

Research output in pheromone biology: a case study of India

Thangavel Rajagopal · Govindaraju Archunan · Muthuraj Surulinathi · Ponnirul Ponmanickam

Received: 17 February 2012 / Published online: 14 June 2012
© Akadémiai Kiadó, Budapest, Hungary 2012

Abstract Analyses the growth and development of pheromone biology research productivity in India in terms of publication output as reflected in Science Citation Index (SCI) for the period 1978–2008. It includes 330 publications from India, including 285 articles, 22 notes, 18 reviews, 4 letters and 1 conference paper, from 200 institutions. About 9.4 % of publications is contributed by Indian Institute of Technology, Kanpur followed by Bhabha Atomic Research Centre, Bombay (7.27 %). All the papers published by Indian researchers have appeared in journals with impact factors between 0.20 and 4.14. About 24.24 % of authors contributed single articles. The growth rate of publications varied from 0.30 to 9.09 % per year. The annual growth rate was highest in the year 2006 at 9.09 %. The study reveals that the output of pheromone biology research in India has gradually increased over the years.

Keywords Pheromone biology · Science citation index · Global citation core · HistCite · Journal citation reports

Introduction

Chemical signals that convey information between members of the same species are commonly termed pheromones. This term was first used by Karlson and Luscher (1959) who defined pheromone as substances secreted outside of an individual and received by a

T. Rajagopal · G. Archunan (✉) · P. Ponmanickam
Centre for Pheromone Technology, Department of Animal Science, School of Life Sciences,
Bharathidasan University, Tiruchirappalli 620 024, Tamil Nadu, India
e-mail: archunan@bdu.ac.in

T. Rajagopal · P. Ponmanickam
Department of Biotechnology, Ayya Nadar Janaki Amman College (Autonomous), Sivakasi 626 124,
Tamil Nadu, India

M. Surulinathi
Department of Library and Information Science, Bharathidasan University, Tiruchirappalli 620 024,
Tamil Nadu, India

second individual of the same species in which they release a specific reaction involving either the release of a specific behaviour or physiological change in the recipients' endocrine or reproductive system. Based on the types of response by recipients, the pheromones are classified as "primer", "releaser" and "imprinting". Primer pheromones induce a delayed response to prolonged stimulation mediated through central nervous system (CNS) and endocrine system. A number of primer pheromonal effects have been studied leading to the establishment of concrete ideas regarding their influences on reproductive functions. Releaser pheromones induce a rapid behavioural response in the recipients, generally mediated through the CNS. Sexual attraction, evocation of aggression, recognition, alarming behaviour and mother-young interactions are examples of releaser pheromones. Imprinting pheromones organizes the CNS of the pre-weaning off-springs at a critical period and cause permanent alterations of adult behaviour.

Non-intrusive pheromonal studies (i.e., without disturbance of animals during sample collection) are now being used in a variety of disciplines viz., animal science, behavioral ecology, pest management and conservation biology. This field is a new avenue for research on pheromone biology that has proven valuable to determine reproductive status of female (pre-ovulatory, ovulatory, post-ovulatory) in both domestic and non-domestic animals (Rasmussen 1998; Rajanarayanan and Archunan 2004; Sankar and Archunan 2008; Rajagopal et al. 2010).

The basic research on pheromones provides an exciting and excellent model in the field of biology. Even though pheromones have been used for few decades for reproduction and social behaviour, it is only in recent years that interest has been developed to make use of pheromones to improve the animal breeding and management. Potential uses of pheromones are in stimulation of spawning and early puberty, in stimulation and synchronization of oestrus in non-breeding season, in the identification of oestrus/heat period, in improving the maternal bonding, in developing the eco-friendly trap for pests, in reducing the aggressiveness, in enhancing the wild animals conservation, in regulating the human fertility and so on (Archunan 2009).

This paper aims to map pheromone biology research in India over a period of 31 years (1978–2008) as reflected through web of science. The study is intended to examine (a) the volume of work published in the discipline of pheromone biology, (b) the journals that publish the research output on pheromone biology and their standing (as reflected by their impact factors) and (c) the institutions which actively publish in this field.

HistCite developed by Garfield and colleagues (HistCite, <http://www.histcite.com/index.htm>; Garfield et al. 2003) is an analytical and visualization tool which enables analysis of a subject and helps a searcher to identify the most significant work on a topic and trace its evolution. It also helps to identify highly productive and highly cited authors in any chosen area of research, particularly top and high impact journals and prominent institutions. HistCite has been used in this study.

The paper also calculates the total local citation score (TLCS) and the total global citation score (TGCS) (Thulasi and Arunachalam 2010). TLCS is the number of times an author's papers included in a collection have been cited by other papers also in the collection. TGCS is the number of times an author's papers included in a collection have been cited in the Web of Science.

Studies of this kind in many areas have been carried out in the past. Arunachalam and Singh were among the earliest to quantify Indian contribution to the world literature of narrow specialties such as liquid crystals (Singh and Arunachalam 1991a), holography (Singh and Arunachalam 1991b), superconductivity (Arunachalam and Singh 1984) etc. Arunachalam and colleagues have also analysed India's contribution in mathematics

(Arunachalam 1996), materials science (Arunachalam et al. 1996), physics (Arunachalam and Dhawan 1996), medicine (Arunachalam 1997), agriculture (Arunachalam 1998; Arunachalam and Umarani 2001) and life sciences (Arunachalam 1999), fisheries (Jayashree and Arunachalam 2000), tuberculosis research (Arunachalam and Gunasekaran 2002) and international collaboration research in science in India (Arunachalam and Doss 2008). Studies by other authors include areas of chemical engineering (Modak and Madras 2008), structural engineering (Maheswaran et al. 2009) and Nobel Laureate Harald zur Hausen (Munnolli et al. 2011) using electronic versions of appropriate international bibliographic databases. However, the review of literature did not find any scientometric study on pheromone biology.

Objectives of the study

- To study the year-wise growth of publications; and
- To study the document type-wise contributions, authorship pattern, source of publications, institution with subdivision and subject domain with GCS and LCS

Methodology

All publications on pheromone biology (keywords used: “pheromone biology”, “chemical signals”, “pheromone compounds”) having ‘India’ in address field were downloaded from *Science Citation Index*. The data were exported and processed in the HistCite to find out the contribution of Indian institutions in the field of pheromone biology research during years 1978–2008. The year of publication, journals and authors were analyzed and displayed in tables using HistCite. The Global Citation Scores and Local Citation Scores are examined to identify the pattern of research contribution on pheromone biology.

The impact factor values from Journal Citation Reports (JCR) 2008 were also added for the identified journal titles.

Analysis

Year wise distribution of research output

The number of records obtained from the SCI database for each publication year is given in Table 1. Journal articles, notes, reviews, letters and conference papers published in the 31-year period were considered for this study. It was found that Indian authors contributed 330 publications out of which 285 were journals articles, 22 notes, 18 reviews, 4 letters and 1 conference paper publication. The first paper in the area of pheromones was published in 1978 and it rose to 27 research articles, the highest during a year 2006.

Global and local citation score of pheromone biology researchers

Figure 1 gives a view of the opening page of how the information is displayed in HistCite. The 330 papers have been cited by 1,758 works. From these data, one can

Table 1 Research output on pheromone biology

Publication year	Journal articles	Note	Review	Letter	Meeting abstract	Total no. of papers	TLCS	TGCS	TCS
1978	1					1	0	0	0
1979	0	0	0	0	0	0	0	0	0
1980	2					2	2	9	11
1981		1				1	3	14	17
1982	1					1	0	2	2
1983	1	1				2	2	25	27
1984	3		1			4	1	33	34
1985	1					1	0	1	1
1986	3					3	5	23	28
1987	2	2				4	1	15	16
1988	5	1				6	4	30	34
1989	4	1				5	5	29	34
1990	5	2				7	2	43	45
1991	12	2				14	3	74	77
1992	4	1		1		6	0	20	20
1993	10	2				12	3	69	72
1994	4	4				8	3	23	26
1995	9	1				10	2	26	28
1996	11		2			13	5	151	156
1997	17		1			18	2	67	69
1998	12	1				13	1	91	92
1999	16		1			17	1	176	177
2000	13	1	1			15	5	81	86
2001	12		2			14	6	89	95
2002	14	1	1		1	17	3	134	137
2003	19		2			21	7	113	120
2004	22					22	5	129	134
2005	20			1		21	4	107	111
2006	27	1	1	1		30	12	73	85
2007	23		4	1		28	4	20	24
2008 (up to June)	12		2			14	0	0	0
Total	285	22	18	4	1	330	91	1,667	1,758

TLCS total local citation score, *TGCS* total global citation score, *TCS* total citation score

obtain a global view of author's work on pheromone biology and the impact over a 31 year period. For each published paper, we can hotlink to both local and global frequencies of citation (Global Citation Score and Local Citation Score). It is to be noted that the highest number of 176 papers with citation score (Total Global Citation Score) was recorded during 1999 followed by 2002 (137), 2004 (134) and 2005 (111).

Records: 330, Authors: 977, Journals: 208
 Yearly output | Document Type | Language | Institution | Institution with Subdivision | Country
 Page 1 of 4: [1 2 3 4]

#	NA	LCR	CR	Date / Author / Journal	LCS	GCS
1	2	0	0	183 Yadav JS, Prasad AR Green chemistry applications in agriculture: Insect sex pheromones as tools in integrated pest management. ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL SOCIETY. 2002 APR 7; 223: U669-U669	0	0
2	1	1	140	8 PANDEY AK CHEMICAL SIGNALS IN FISHES - THEORY AND APPLICATION ACTA HYDROCHIMICA ET HYDROBIOLOGICA. 1984; 12 (5): 463-478	0	2

Fig. 1 A view of the HistCite output

Source-wise distribution of research output

Out of 285 journal articles, 28 (8.5 %) journal articles were published in *Indian Journal of Chemistry Section B-Organic Chemistry Including Medicinal Chemistry* and 17 (5.2 %) were published in *Current Science* and 8 (2.4 %) in *Synthetic Communications* (Table 2).

Table 2 also shows that 330 papers have been published by Indian pheromone researchers in journals having impact factors between 0.20 and 4.14. It is to noted that the higher global citation score (GCS) was recorded for the *Indian Journal of Chemistry Section B-Organic Chemistry Including Medicinal Chemistry* (96) followed by *Organic Chemistry* (84), *Tetrahedron* (59), *Synthetic Communications* (55), *Journal of Organic Chemistry* (33), *Current Science* (28) etc.

Author rankings

As per Table 3, Archunan G had published the highest number of 10 papers on the subject followed by Chattopadhyay S (9), Mamdapur VR (9) and Yadav JS (9). However, on the high score of global citations, it was found that Yadav's 9 papers had 58 citations followed by Mamdapur (47 citations) and Gadagkar (45 citations).

Authorship pattern

It is found that the highest, 27 % (89) of the 330 contributions are by three authors. Single authorship come next with 24 %. There were two contributions with eight authors (Table 4).

Table 2 Leading journals publishing Indian works on pheromone research

Sl. no.	Journal title	TLCS	TGCS	Publication country	Impact Factor (JCR-2008)	No. of papers
1	<i>Indian Journal of Chemistry Section B-Organic Chemistry Including Medicinal Chemistry</i>	16	96	India	0.46	28
2	<i>Current Science</i>	4	28	India	0.77	17
3	<i>Synthetic Communications</i>	5	55	USA	0.98	8
4	<i>Tetrahedron Letters</i>	2	34	USA	2.53	6
5	<i>Indian Journal of Chemistry Section A-Inorganic Bio-Inorganic Physical Theoretical & Analytical Chemistry</i>	0	11	India	0.57	5
6	<i>Tetrahedron</i>	3	59	USA	2.89	5
7	<i>Inorganic Chemistry</i>	4	84	USA	4.14	4
8	<i>Journal of Biosciences</i>	5	18	India	1.70	4
9	<i>Journal of Organic Chemistry</i>	1	33	USA	3.95	4
10	<i>Magnetic Resonance In Chemistry</i>	0	5	UK	2.25	4
11	<i>Proceedings of The Indian Academy of Sciences-Chemical Sciences</i>	0	19	India	0.75	4
12	<i>Asian Journal of Chemistry</i>	0	1	India	0.26	3
13	<i>Behavioural Processes</i>	3	8	USA	1.41	3
14	<i>Bulletin of Electrochemistry</i>	0	7	Netherlands	1.42	3
15	<i>Collection of Czechoslovak Chemical Communications</i>	0	6	Czech Republic	0.38	3
16	<i>European Journal of Mass Spectrometry</i>	1	2	UK	1.2	3
17	<i>Journal of The Indian Chemical Society</i>	1	10	India	0.33	3
18	<i>Molecules</i>	0	3	Switzerland	1.11	3
19	<i>Spectrochimica Acta Part A-Molecular And Biomolecular Spectroscopy</i>	1	4	USA	1.51	3
20	<i>Tetrahedron-Asymmetry</i>	0	9	USA	2.79	3
	Journals with two papers	14	366		0.2 to 1.25	52
	Journals with one paper	31	809		0.21 to 2.17	162
Total number of Journals 208	Total	91	1667			330

Leading Indian institutions in pheromone research

Table 5 gives the leading institutions researching on pheromones. Indian Institute of Technology, Kanpur ranks first with 31 contributions (4.8 %) followed by Bhabha Atomic

Table 3 Indian authors in the area of pheromone research

Sl. no.	Authors	Publication	TLCS	TGCS
1	Archunan G, Dept. of Anim. Sci. Bharathidasan Univ., Trichy	10	11	28
2	Chattopadhyay S, Bio-orga. Divi. Bhabha Atom. Res. Cent., Bombay	9	5	44
3	Mamdapur VR, Bio-orga. Divi. Bhabha Atom. Res. Cent., Bombay	9	5	47
4	Yadav JS, Orga. Divi., Indian Inst. of Chem. Technol. Hyderabad	9	7	58
5	Das B, Orga. Divi., Indian Inst. of Chem. Technol. Hyderabad	6	11	42
6	Gadagkar R, Cent. Ecol. Sci. Indian Inst. of Sci., Bangalore	6	6	45
7	Kad GL, Dept. of Chem. Panjab Univ., Chandigarh	6	2	21
8	Pawar AS, Bio-orga. Divi. Bhabha Atom. Res. Cent., Bombay	6	3	21
9	Sharma ML, Dept. of Chem. Panjab Univ., Chandigarh	6	1	16
10	Singh J, Dep. Chem., Punjab Agric. Univ., Ludhiana	6	7	13
11	Chowdhury N, Orga. Divi., Indian Inst. of Chem. Technol. Hyderabad	5	11	26
12	Dhillon RS, Dep. Chem., Punjab Agric. Univ., Ludhiana	5	7	10
13	Dominic CJ, Dept. Zool. Banaras Hindu Univ., Varanasi	5	2	34
14	Gowda GAN, Cent. of Biomed. Magnetic Resonance, Sanjay Gandhi Postgrad. Inst. for Med. Sci., Lucknow	5	2	15
15	Sharma A, Bio-orga. Divi. Bhabha Atom. Res. Cent., Bombay	5	2	40
16	Sharma S, Cent. Drug Res. Inst., Lucknow	5	2	17
17	Vig OP, Scientific Res. Inst., Republic of Belarus	5	2	21
18	Banerjee J, Orga. Divi., Indian Inst. of Chem. Technol. Hyderabad	4	9	23
19	Brahmachary RL, Biol. Divi., Indian Stati. Inst. Calcutta	4	3	16
20	Basu S, Dept. of Chem. Eng. Indian Inst. of Chem. Technol. Delhi	4	2	6
	Others	210		
	Total authors contributed 977	330		

TLCS total local citation score, TGCS total global citation score

Table 4 Authorship pattern

Sl. no.	Authors	Contributions	Percent
1	Single Authors	80	24.24
2	Double Authors	50	15.15
3	Three Authors	89	26.97
4	Four Authors	60	18.18
5	Five Authors	28	8.50
6	Six Authors	13	3.94
7	Seven Authors	8	2.42
8	Eight Authors	2	0.60
	Total	330	100

Table 5 Leading Indian institutions in pheromone research

Sl. no.	Institutions	No. of papers
1	Indian Institute of Technology, Kanpur	31
2	Bhabha Atomic Research Centre, Bombay	24
3	Indian Institute of Chemical Technology, Hyderabad	17
4	Indian Institute of Science, Bangalore	16
5	Banaras Hindu University, Varanasi	14
6	National Chemical Laboratory, Pune	13
7	Bharathidasan University, Tiruchirappalli	9
8	Central Food Technological Research Institute, Mysore	7
9	Panjab University, Chandigarh	7
10	Regional Research Laboratory, Hyderabad	7
11	Indian Association for Cultivation of Science, Calcutta	6
12	Jadavpur University, Calcutta	6
13	Indian Institute of Chemical Biology, Calcutta	6
14	Sanjay Gandhi Postgraduate Institute for Medical Sciences, Lucknow	5
15	SPIC Science Foundation, Madras	5
16	Defence Research & Development Establishment, Gwalior	4
17	Jawaharlal Nehru Centre for Advance Science Research, Bangalore	4
18	University of Lucknow, Lucknow	4
19	University of Rajasthan	4
20	Aligarh Muslim University	3
	180 other institutions	138
	Total	330

Research Centre, Indian Institute of Chemical Technology and so on. In all 200 institutions have contributed the 330 publications during the period of 1978–2008.

Discussion

The HistCite based analysis of the pheromone biology research in India has shown how the field has evolved and has helped in identifying the institutions that are active and the journals in which they publish their works. Institutions such as Indian Institute of Technology, Kanpur, Bhabha Atomic Research Center, Bombay, Indian Institute of Chemical Technology, Hyderabad are doing considerable research on pheromone biology. Research communications on pheromone biology are published in high impact journals such as *Inorganic Chemistry*, *Journal of Organic Chemistry*, *Tetrahedron*, *Tetrahedron Letters* etc. by Indian authors. The publication trend shows that research activities are growing in this area.

Three hundred and thirty publications in 31 years in a research field is not reflective of a considerable research contribution. A comparison of Indian pheromone biology research output in relation to the world output may help in understanding the Indian contributions better. The research output on pheromone research from India would be higher than those found indexed in the Web of Science as it is likely that many works might have appeared in publications, including journals not covered by Web of Science. For a comprehensive coverage of research output and analysis, multiple data sources need to be used.

Acknowledgments The authors are thankful to The Director, National Centre for Science Information, IISc, Bangalore for data collection. This investigation was supported partially by grants from DST-FIST and UGC-SAP, New Delhi. One of the author, Dr.T.Rajagopal, is thankful to the UGC for awarding the Rajiv Gandhi National Research fellowship, New Delhi.

References

- Archunan, G. (2009). Vertebrate pheromones and their biological importance. *J Exp Zool India*, *12*, 227–239.
- Arunachalam, S. (1996). India's contribution to the literature of mathematics and related fields: an analysis based on *Mathsci* 1988–mid-1995, Report submitted to the Department of Science and Technology, New Delhi.
- Arunachalam, S. (1997). How relevant is medical research done in India?—A study based on Medline. *Current Science*, *72*, 912–922.
- Arunachalam, S. (1998). Agricultural research in India—A profile based on *CAB Abstracts* 1990–1994, Report submitted to the NISSAT, DSIR, New Delhi.
- Arunachalam, S. (1999). Mapping life sciences research in India: a profile based on *BIOSIS* 1992–1994. *Current Science*, *76*, 1191–1203.
- Arunachalam, S., & Dhawan, S. M. (1996). Physics research in India: an analysis based on *Physics Abstracts* 1992, Report submitted to the Department of Science and Technology, New Delhi.
- Arunachalam, S., & Doss, M. J. (2000). Mapping international collaboration in science in Asia through coauthorship analysis. *Current Science*, *79*, 621–628.
- Arunachalam, S., & Gunasekaran, S. (2002). Tuberculosis research in India and China: from bibliometrics to research policy. *Current Science*, *82*, 933–947.
- Arunachalam, S., Meyyappan, N., & Sridhar, G.S. (1996). India's contribution to the literature of materials science and related fields: An analysis based on *Materials Science Citation Index* 1991–1997, Report submitted to the Department of Science and Technology, New Delhi.
- Arunachalam, S., & Singh, U. N. (1984). Publication & citation patterns in the literature of a high metabolism area: the case of superconductivity in 1970. *Journal of Information Science*, *8*, 93–102.
- Arunachalam, S., & Umarani, K. (2001). Mapping agricultural research in India: a profile based on CAB abstract 1998. *Current Science*, *81*, 896–96.
- Garfield, E., Pudovkin, A. I., & Istomin, V. S. (2003). Why do we need algorithmic historiography? *Journal of the American Society for Information Science and Technology*, *54*, 400–412.
- Jayashree, B., & Arunachalam, S. (2000). Mapping fish research in India. *Current Science*, *79*, 613–620.
- Karlson, P., & Luscher, M. (1959). A new term for a class of biological active substance. *Nature*, *183*, 55–56.
- Maheswaran, S., Sathish Kumar, R. D., & Sridharan, K. R. (2009). Scientometric analysis of area-wise publications in the field of structural engineering: a case study of SERC, India. *Annals of Library and Information Studies*, *56*, 22–28.
- Modak, J. M., & Madras, G. (2008). Scientometric analysis of chemical engineering publications. *Current Science*, *94*, 1265–1272.
- Munnolli, S. S., Pujar, S. M., & Kademani, B. S. (2011). Scientometric Portrait of Nobel Laureate Harald zur Hausen. *Annals of Library and Information Studies*, *58*, 71–78.
- Rajagopal, T., Archunan, G., Geraldine, P., & Balasundaram, C. (2010). Assessment of dominance hierarchy through urine scent marking and its chemical constituents in male blackbuck *Antelope cervicapra*, a critically endangered species. *Behavioural Processes*, *85*, 58–67.
- Rajananarayanan, S., & Archunan, G. (2004). Occurrence of flehmen in male buffaloes (*Bubalus bubalis*) with special reference to estrus. *Theriogenology*, *61*, 861–866.
- Rasmussen, L. E. L. (1998). Chemical communication and integral part of functional Asian elephant (*Elephas maximus*) society. *Ecoscience*, *5*, 410–426.
- Sankar, R., & Archunan, G. (2008). Identification of putative pheromones in bovine (*Bostaurus*) faeces in related to estrus detection. *Animal Reproduction Science*, *103*, 149–153.
- Singh, U. N., & Arunachalam, S. (1991a). Publication and citation patterns in the literature of liquid crystals with special reference to the contribution of India, Canada, Japan, United Kingdom and the Soviet Union. *Scientometrics*, *20*, 197–220.
- Singh, U. N., & Arunachalam, S. (1991b). High tech science in middle level countries: publication and citation patterns in the literature of holography. *Journal of Scientific & Industrial Research*, *50*, 516–532.
- Thulasi, K., & Arunachalam, S. (2010). Mapping of cholera research in Indian using HistCite. *Annals of Library and Information Studies*, *57*, 310–326.