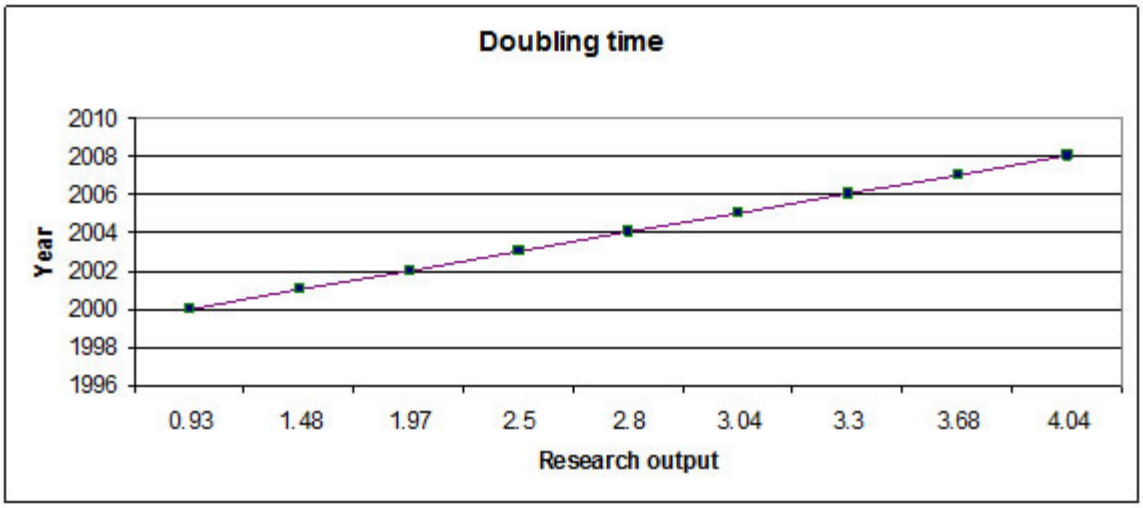
and

0.693

Doubling time for pages Dt (p) =

1 -2 `R (pp-1 year-1)

Figure 2. Publication Types Vs. yearwise Distribution of Stem Cells Research



The Table 8 reveals that the distribution of the stem cell research output according to publication type and year of publication.

It is an accepted fact that most of the scholarly communication of scientific research is published in journals and sometimes presented in the conferences. Of course, those conference papers are further updated and published in journals of the respective field of knowledge. Therefore, scientific communication is being mostly made through periodicals, the primary vehicles of research communication.

In this study, about 75.27% have published in journals, 7.45% have published in comparative studies, and 2.47% are published in comments.

Table 8. Publication Type of Stem Cells Vs Year

Publication Type	1999	2000	01	02	03	04	05	06	07	08	Total	%
Case Reports	39	95	89	99	89	84	60	92	83	67	797	1.47
Clinical Trial	109	101	79	74	93	54	78	84	101	50	823	1.51
Comment	33	75	69	101	114	138	172	183	205	254	1344	2.47
Comparative Study	216	232	302	301	407	516	602	616	474	385	4051	7.45
Journal Article	2341	2535	2749	3247	3335	3887	4508	5330	6101	6895	40928	75.27
Letters	25	24	28	21	20	40	40	42	59	56	355	0.65
Others	275	291	499	460	543	649	799	847	847	865	6075	11.18
Total	3038	3353	3815	4303	4601	5368	6259	7194	7870	8572	54373	100

Figure 3

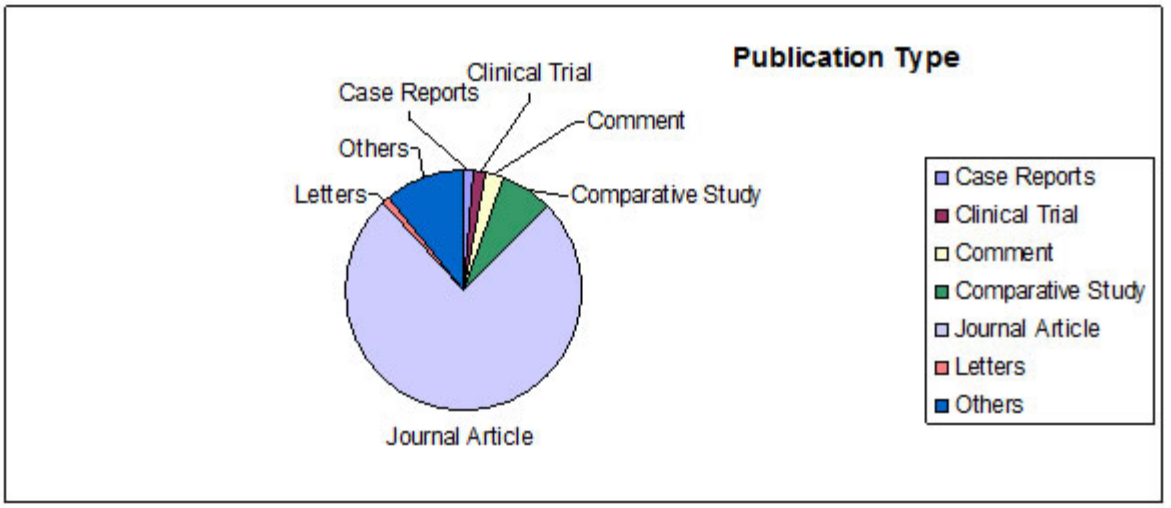


Figure 3 represents the different types of publications in the research output in Stem Cells.

Ranking of Journals in Stem Cell Research

Ranking of the journals on the research output on 'Stem Cell "during the study period has been presented in the below Table 9. With the 1908 contributions *"Blood"* Journal took in the First Rank, the *"Stem-Cells" with 971 contributions and "Proc-Natl-Acad-Sci-U-S-A."* 890 contributions stand Second and Third Rank. The researcher finds out of 15 ranking journals for the specific publication. Bone Marrow Transplantation goes to sixth place.

Table 9. Ranking of Journals in Stem Cell Research

Name of the Journal	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total	Rank
Blood.	202	212	178	223	214	188	190	167	178	156	1908	1
Stem-Cells.	48	32	65	68	76	77	82	313	95	115	971	2
Proc-Natl-Acad-Sci-U-S-A.	79	56	52	79	89	70	101	121	124	119	890	3
Bone-Marrow-Transplant.	104	88	79	106	73	72	85	81	89	67	844	4
J-Immunol.	90	76	82	71	79	60	61	66	44	51	680	5
Bone-Marrow-Transplant.	110	94	73	51	79	48	54	41	42	67	659	6
Development.	55	72	67	61	39	65	60	67	72	80	638	7
Science.	47	54	69	66	47	65	77	67	81	56	629	8
Nature.	28	46	5	51	55	76	80	96	84	102	623	9
J-Biol-Chem.	31	33	42	47	45	87	71	61	56	61	534	10
Dev-Biol.	31	29	36	26	36	43	54	75	81	65	476	11

Leukemia.	66	42	31	56	37	26	29	34	59	34	414	12
Br-J-Haematol.	60	76	54	55	46	32	14	23	21	26	407	13
Ann-N-Y-Acad-Sci.	39	8	36	15	34	20	63	23	43	11	292	14
Haematologica.	47	32	16	22	31	24	31	34	29	22	288	15

Distribution of Journals in Stem Cells based on Bradford Law of Scattering

Bradford first formulated his law, but it did not receive wide attention until the first publication of his book 'Documentation' in 1948. Bradford examined all of the journal titles contributing to a bibliography on applied Geophysics. He divided the list into three 'zones' each containing roughly equal number of references. On the basis of this observation Bradford deduced his law.

"If scientific periodicals are arranged in the order of decreasing productivity of articles on a given subject, they may be divided into a nucleus of periodicals more particularly devoted to the subject and several groups or zones containing the same number of articles as the nucleus where the number of periodicals in the nucleus and the succeeding zones will be as 1: n:n2"

Table 10. Distribution by Zone of Cited Journals and References in Stem Cells

Zone	No. of Journals		No. of Papers	
	No.	(%)	No.	(%)
Zone 1	156	1.46	18156	33.39
Zone 2	1288	12.02	17458	32.10
Zone 3	9269	86.52	18759	34.51
Total	10713	100	54373	100

It is seen from the table 10 shows that 156 core journals are grouped in zone-1 published 18156 articles accounts for one third of the total output. Similarly the second zone comprises of 1288 journals and 9269 journals grouped in third zone. The Bradford's Law states that the number of periodicals in zones, the first zone and second zones will be 1: n: n2····· According to the relationship is the zone will be 156: 1288: 9269. On comparison with the data in Table, it is clear that the trend of research publication confirms the implication of Bradford's Law

Findings

1. A total of 54,373 publications were covered in MEDLINE database for the period 1999-2008.

2. USA ranks as the top most country with maximum number of contributions followed by United Kingdom England and Netherland as second and third positions respectively..

3. It was found that about 88.52% of total output was published in English language, followed by Chinese 2.86% and Japanese 0.94%

4. "Journal articles" contributed 75.27% followed by "Comparative Study" 7.45% of the total output.

5. There was a decrease in Relative Growth Rate and an increase in the Doubling Time for research productivity from year after year throughout the study period.

6. The degree of collaboration has been arrived at 0.9 during the study period

7. It was found that a maximum number of contributions (1908) were published in the journal *'Blood.*. This is followed by 'Stem Cell*' w*ith 971 contributions

8. The research productivity of Stem Cell confirms the implications of Bradford's Law of Scattering

9. There exists a significant level of difference between Stem Cell research performance of Indian scientists and scientists of other countries.

10. Among the developing countries, India contributes substantially in Stem Cell Research.

Conclusion

Research in stem cells will help us understand how they transform into the dazzling array of specialized cells that make us what we are. A better understanding of normal cell development will allow us to understand and perhaps correct the errors that cause of medical deffects. Another imprtant application of stem cells is making cells and tissues for medical therapies. Today, donated organs and tissues are often used to replace the diseased or destroyedn organs. Unfortunately, a large number of people needing a transplant far exceeds the number of organs available for transplantation. Stem cells offer the possibility of a renewable source of replacement cells and tissues to treat a myriad of diseases, conditions, and disabilities including Parkinson's disease, amyotrophic lateral sclerosis, spinal cord injury, burns, heart disease, diabetes, and arthritis. Research with the use of stem cells in the treatment of diseases like heart, liver, brain and spinal cord had remained in the experimental stage like India. Limited contolled clinical trials in human had been permitted. The results were closely monitored by experts. [14] India started to set up a "stem cell priority fund" to maintain research via stem cells and find healing for diabetes, heart and nerve diseases. "We have submitted a proposal of an exclusive fund for stem cell research. I think the government is keen to set up the stem cell priority fund," announced D Balasubramanian, Chairman of the task force on stem ccell research of the Department of Biotechnology (DBT), at the Indo-UK stem cell workshop organised jointly by India and Britain.

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