Research Collaboration Pattern in Indian Contributions to Chemical Sciences

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Abstract

The present paper describes the year wise (2000-2005) growth of Indian research papers in the thirteen fields of Chemical sciences. It investigates the pattern of authorship, type of collaborated research and the degree of collaboration linkages in 13 subfields. Attempts have been made to evaluate growth v/s collaboration. Finally concludes that there is a high degree of collaboration in the Indian Chemical Sciences

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1 Introduction

Publishing articles in professional journals is the principal means of reporting research for a scientist. This mode provides the latest advances to the research community and helps the scientist in securing professional recognition, career advancement and support for his/her research proposals. A publication is a research work taking the conventional physical form which can be circulated, assessed, utilized and acknowledged by the scientific community. Scientific productivity is assessed in terms of publications.

The structure and organization of science have undergone significant changes leading to multidisciplinary and interdisciplinary research compelling the scientists for collaboration. The literal meaning of collaboration is the contact among scientist, nations, communities and institutions to achieve a common goal. Collaboration has been the salient feature of current science research organization. The change from little science to big science has resulted in a shift from solo research to team research. The reason for collaboration in science activity is compounded by several variables such as institutional policies, financial support, and nature of subject of investigation. Evaluating the scientific output using, that is, published paper as an indicator has been a conventional practice since long in scientometric studies. Some of the notable studies from India in the fields of chemical sciences were Karki and Garg (1999), Karki,Garg and Sharma (1999), Kundra and Srinivasan (2004) and Nagpal, Kundra and Wahid (1985).

2 Method

Data for the collaborative study for the period 2000-2005 has been collected in to 13 most contributed subfields namely; Electronic Phenomenon, Pharmacology, Optical Electron Microscopy, Nuclear Phenomenon, Plant Bio-

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chemistry, Inorganic Chemical Reaction, Heterocyclic Compound, Toxicology, Physical Organic Chemistry, Crystallography, Agrochemical Bioregulators, General Physical Chemistry and Fertilisers, Soil and Plant Nutrition. Chemical Abstracts Section Analysis search option of SCI Finder Scholar has been used to collect 36856 data for the period 2000-2005. The data was further analyzed to study the collaborative pattern, collaboration and collaborative index, degree of collaboration and collaborative coefficient for Indian Chemical Sciences. The methodology used for calculating these values is based on the principles formulated by Lawani (1980), Subramanyan (1983) and Ajefruke (1988) respectively,.

3. Results

3.1 Relative Growth Rate and Doubling Time of Articles

The word growth represents an increase in actual size, implying a 'change of state'. Change in size of literature over a specific period of time is termed as growth of literature. A systematic study in the increase of scientific literature, scientific community and institution etc. facilitates quantitative and qualitative understanding of science and various scientific phenomenons.

The analysis of the table 1 reveals that Heterocyclic Compound has got the highest growth rate (mean value 0.45) followed by Crystallography (mean value 0.425), Pharmacology (mean value 0.423), Plant Biochemistry (mean value 0.407), Physical organic compound (mean value 0.403) and Toxicology (mean value 0.400). Optical Electron Microscopy (mean value0.38), General Physical Chemistry (mean value 0.36), Pharmacology(mean value 0.36),, Fertilisers Soil and Plant Nutrition(mean value 0.35),, Electronic Phenomenon(mean value 0.367), and Nuclear Phenomenon (mean value 0.344), have shown growth rate less than 0.4 mean value. Accordingly their doubling time period is increasing for every subfield.

Table 1.Growth Rate and Doubling Time in Different Sub Fields Indian Chemical Sciences

Year	EP			PH			OEMS		
	Articles	GR	Dt	Articles	GR	Dt	Articles	GR	Dt
2000	789			475			561		
2001	686	0.625647	1.107653	564	0.782699	0.885398	549	0.682394	1.015542
2002	766	0.418264	1.656847	549	0.424217	1.633599	545	0.399441	1.734925
2003	865	0.326414	2.123074	604	0.322339	2.14991	615	0.315979	2.193185
2004	905	0.255705	2.710156	820	0.31779	2.180686	689	0.265072	2.614389
2005	952	0.21297	3.253982	945	0.272882	2.539561	800	0.239302	2.895927
Mean		**0.3678**	**2.170343**		**0.423985**	**1.877831**		**0.380437**	**2.090793**

Table 1.Growth Rate and Doubling Time in Different Sub Fields Indian Chemical Sciences

Year	NP			PB			ICR		
	Articles	GR	Dt	Articles	GR	Dt	Articles	GR	Dt
2000	672			452			486		
2001	615	0.649811	1.066464	559	0.805013	0.860856	486	0.693147	0.999788
2002	642	0.404688	1.712431	529	0.420842	1.646697	568	0.460182	1.505926
2003	601	0.271218	2.555144	591	0.324809	2.133562	601	0.329491	2.103247
2004	576	0.205116	3.378569	656	0.268374	2.582214	656	0.267274	2.592841
2005	648	0.189486	3.657258	686	0.220053	3.149241	645	0.207505	3.339674
Mean		**0.344064**	**2.473973**		**0.407818**	**2.074514**		**0.39152**	**2.108295**

Year	HC			TOX			POC		
	Articles	GR	Dt	Articles	GR	Dt	Articles	GR	Dt
2000	329			396			358		
2001	397	0.791492	0.875561	424	0.72789	0.952067	394	0.742203	0.933706
2002	473	0.501693	1.381322	450	0.437468	1.584116	433	0.454762	1.523875
2003	595	0.40296	1.719774	474	0.317164	2.184987	421	0.304004	2.279576
2004	656	0.31164	2.223718	553	0.275423	2.516133	526	0.283314	2.44605
2005	685	0.246541	2.81089	637	0.244763	2.831313	564	0.234709	2.952596
Mean		**0.450865**	**1.802253**		**0.400542**	**2.013723**		**0.403798**	**2.027161**

Year	CRY			AGB			GPC			FSPN		
	Articles	GR	Dt	Articles	GR	Dt	Articles	GR	Dt	Articles	GR	Dt
2000	287			256			272			344		
2001	375	0.835783	0.829162	258	0.697046	0.994196	274	0.696817	0.994522	279	0.593905	1.166854
2002	381	0.454591	1.524448	260	0.409349	1.692934	239	0.363065	1.90875	347	0.44275	1.565219
2003	439	0.351291	1.972721	327	0.352402	1.966503	228	0.254988	2.717777	324	0.288197	2.404602
2004	390	0.233615	2.966421	382	0.297848	2.326689	274	0.239398	2.894765	316	0.218496	3.171683
2005	534	0.250958	2.761416	345	0.209155	3.313326	367	0.250883	2.762247	377	0.210392	3.293855
Mean		**0.425248**	**2.010834**	**1828**	**0.39316**	**2.058729**		**0.36103**	**2.255612**		**0.350748**	**2.320442**

EP- Electronic Phenomenon, PH-Pharmacology, OEMS-Optical electron microscopy,NP- Nuclear Phenomenon, PB-Plant biochemistry, ICR-Inorganic Chemical Reaction, TOX-Toxicology, HC-Heterocyclic compound, POC- physical organic chemistry, CRY-Crystallography, AGB-Agrochemical bioregulators, GPC-General physical chemistry, FSPN- Fertilisers, Soil and Plant nutrition, DR = Growth Rate, Dt= Doubling Time

3.2 Pattern of Authorship

Analysis of the table 2 and figure 1, 2 shows that there is a gradual decrease in single author from 8.79% in 2000 to

7.03% in 2005; double author from 32.24% to 25.49% in 2005 and three authored papers from 29.98 % in 2000 to 26.16% in 2005, with a slight increase in single authorship to (8.61%) in 2003. More than three author papers are increasing from 34.79% in 2000 to 43.70% in 2005. Single and multiple author papers are 7.75% and 92.86% respectively. It can be said that Lotka's Law is not applicable here.

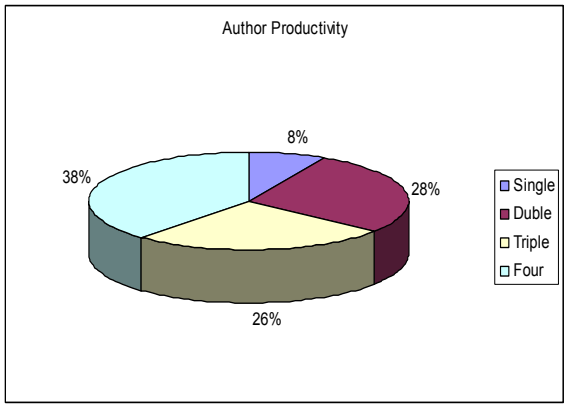

Figure No. 1: Author Productivity

Table -2.Authorship Pattern and Collaborative Measures in Chemical Sciences (2000-2005)

Year	S	D	T	F	TMA	Total Articles	Total Authors	Average Author (CI)	DC	CC
2000	490 (8.79)	1809 (32.24)	1559 (29.98)	1938 (34.79)	5306 (95.27)	5507 (14.94)	16537 (15.11)	3.003	0.963	0.569
2001	430 (8.10)	1513 (28.51)	1463 (27.57)	1901 (35.82)	4877 (91.89)	5307 (14.39)	15449 (14.11)	2.911	0.919	0.595
2002	440 (7.86)	1576 (28.16)	1528 (27.31)	2051 (36.67)	5156 (92.14)	5596 (15.18)	16384 (14.96)	2.927	0.921	0.598
2003	528 (8.61)	1689 (27.54)	1635 (26.66)	2281 (37.19)	5605 (91.39)	6133 (16.64)	17935 (16.39)	2.924	0.941	0.594
2004	479 (7.02)	1806 (26.52)	1745 (25.63)	2779 (40.81)	6330 (92.97)	6809 (18.47)	20442 (18.68)	3.002	0.929	0.609
2005	490 (7.03)	1897 (25.49)	1798 (24.16)	3256 (43.70)	6951 (93.41)	7441 (20.18)	22702 (20.74)	3.051	0.934	0.616
Total	**2857 (7.75)**	**10290 (27.91)**	**9728 (26.39)**	**14207 (38.54)**	**34225 (92.86)**	**36856**	**109449**	**2.969**	**0.928**	**0.603**

S: Single author, D: Double author, T: Three authors, TMA: Total Multi authored. (Figures in parentheses is % values)

CI = Collaborative Index, DC= Degree of Collaboration, CC= Collaborative Coefficient

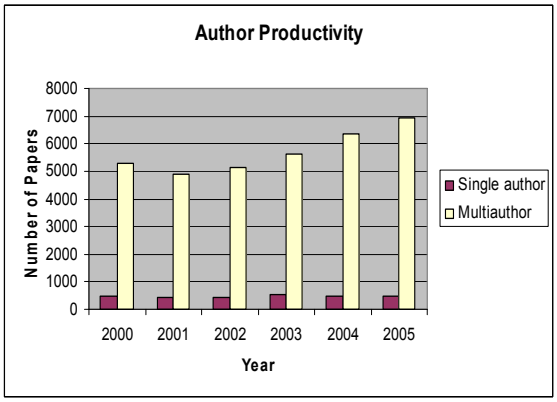

Figure No. 2: Single Vs Multi Author Productivity

3.3 Comparative Analysis of Collaborative Measures in Sub Fields

Interdependency of the subject fields and multidisciplinary nature of problems leads towards collaborative research work. For the analysis of the collaborative pattern in Indian chemical sciences, it has been observed that there is a clear trend towards collaboration. Only 7.75 articles are single authored and rest 92.43% is written by two and more authors.

Analysis of the table 3 and Fig. 3 shows that Collaborative Index value for the fields general physical chemistry, pharmacology, plant biochemistry, inorganic chemical reaction, heterocyclic compound and cryptography is above three authors per paper, while fertilizers, soil and plant nutrition, electronic phenomenon, optical electron microscopy, nuclear phenomenon, toxicology, physical organic chemistry and agro chemical bio-regulator have Collaborative Index value above two author per paper. Highest value for collaborative index is observed by Crystallography (3.28) followed by General Physical Chemistry and Heterocyclic Compound.

Degree of collaboration is the highest for the field of heterocyclic compound (0.97) followed by pharmacology (0.96), inorganic chemical reaction (0.957), crystallography (0.955) and plant bio chemistry (0.951). Toxicology (0.93) and Agro Chemical bioregulators and Physical Organic Chemistry are having degree of collaboration value above (0.93), while electronic phenomenon, Optical Electron Microscopic and Fertilizer Soil and Plant Nutrition having above 0.92 values. Nuclear phenomenon is having the least value of degree of collaboration as 0.741 and Collaborative Coefficient as 0.459.

Same trend has been supported by the Collaborative Coefficient values of the sub fields. The table shows that the highest value for Collaborative Coefficient has been observed by Heterocyclic Compound (0.6296); Inorganic Chemical Reaction (0.642) followed by crystallography (0.637) and Pharmacology (0.628).

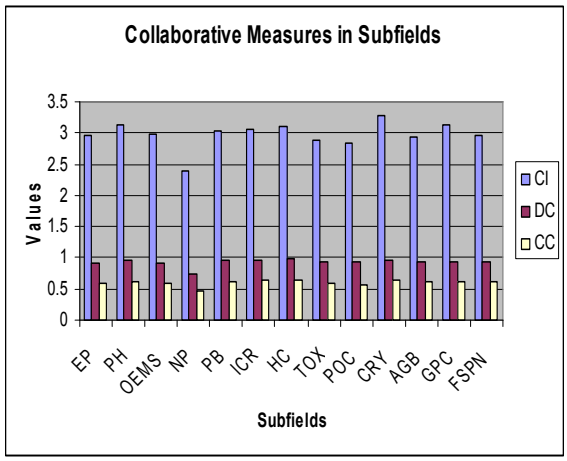

Figure No. 3: Comparative View of DC, CI and CC in Sub fields

Table 3. Comparative analysis of Collaborative Measures in Sub Fields

Year	EP			PH			OEMS		
	CI	DC	CC	CI	DC	CC	CI	DC	CC
2000	2.851711	0.903676	0.581	2.888421	0.962105	0.569	2.755793	0.901961	0.569
2001	2.96793	0.927114	0.604	3.031915	0.950355	0.623	2.863388	0.919854	0.588
2002	3.007833	0.926893	0.609	3.151184	0.959927	0.641	2.904587	0.902752	0.587
2003	2.951445	0.914451	0.597	3.049669	0.948675	0.625	3.001626	0.920325	0.604
2004	2.973481	0.914917	0.603	3.181707	0.960976	0.654	3.166909	0.940493	0.63
2005	3.023109	0.940126	0.616	3.269841	0.973545	0.658	3.06375	0.9275	0.616
Mean	**2.964336**	**0.921418**	**0.601667**	**3.121809**	**0.960576**	**0.628333**	**2.974195**	**0.920192**	**0.599**

Year	HC			TOX			POC		
	CI	DC	CC	CI	DC	CC	CI	DC	CC
2000	2.924012	0.969605	0.617	2.962121	0.939394	0.608	2.882682	0.927374	0.442
2001	2.947103	0.972292	0.621	2.990566	0.945755	0.615	2.847716	0.916244	0.589
2002	3.107822	0.978858	0.613	2.804444	0.937778	0.589	2.792148	0.942263	0.59
2003	3.102521	0.97479	0.641	2.814346	0.898734	0.574	2.629454	0.914489	0.564
2004	3.121951	0.969512	0.64	2.743219	0.929476	0.584	2.86692	0.942966	0.599
2005	3.309489	0.988321	0.646	2.981162	0.935636	0.607	2.927305	0.941489	0.605
Mean	**3.114195**	**0.976396**	**0.629667**	**2.88105**	**0.930811**	**0.596167**	**2.829748**	**0.932122**	**0.564833**

Year	NP			PB			ICR		
	CI	DC	CC	CI	DC	CC	CI	DC	CC
2000	2.299107	0.738095	0.448	2.971239	0.955752	0.618	3.080247	0.967078	0.636
2001	2.304065	0.726829	0.444	2.991055	0.958855	0.621	3.063786	0.969136	0.635
2002	2.417445	0.750779	0.469	3.068053	0.958412	0.629	3.003521	0.961268	0.623
2003	2.372712	0.717138	0.448	2.954315	0.937394	0.606	3.044925	0.955075	0.627
2004	2.46875	0.762153	0.478	3.074695	0.95122	0.625	3.085366	0.946646	0.627
2005	2.42284	0.753086	0.469	3.084548	0.94898	0.626	3.085271	0.953488	0.628
Mean	**2.379329**	**0.741343**	**0.601667**	**3.121809**	**0.951339**	**0.620833**	**3.061011**	**0.957873**	**0.629**

Year	CRY			AGB			GPC			FSPN		
	CI	DC	CC	CI	DC	CC	CI	DC	CC	CI	DC	CC
2000	3.062718	0.923345	0.559	3.152344	0.949219	0.637	3.110294	0.959559	0.541	3.101744	0.950581	0.628
2001	3.205333	0.946667	0.643	3.065891	0.94186	0.563	3.116788	0.948905	0.631	2.88172	0.946237	0.6003
2002	3.24147	0.952756	0.648	2.730769	0.907692	0.567	3.07113	0.941423	0.684	3.014409	0.942363	0.616
2003	3.369021	0.961276	0.634	2.831804	0.926606	0.588	3.057018	0.942982	0.509	2.947531	0.944444	0.608
2004	3.35641	0.969231	0.679	2.918848	0.937173	0.6012	3.171533	0.945255	0.636	2.924051	0.939873	0.604
2005	3.365169	0.964419	0.664	2.878261	0.930435	0.5947	3.185286	0.945504	0.638	2.923077	0.938992	0.603
Mean	**3.283874**	**0.955112**	**0.637833**	**2.922319**	**0.932166**	**0.621817**	**3.125151**	**0.9474**	**0.6065**	**2.968294**	**0.943634**	**0.609833**

EP-Electronic Phenomenonenon, PB-Plant biochemistry, ICR- Inrganic Chemical Reactin, TOX-Toxicology, HC-Heterocyclic compound, POC-physical organic chemistry, CRY-Crystallography, AGB-Agrochemical bioregulators, GPC-General physical chemistry, FSPN- Fertilisers, soil and plant nutrition, CI = Collaborative Index, DC= Degree of Collaboration, CC= Collaborative Coefficient

3.4 Application of Poisson and Geometric Distribution

In order to understand the distribution pattern of authorship and their goodness of fit in publication pattern Geometric and Truncated Poisson distributions have been applied. Maximum numbers of authors for some of the publications are up to 26 authors, so truncated Poisson distribution is applied. After obtaining the basic statistics, mean and variance values for the data in two block periods 2000-2002 and 2003-2005, probability distributions are applied and their value obtained are again tested with chi square Test to know the applicability of these two distributions. The analysis of the data from table 4 reveals that geometric distribution values were decreasing in Toxicology (from 0.744 to 0.740); physical, Inorganic and Analytical chemistry (from 0.7405 to 0.739); Agrochemical Bio regulators (from 0.748 to 0.742) from one block to another, and correspondingly the chi-square values also vary. But for other fields increasing values have been obtained. The higher values of chi square tests obtained at the 2% level of significance for these fields show the distribution patterns of authors follows the Geometric Probability distribution.

Table- 4. Application of Geometric and Poisson distribution

Sub Fields	Block periods	Mean	Variance	Poisson (λ)	Chi Square	Geometric (P)	Chi Square
TOX	2000- 2002	2.9157	0.8929	0.5411	314.77	0.7446	12699.01
	2003-2005	2.854	0.9091	0.575	212.199	0.7405	24526.02
POC	2000- 2002	2.837	0.8581	0.0585	366.533	0.7405	24526.02
	2003-2005	2.823	0.8390	0.594	239.374	0.7394	14565.54
CRY	2000-2002	3.1792	0.8566	0.04161	451.696	0.7607	11017.82
	2003-2005	3.3639	0.7964	0.0346	1639.739	0.7708	8345.93
AGB	2000 -2002	2.9819	0.9764	0.0506	577.983	0.7488	3371.47
	2003-2005	2.8785	0.9340	0.0562	444.0192	0.7421	7249.87
GPC	2000-2002	3.1006	0.8497	0.0450	469.019	0.7561	6204.93
	2003-2005	3.1472	0.8643	0.0429	433.66	0.7588	7317.67
FSPN	2000 -2002	3.007	0.9185	0.0494	432.65	0.7504	6113.34
	2003-2005	2.9311	0.9097	0.0533	429.95	0.7456	7404.70

EP	2000 -2002	2.940	0.992	0.0528	787.838	0.7462	32622.11
	2003-2005	2.98	0.970	0.0505	1798.133	0.7489	54313.53
PH	2000- 2002	3.030	0.840	0.0483	426.203	0.7518	25237.83
	2003-2005	3.103	0.808	0.0483	2752.655	0.7609	51322.71
OEMS	2000- 2002	2.8404	0.992	0.4598	229.6562	0.7396	17635.76
	2003-2005	3.079	0.997	0.0459	1492.102	0.7548	22230.80
NP	2000-2002	2.340	1.123	0.0963	521.99	0.7006	11927.36
	2003-2005	2.420	1.122	0.0888	454.848	0.7076	9217.28
PB	2000-2002	3.011	1.228	0.0492	384.89	0.7507	22142.97
	2003-2005	3.041	0.0836	0.0477	910.47	0.75256	22698.61
ICR	2000- 2002	3.046	0.7926	0.0475	430.30	0.7528	25696.64
	2003-2005	3.072	0.8685	0.0463	891.85	0.7544	30934
HC	2000- 2002	3.00	0.7514	0.0495	330.566	0.7502	16849.91
	2003-2005	3.182	0.7430	0.0414	1493.923	0.7608	39882.20

*** Significance at 2% Level**

4. Conclusion

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Considering the above facts; it may be concluded that there is variation in collaboration from one discipline to another and periods within the same discipline for different periods, from one region to another. The collaboration in research is affected by various socio economic and the other environmental factors prevailing in a specific society. Hence it is proposed further research be conducted to study the nature of collaborative output of different subject areas in science, social science, and humanities. The investigations of such nature may be found useful in understanding the research and communication patterns for Indian Chemical Sciences. The findings of the study will be helpful in planning more effective research and communication systems.

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