Research Output on Plant Pathology Research: A Bibliometric Analysis

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ABSTRACT: This paper presents a bibliometric analysis of 4,392 journal articles published in different journals during the period of 2008-2012 and covered in the CeRA (Consortium for e-Resources in Agriculture) database. The analysis is focused on the number of articles by year, authorship patterns, degrees of collaboration, contribution by institution, ranking of leading contributors, geographical distribution of articles at the national and the international level, subject growth of literature in plant pathology, and journal productivity patterns in plant pathological research. The findings of the study revealed that out of 4,392 articles, single authors contributed 3.26% of the articles while 95.99% of the articles showed multiple authorships. The average degree of collaboration is found to be 0.97. Universities contributed the maximum number of 3,383 articles. University of California got first rank with 222 publications. In India, Uttar Pradesh contributed the highest number of articles (143). The United States of America published the maximum number of 1,980 articles at the international level.

I. Introduction

The present study is a bibliometric analysis of the articles published in different journals during the period of 2008-2012 and covered in the CeRA database. CeRA is the acronym of the Consortium for e-Resources in Agriculture in India.

The term "bibliometrics" was first defined by Pritchard in 1969 as "the application of mathematical and statistical methods to books and other media" (p. 349). It involves the analysis of a set of publications, characterized by bibliographic variables such as the author(s), the place of publication, the associated subject keywords, and the citations.

According to the ALA Glossary (Young & Belanger, 1983), "Bibliometrics is the use of statistical methods in the analysis of a body of literature to reveal the historical development of subject fields and patterns of authorship, publication, and use." In other words it is a type of research method used in library and information science by applying quantitative analysis and statistics to describe patterns of publications within a given field or body of literature.

In the present era when information is overflowing everywhere, bibliometrics is a tool or mechanism to find out research output in a particular field of knowledge. This type of study becomes very fruitful for further research in that particular field. Today, researchers like to conduct research in a team in order to utilize their individual expertise for better results.

Globalization encourages research across countries. Interdisciplinary research is another trend that pulls together scientists from different fields to achieve maximum results.

According to Wikipedia, "Plant pathology (also phytopathology) is the scientific study of diseases in plants caused by pathogens (infectious organisms) and environmental conditions (physiological factors)".

In a nutshell, plant pathology is "the study of nature, development and management of plant diseases" (Ravichandra, 2013).

II. Literature Review

Zhang (1994) analyzed 3,006 references from the articles on MCT (Medicine Chinese Traditional) published in 343 periodicals during the period of 1974-1992. "This bibliometric analysis was examined by the references of the articles on Medicine Chinese Traditional (MCT) searched by the CD-ROM Medline" (Zhang, 1994). "The results were illustrated in order to identify reasonably a hierarchical ranking of periodicals and to evaluate objectively a distribution of countries where those articles were published and languages in which those articles were written" (Zhang, 1994).

Moed, Bruin, and Leeuwen (1994) in their paper gave

> an outline of a new bibliometric database based upon all articles published by authors from the Netherlands, and processed during the time period 1980-1993 by the Institute for Scientific Information (ISI) for the Science Citation Index (SCI), Social Science Citation lndex (SSCI) and Arts & Humanities Citation Index (A&HCI).

Chen, Wu, Haschler, Majeed, Chen, and Wetter (2011) in their study observed that using electronic health databases as research material is "getting popular but the influence of a single electronic health database had not been well investigated".

Ramakrishnan and Babu (2007) analyzed "the literature output in the field of Hepatitis covered in three bibliographic databases namely MEDLINE, CINAHL and IPA" and found that the collaboration in authorship pattern is prevalent with the collaboration degree as 0.85 on average.

Asha (2007) analyzed "articles and citations in 'Demography India' from 1972-2001" and identified "core areas of demographic studies, institution-wise contribution of articles and geographical area pertaining to the articles".

Rajendiran and Parihar (2007) identified "various bibliometric indicators of articles published by the Indian researchers in the field of laser science and technology during the period 1995-2005".

Krishnamoorthy, Ramakrishnan, and Devi (2009) analyzed "diabetes literature indexed in the MEDLINE database for the period 1995-2004" to study the growth rate in the field of diabetes and to identify core journals, ranking of journals, country-wise distribution, and research productivity.

Kouici, Harik, and Dahmani (2010) did a bibliometric study on Algerian scientific production using SCOPUS database. Their study "represented a modest attempt of evaluation of national scientific production". The indicators proposed were generated using SJR (Scimago Journal & Country Rank) portal. They argued that the "evaluation of scientific production constitutes an essential element for decision makers on the setting up policies and strategies process for the future". Likewise, "the citation constitutes the inevitable criterion in studies of qualitative assessment".

Burnham, Shearer, and Wall (1992) described

> a recent multidisciplinary study conducted by two library faculty members and one allied health faculty member to test a bibliometric method that used the MEDLINE and CINAHL databases on CD-ROM and the Papyrus database management program to produce a new collection development methodology

Ram (2011) analyzed "data indexed in the PubMed database for the period of fifteen years (1996–2010) to study the research on Artemisia data indexed in PubMed database for the period of fifteen years (1996-2010) to study the research on Artemisia".

Jeyshankar, Babu, and Rajendran (2011) analyzed "bibliographical details of 1282 research articles published by the scientists of CSIR-Central Electrochemical Research Institute during the period 2000-2009" and found that

> 2009 was the most productive year with 194 articles (15.13%) published in the year. Collaborative research was dominant with the highest degree of collaboration being 0.98, in the year 2005. Further, the study investigated authorship pattern, co-authorship pattern, highly prolific authors and highly preferred journals by the scientists of CECR.

A Quantitative analysis by Khatun and Ahmed (2011) was carried out to "identify the literature growth, authorship pattern, collaboration and journal distribution on diarrhoeal disease research in Bangladesh based on data obtained from PubMed, Web of Science and Scopus databases".

Gupta, Bala, and Kshitig (2012) analyzed quantitatively

> the Indian research in Materials Science during 2001-2010 on several parameters including publication growth and rank, country-wise contribution, material-wise contribution, share of international collaborative linkages and leading collaborating countries, most productive Indian institutions and authors, and characteristics of high cited papers.

Pillai and Priyalakshmi (2013) analyzed "bibliographical details of 1076 research articles obtained from the annual reports of Central Tuber Crops Research Institute (CTCRI)" and found that

> the highest number of 169 papers was published in the year 2006 and the average number of publications per year was 97.82. Most of the contributions were multi authored (87.68%). The degree of collaboration of scientists of CTCRI was 0.87 and most of the articles published by the scientists were in the foreign journals (51.89%). Journal of Root Crops published by Indian Society of Root Crops tops the list with the highest number of articles 125 (39.30%).

Prathap (2014) used 3-D bibliometric analysis to

> identify the leading countries, organizations and authors and also the most influential journals in the area of monsoon research. Scholarly performance is broken down into three components – quantity, quality and consistency. The citation data retrieved from the web of science was used to categorise the entities according to these quantities. It is noticed that China has become a leading player in monsoon research, while relatively; India's output has remained stable. The most productive organizations and authors from India and also the most influential journals in which they publish have also been identified. (p. 195)

Gupta, Gupta, and Ahmed (2014) analyzed "37047 world papers in mouth cancer, indexed in Scopus database during 2003-2012" and found "an annual average growth rate of 5.15% and citation impact of 9.72".

III. Objectives of the Study

The objectives of the study are as follows:

- to determine the distribution of articles by year
- to examine and analyze the authorship pattern in plant pathology
- to determine the degree of collaboration
- to determine the contributions by institution
- to find out the ranks of leading contributors
- to identify geographical distribution of articles at national level
- to identify geographical distribution of articles at international level
- to study the growth of literature in different area of plant pathology
- to identify journal productivity patterns in plant pathology research

IV. Research Methodology

The methodology applied in the present study is bibliometric analysis, which is used to study in detail the bibliographic features of the articles covered in CeRA (Consortium for e-Resources in Agriculture) during the period of 2008-2012. There were 4,392 papers related to the topic of plant pathology, which were used as the source data. The data were tabulated and analyzed.

V. Data Analysis and Discussion

A total of 4,392 journal articles published and contained in CeRA during the period of 2008-2012 were selected for analysis as per the objectives. The data collected was tabulated and analyzed. The results are discussed.

Table 1. Journal Article Distribution Pattern by Year

Year	No. of papers	Percentage
2008	790	17.99
2009	855	19.47
2010	920	20.95
2011	977	22.24
2012	850	19.35
Total	**4,392**	**100**

Table 1 shows the journal article distribution pattern by year. 2011 is the most productive year with 977 articles, followed by 2010 with 920 articles, 2009 with 855 articles, 2012 with 850 articles, and 2008 with 790 articles.

Table 2. Patterns of Authorship

Authorship Pattern	2008	2009	2010	2011	2012	Total	Percentage
Single Author	31	23	31	33	25	143	3.26
Multiple Authors	754	827	885	929	821	4,216	95.99
No Author	2	4	3	10	3	22	0.50
Repeated			1			1	0.02
Missing	3	1		5	1	10	0.23
Total	**790**	**855**	**920**	**977**	**850**	**4,392**	**100**

Table 2 shows the authorship patterns of publications during the period of 2008-2012. Out of 4,392 journal articles, 95.99% (4,216) were written by multiple authors whereas only 3.26% (143) were contributed by single authors. 22 journal articles do not show authors. 1 journal article is repeated in the database. 10 journal articles are found missing. The findings indicate that the trend of research is overwhelmingly collaborative.

Table 3. Degree of Collaboration by Year

Year	No. of Papers	Not Available	Nm	Ns	C=Nm/(Nm+Ns)
2008	790		754	31	0.96
2009	855		827	23	0.97
2010	920		885	31	0.97
2011	977		929	33	0.97
2012	850		821	25	0.97
	4,392	33	4,216	143	Average = 0.97

Notes: Nm = number of multi-authored papers; Ns = number of single-authored papers

As some records are missing in the database, calculations have been made according to the available data. The extent or degree of collaboration is calculated by applying Subramanyam's formula, which states that the degree of collaboration is a ratio between the number of multi-authored articles (Nm) to the number of multi-authored articles (Nm) plus the single-authored (Ns) ones.

$$C = \frac{Nm}{Nm+Ns} \quad \text{where,}$$

Table 3 shows the average degree of collaboration in plant pathology is 0.97, which again points to a high degree of joint research in this discipline.

Table 4. Paper Contributions by Institution Type

Year	Institute	University	Center	College	Misc.	Not Available	Total
2008	52	604	27	47	46	14	790
2009	57	652	26	32	65	23	855
2010	65	707	29	37	59	23	920
2011	74	750	31	34	70	18	977
2012	50	670	30	47	49	4	850
Total	**298**	**3,383**	**143**	**197**	**289**	**82**	**4,392**
%	**6.79**	**77.03**	**3.26**	**4.49**	**6.58**	**1.87**	**100**

Table 4 shows the distribution of publications by institution type. Out of 4,392 journal articles, universities have contributed 3,383 (77.03%), followed by institutes with 298 (6.79%), colleges with 197 (4.49%), and centers with 143 (3.26%). The miscellaneous category includes industries, experimentation stations, laboratories, academics, councils, departments, and others.

Table 5. Journal Article Contributions by Institution

Institutions	No. of Contributions	Rank
University of California, USA	222	1
Cornell University, USA	110	2
Washington State University, USA	101	3
Oregon State University, USA	100	4
Rutgers, The State University of New Jersey, USA	93	5
North Carolina State University, USA	81	6
China Agricultural University, China	79	7
Michigan State University, USA	79	7
Tamil Nadu Agricultural University, India	78	8
Indian Agriculture Research Institute, India	77	9
Ohio State University, USA	76	10
University of Florida, USA	72	
University of Pretoria, South Africa	72	

University of Wisconsin-Madison, USA	68	
Nanjing Agricultural University, China	62	
Montana State University, USA	60	
Kansas State University, USA	59	
Iowa State University, USA	57	
North Dakota State University, USA	57	
Purdue University, USA	56	
University of Georgia, USA.	51	
Pennsylvania State University, USA	49	
University of Minnesota, USA	49	
USDA-Agricultural Research Service, USA.	48	
C.S. Azad University of Agriculture and Technology, India	46	
Sher-e-Kashmir University of Agriculture Sciences and Technology, India	45	
Auburn University, USA	41	
National Chung-Hsing University, Taiwan	41	
Oklahoma State University, USA	40	
University of Tennessee, USA	40	
Rothamsted Research, UK	39	
Virginia Tech, USA	39	
University of Kentucky, USA	37	
Dr. Panjabrao Deshmukh Krishi Vidhyapeeth, India	36	
University of Punjab, Pakistan	36	
G. B. Pant University of Agriculture and Technology, India	33	
University of Arkansas, USA	33	
Volcani Center, Israel	33	
University of Agricultural Sciences, India.	31	
Punjab Agricultural University, India	30	
Tarbiat Modarres University, Iran	30	
Hebrew University of Jerusalem, Israel	29	
University of Nebraska Lincoln, USA	29	
Aligarh Muslim University, India.	28	
Annamalai University, India	28	
Huazhong Agricultural University, China	28	
Swiss Federal Institute of Technology, Switzerland	28	
National Research Centre, Egypt	28	
Banaras Hindu University, India	27	
Mississippi State University, USA	27	
Korea University, Republic of Korea	25	
Louisiana State University and LSU Agricultural Center, USA	25	
Shandong Agricultural University, China	25	

Table 5 shows the journal article contributions by various institutions around the world. The institutions with at least 25 contributions during the period are listed in the table and arranged in the decreasing order by the number of contributions. The top ten institutions are University of

California (222 articles), Cornell University (110 articles), Washington State University (101 articles), Oregon State University (100 articles), Rutgers, The State University of New Jersey (93 articles), North Carolina State University (81 articles), China Agricultural University (79 articles), Michigan State University (79 articles), Tamil Nadu Agricultural University (78 articles), Indian Agricultural Research Institute (77 articles), and Ohio State University (76 articles).

Table 6. Journal Articles Contributions by State in India

State	No. of Contributions	Percentage
Andhra Pradesh	44	4.91
Assam	3	0.33
Arunachal Pradesh	1	0.11
Bihar	6	0.67
Chhatisgarh	22	2.46
Gujarat	36	4.02
Haryana	6	0.67
Himachal Pradesh	25	2.79
Jammu & Kashmir	47	5.25
Jharkhand	1	0.11
Karnataka	63	7.03
Madhya Pradesh	11	1.23
Maharashtra	132	14.73
Meghalaya	5	0.56
New Delhi	78	8.71
Odisha	5	0.56
Puducherry	1	0.11
Punjab	30	3.35
Rajasthan	54	6.03
Tamil nadu	126	14.06
Uttar Pradesh	143	15.96
Uttarakhand	36	4.02
West Bengal	21	2.34
Total	**896**	**100**

Table 6 shows that the total journal articles contributions from India are 896. Of all the states in India, Uttar Pradesh ranks first with 143 (15.96%) articles, followed by Maharashtra with 132 (14.73%), Tami Nadu with 126 (14.06%), New Delhi with 78 (8.71%), and Karnataka 63 (7.03%). The rest states share smaller percentages.

Table 7. Journal Article Contributions by Country or Region

Country	No. of Contributions	Percentage
Algeria	1	0.02
Argentina	3	0.07
Australia	35	0.80

Austria	1	0.02
Bangladesh	10	0.23
Belgium	16	0.36
Benin	1	0.02
Brazil	37	0.84
Bulgaria	3	0.07
Canada	6	0.14
China	240	5.46
Colombia	5	0.11
Costa Rica	1	0.02
Croatia	1	0.02
Cuba	3	0.07
Czech Republic	1	0.02
Denmark	6	0.14
Egypt	67	1.53
Finland	4	0.09
France	10	0.23
Germany	48	1.09
Ghana	1	0.02
Greece	43	0.98
Hong Kong	1	0.02
Hungary	7	0.16
India	896	20.40
Iran	79	1.88
Israel	74	1.68
Italy	67	1.53
Japan	119	2.71
Korea	31	0.71
Lithuania	3	0.07
Malaysia	2	0.05
Mali	1	0.02
Mauritius	5	0.11
Mexico	4	0.09
Myanmar	2	0.05
Netherlands	18	0.41
New Zealand	6	0.14
Nigeria	8	0.18
Norway	2	0.05
Pakistan	55	1.25
Philippines	2	0.05
Poland	12	0.27

Portugal	2	0.05
Russia	2	0.05
Serbia	3	0.07
Slovenia	1	0.02
Saudi Arabia	1	0.02
South Africa	133	3.03
South Korea	2	0.05
Spain	28	0.64
Sudan	1	0.02
Sweden	15	0.34
Switzerland	41	0.93
Syria	2	0.05
Taiwan	70	1.59
Tasmania	1	0.02
Thailand	8	0.18
Trinidad & Tobago	1	0.02
Tunisia	1	0.02
Turkey	3	0.07
United Kingdom	84	1.91
United States of America	1,980	45.08
Not Available	76	1.73
Total	**4,392**	**100**

Table 7 shows the geographical distribution of journal articles by country or region. Out of 4,392 contributions, 1,980 (45.08%) articles came from the United States of America, followed by India with 896 (20.40%) articles, China with 240 (5.46%) articles, South Africa with 133 (3.03%) articles, and Japan with 119 (2.71%) articles. The rest countries have made contributions less than 3%.

Table 8. Subject Growth of Literature in Plant Pathology

Subject	**No. of Publications**	**Percentage**
Advance plant pathology	9	0.20
Beneficial plant pathogens	21	0.48
Biological control	251	5.71
Disease control by changing conditions/ chemical application /fungicides/ insecticides/herbicides	232	5.20
Disease control by soil treatment/	91	2.07

fertilizing/composting		
Disease diagnostics	83	1.89
Disease management	119	2.71
Disease resistance changing conditions/genetics/transgenic/genetically modified species/hybrids	341	7.76
Economics, extension and education	132	3.01
Environmental factors	227	5.17
Epidemiology	39	0.89
Forest pathology	69	1.57
Fruit/vegetable pathology	189	4.30
Genetic diversity/pathogen diversity	70	1.59
Host pathogen interaction	102	2.32
Integrated disease management	61	1.39
Molecular plant pathology	395	8.99
Mushroom cultivation	15	0.34
Nematology	90	2.05
New reports of pathogens/diseases	178	4.05
Not available	10	0.23
Oilseed pathology	53	1.21
Others/miscellaneous	48	1.09
Pathogenomics	209	4.76
Pathogen biology/ecology	184	4.19
Pathogen genetics	57	1.30
Pathogen- pathogen interaction	50	1.14
Pathogen taxonomy	15	0.34
Pathogenic infections	33	0.75
Plant genetics	160	3.64
Plant pathogens	535	12.18
Plant-microbe interaction mechanisms	34	0.77
Postharvest pathology	69	1.57
Seed pathology	89	2.03
Techniques, equipment, machinery, systems, methods, and models	114	2.60
Turf grass pathology	18	0.41
Total	**4,392**	**100**

Table 8 shows the growth of literature in plant pathology by subject area. The literature on plant pathology is categorized in thirty-six subject areas. It is observed that among the total of 4,392 publications in various subject areas, “Plant pathogens”, which affect plants and responsible for infecting various diseases in plants, have attracted most attention in research with 535 journal articles, followed by “Molecular plant pathology” with 395 articles, “Disease resistance by different applications” with 341 articles, “Biological control” with 251 articles, “Disease control by various treatments” with 232 articles, “Environmental factors” with 227 articles, and “Pathogenomics” with 209 articles. There is also research done in the fields of “Disease

management", "Economics/extension and education", "Fruit/vegetable pathology", "New reports of pathogens/diseases", "Pathogen biology/ecology", "Plant genetics", and "Techniques, equipments, machinery, systems, methods, and models".

Table 9. Journal Productivity in Plant Pathology Research

Journal	Paper published	Rank
Plant Disease	332	1
Phytopathology	217	2
Journal of Plant Disease Sciences	193	3
Archives of Phytopathology and Plant Protection	162	4
Annals of Plant Protection Sciences	134	5
European Journal of Plant Pathology	121	6
Plant Pathology	95	7
Archives of Virology	83	8
Crop Protection	83	8
Molecular Plant-Microbe Interactions	76	9
African Journal of Biotechnology	69	10
Journal of Phytopathology	67	11
Mycologia	67	11
Biological Control	64	12
Crop Science	62	13
Applied and Environmental Microbiology	61	14
Fungal Genetics and Biology	49	15
Physiological and Molecular Plant Pathology	47	16
Fungal Biology	45	17
Journal of General Plant Pathology	42	18
Indian Journal of Plant Protection	41	19
Australasian Plant Disease Notes	39	20
Bioinfolet	39	20
Virus Research	38	21
HortScience	36	22
Annual Review of Phytopathology	33	23
Canadian Journal of Plant Pathology	33	23
Theoretical and Applied Genetics	33	23
Australasian Plant Pathology	31	24
plant Cell	31	24
Plant Journal	30	25
Annals of Applied Biology	29	26
FEMS Microbiology Letters	29	26
Plant Disease Research	29	26
Molecular Plant Pathology	28	27
Pest Management Science	28	27
Plant Physiology	28	27
African Journal of Microbiology Research	27	28

Biocontrol Science and Technology	27	28
African Journal of Agricultural Research	26	29
Euphytica	25	30
Journal of Virological Methods	25	30
Journal of Virology	24	31
Journal of Nematology	23	32
Microbiology	23	32
Plant Physiology	22	33
New Disease Reports	21	34
Journal of Agricultural and Food Chemistry	19	35
Pesquisa Veterinaria Brasileira	19	35
Indian Journal of Nematology	18	36
Planta	18	36
Journal of Microbiological Methods	17	37
Applied Biological Research	16	38
HortTechnology	16	38
Nematology	16	38
World Journal of Microbiology and Biotechnology	16	38
Vegetos	15	39

Table 9 shows the journal productivity in plant pathology research. There are fifty-seven journals which have published fifteen or more articles on plant pathology. *Plant Disease* attained the first rank among all journals with 332 articles, followed by *Phytopathology* with 217 articles, *Journal of Plant Disease Sciences* with 193 articles, *Archives of Phytopathology and Plant Protection* with 162 articles, *Annals of Plant Protection Sciences* with 134 articles, and *European Journal of Plant Pathology* with 121 articles.

VI. Conclusion

Bibliometric studies analyze the research output in a specific field over a period of time to reveal patterns or trends so as to further research in that field. The findings of this study show a steady development in plant pathology research. Like other disciplines of applied sciences, researchers in plant pathology now conduct research as a team work, which is more fruitful than that of solo work. The high degree of collaboration clearly indicates a trend towards collaborative research. Universities are the leading contributors.

Compared with other countries, India has done well in plant pathology research. India is the second most productive country in plant pathology research in the world with 896 (20.40%) journal articles published in the period of 2008-2012. Two Indian institutions (i.e., Tamil Nadu Agricultural University and Indian Agriculture Research Institute) are among the top ten most productive institutions in the world. One of the Indian journal (*Annals of Plant Protection Sciences*) is among the top five most productive journals in the world.

The findings of this study also show that not enough research has been conducted in many subject areas such as “Advance plant pathology”. More attention should be directed to those

subject areas in order to benefit those who work in the field and obtain the maximum benefits from plants for mankind.

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