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Trends and Patterns in Collaborative Authorship: Insights into Advancing Seed Technology Research

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***Abstract* - Seed technology is an essential area of study for healthy and profitable agricultural practices. The study's results will assist in evaluating and advancing seed technology. It will encourage seed technologists and research institutions to improve their performance and review their research policies. The study also highlights that the double authorship pattern (two authors) was the dominant trend in seed technology research, followed closely by the three-authored pattern. It was observed that collaborative authorship was more dominant than single authorship, with 91.3% of publications following this pattern, while only 8.7% of publications were authored by a single person. The years 2014, 2016, and 2017 saw the highest degree of collaboration. The most productive author was Lamont BB with a total of 50 publications. The top-cited author was Shewry PR, affiliated with Rothamsted Research in Harpenden, England, who received 3495 citations for 37 publications.**
Keywords: **Seed Technology, Scientometrics, Authorship Pattern, Collaboration Index, Citation, Time Series Analysis, Sustainable Agriculture**

I. INTRODUCTION

In agriculture, having a quality seed is crucial. A famous Tamil saying expresses the importance of fertile seed, "A good seed gives one hundred bundles of rice." Over 10,000 years ago, the practice of agriculture was initiated on the flood plains of the great rivers of North Africa and the Middle East. This began with the discovery made by humans that seeds have a propagative function.

The significance of high-quality seeds in farming and crop production cannot be overstated. From the very beginning of crop farming, seeds have had an essential role in establishing, developing, diversifying, and improving crop production. It's a fact that seeds are an indispensable component in agriculture. Even with the most excellent fertilisers, irrigation, weed control, and plant insecticides, all attempts will be futile if the seed fails to germinate. The success of agricultural production depends on the quality of the seed, as it has been discovered that the use of quality seed can increase agricultural production by 10-30%.

Therefore, the role of quality seed in reducing food deficit by increasing production is imperative. Good seeds are not only the symbol, but also the foundation of good agriculture, and our life and health are also dependent on seeds and their products (Pratheepan T, 2019).

II. NEED FOR THE STUDY

Agriculture is an important occupation ever since the evolution of humankind and is considered to be the backbone for any country's socio-economic development. The challenges in agriculture sector have increased manifold due to climate change, soil erosion, biodiversity, lack of technology, finance, manpower, and so on. The rise of Covid -19 and following uncertainties have shown the world how people across the globe would suffer due to inevitable health emergencies and how unending lockdowns may render the population of a country confused in meeting their basic necessities of living.

This testing time once again proved that along with the healthcare sector, it is the agriculture sector of a country that plays a pivotal role in efficiently supplying the food demands of people. A country should always resort to healthy and advanced crop production practices and have a well thought out agriculture policy taking care of each and every phase of crop production and their storage requirements (Prakash M & Jayaprakash M, 2019).

Any research relating to agriculture helps to generate new technologies and increase agricultural productivity. Seed technology research helps to get high-quality seeds to ensure more productive and healthy agriculture and thereby contributing to the area of knowledge in terms of scholarly communication.

It is possible to conduct research productivity studies in Seed technology by using statistical measurements to gather insights about the distribution of research activities in the field, including year-wise and subject-wise distribution, as well as identifying the strengths and weaknesses of such activities. The findings of such studies can be particularly useful for government policy-making (Thanuskodi S, 2013). Therefore, it is important to examine Seed technology

literature's research output both quantitatively and qualitatively using scientometric indicators.

III. REVIEW OF LITERATURE

Kane *et al.,* (2016) analyzed scientific literature on five crops and found that publication rate increased over time, with each crop showing unique research patterns. Rajendran (2019) investigated banana research output over a 40-year period, utilizing the CAB Direct Online database. The study identified 2420 papers, with the peak in 2013.

The Asian Journal of Horticulture ranked first with 67 papers, and India emerged as the most productive country with 399 papers. Suresh and Ramesh Babu (2019) conducted a study on Agronomy research using the Scopus database from 1956 to 2017. The findings revealed 1206 publications, with articles being the most common document type (87.65%).

The Indian Journal of Agronomy published the highest number of documents (435). Liu, Zhang, and Wang (2017) performed a bibliometric study on rice research from 1985 to 2014, utilizing the Web of Science database. The study downloaded 38732 rice-related publications, observing significant growth over the past 30 years. The USA led in publications, followed by India and China. The International Rice Research Institute (IRRI) and Yano, M. were notable contributors.

Nove E. Variant Anna (2018) analyzed Library and Information Science research trends in Indonesia from 2006 to 2017. Information was collected through a library study on thesis reports from digital repositories of all universities, totaling 1436 titles. Vimlesh Patel (2018) conducted a Scientometric analysis of papers published in the Journal of Artificial Intelligence Research from 2010 to 2016. The study revealed the highest number of papers published in 2014, with the USA leading in publications (34.33%) and the University of Oxford contributing the most (17 publications).

Chattopadhyay and Ash (2019) conducted a bibliometric study of 'IASLIC Bulletin' from 1996 to 2016. The study covered 84 issues, revealing that most papers were authored by single authors, and bibliometrics was a popular topic during the study period.

Garg, M and Priya (2019) performed a bibliometric analysis of 'Accountability in Research' from 1989 to 2015. The study analyzed 575 papers, noting that 50.43% were authored by a single author. The USA had the highest contribution and the highest number of citations.

Fu and Ho (2015) examined highly cited articles published by Canada from 1920 to 2012, using the Web of Science database. The study identified 31351 highly cited papers, with the University of Toronto being the most productive institution.

Suresh and Thanuskodi (2019) explored seed technology research publications from 2008 to 2017, utilizing the Scopus database.

Analyzing 8576 publications, their findings revealed a linear growth pattern. Journal articles comprised the majority at 73.83%, with the International Journal of Food Science and Technology and Nongye Gongcheng Xuebao Transactions of The Chinese Society of Agricultural Engineering emerging as top journals.

Thanuskodi, S. (2012) conducted an analysis of the online journal titled "Indian Journal of Agricultural Research," published in India. Noteworthy findings include a predominant presence of joint authors, constituting 564 articles (93.69%). Plant Pathology emerged as the primary subject with 63 contributions (10.47%), closely followed by Agronomy with 57 contributions (9.47%).

IV. OBJECTIVES OF THE STUDY

The objectives of the study on seed technology literature between 1990 and 2019:

1. To determine how the output of research in seed technology publications has grown over time.
2. To analyze Doubling Time (DT) trends and its variations over the study period.
3. To utilize time series analysis to predict future trends in seed technology publications.
4. To highlight the prevalence and implications of collaborative multi-authorship in seed technology research.
5. To identify and rank the top 10 highly cited authors in seed technology research.
6. To provide comprehensive details on their total publications, total citations, country, and affiliated institution

V. METHODOLOGY

This study conducted to quantitative Scientometric investigation into the research productivity of publications in the field of Seed Technology. The data for this study were obtained from the Web of Science database, utilizing the following search string: SU= (Seed Technology) AND PY= (1990-2019).

The research covers a 30-year period, spanning from 1990 to 2019. The analysis and organization of the obtained data were carried out using Microsoft Excel.

VI. DISCUSSION AND ANALYSIS

A. The Distribution of Research Output Related to Seed Technology is Organized by Year.

TABLE I THE RESEARCH OUTPUT OF SEED TECHNOLOGY HAS BEEN DISTRIBUTED YEAR-WISE FROM 1990 TO 2019

Sl. No.	Year	Number of Publications	% of 16613	Cumulative Total	Cumulative %
1	1990	121	0.73	0	0.00
2	1991	316	1.90	437	2.63
3	1992	300	1.81	737	4.44
4	1993	342	2.06	1079	6.49
5	1994	362	2.18	1441	8.67
6	1995	375	2.26	1816	10.93
7	1996	378	2.28	2194	13.21
8	1997	389	2.34	2583	15.55
9	1998	426	2.56	3009	18.11
10	1999	382	2.30	3391	20.41
11	2000	442	2.66	3833	23.07
12	2001	417	2.51	4250	25.58
13	2002	447	2.69	4697	28.27
14	2003	472	2.84	5169	31.11
15	2004	508	3.06	5677	34.17
16	2005	529	3.18	6206	37.36
17	2006	514	3.09	6720	40.45
18	2007	610	3.67	7330	44.12
19	2008	660	3.97	7990	48.09
20	2009	673	4.05	8663	52.15
21	2010	682	4.11	9345	56.25
22	2011	690	4.15	10035	60.40
23	2012	678	4.08	10713	64.49
24	2013	711	4.28	11424	68.77
25	2014	790	4.76	12214	73.52
26	2015	808	4.86	13022	78.38
27	2016	862	5.19	13884	83.57
28	2017	880	5.30	14764	88.87
29	2018	897	5.40	15661	94.27
30	2019	952	5.73	16613	100.00
Total		16613	100		
The number of publications per year, on average.			553.77		

In the Web of Science database, a total of 16,613 publications were discovered. The year 2019 had the highest number of publications with 952 (5.73%), followed by 2018 with 897 publications (5.40%). The lowest number of publications was recorded in 1990 with 121 publications (0.73%).

It was also observed that 20.41% of the publications were from 1990 to 1999 (a period of ten years), while 79.59% of the publications were from 2000 to 2019 (a period of twenty years), with an average of 553.77 publications per year. The trajectory of Seed technology literature for the study period (1990-2019) fits a linear growth model, which has been proven by statistical analysis.

B. Annual Growth Rate and Compound Annual Growth Rate

TABLE II ANNUAL GROWTH RATE AND COMPOUND ANNUAL GROWTH RATE

Sl. No.	Year	No. of Publications	AGR	CAGR
1	1990	121		0.00
2	1991	316	161.16	0.62
3	1992	300	-5.06	-0.02
4	1993	342	14.00	0.03
5	1994	362	5.85	0.01
6	1995	375	3.59	0.01
7	1996	378	0.80	0.00
8	1997	389	2.91	0.00
9	1998	426	9.51	0.01
10	1999	382	-10.33	-0.01
11	2000	442	15.71	0.01
12	2001	417	-5.66	-0.00
13	2002	447	7.19	0.01
14	2003	472	5.59	0.00
15	2004	508	7.63	0.00
16	2005	529	4.13	0.00
17	2006	514	-2.84	-0.00
18	2007	610	18.68	0.01
19	2008	660	8.20	0.00
20	2009	673	1.97	0.00
21	2010	682	1.34	0.00
22	2011	690	1.17	0.00
23	2012	678	-1.74	-0.00
24	2013	711	4.87	0.00
25	2014	790	11.11	0.00
26	2015	808	2.28	0.00
27	2016	862	6.68	0.00
28	2017	880	2.09	0.00
29	2018	897	1.93	0.00
30	2019	952	6.13	0.00
Total				
Compound Annual Growth Rate (CAGR)				9.49%

Between 1990 and 2019, the Annual Growth Rate (AGR) for Seed technology publications showed an irregular pattern, with values ranging from 161.16 to 6.13.

Over the same period, the Compound Annual Growth Rate (CAGR) stood at 9.49%, indicating fluctuations in both the AGR and CAGR.

C. Year-Wise Analysis of Relative Growth Rate and Doubling Time

TABLE III RELATIVE GROWTH RATE AND DOUBLING TIME

Year	Number of Publications	Cumulative Total	Log_1	Log_2	RGR	Dt
1990	121					
1991	316	437	4.8	6.08	1.28	0.54
1992	300	737	5.76	6.6	0.85	0.82
1993	342	1079	5.7	6.98	1.28	0.54
1994	362	1441	5.83	7.27	1.44	0.48
1995	375	1816	5.89	7.5	1.61	0.43
1996	378	2194	5.93	7.69	1.77	0.39
1997	389	2583	5.93	7.86	1.92	0.36
1998	426	3009	5.96	8.01	2.05	0.34
1999	382	3391	6.05	8.13	2.07	0.33
2000	442	3833	5.95	8.25	2.31	0.3
2001	417	4250	6.09	8.35	2.26	0.31
2002	447	4697	6.03	8.45	2.42	0.29
2003	472	5169	6.1	8.55	2.45	0.28
2004	508	5677	6.16	8.64	2.49	0.28
2005	529	6206	6.23	8.73	2.5	0.28
2006	514	6720	6.27	8.81	2.54	0.27
2007	610	7330	6.24	8.9	2.66	0.26
2008	660	7990	6.41	8.99	2.57	0.27
2009	673	8663	6.49	9.07	2.57	0.27
2010	682	9345	6.51	9.14	2.63	0.26
2011	690	10035	6.53	9.21	2.69	0.26
2012	678	10713	6.54	9.28	2.74	0.25
2013	711	11424	6.52	9.34	2.82	0.25
2014	790	12214	6.57	9.41	2.84	0.24
2015	808	13022	6.67	9.47	2.8	0.25
2016	862	13884	6.69	9.54	2.84	0.24
2017	880	14764	6.76	9.6	2.84	0.24
2018	897	15661	6.78	9.66	2.88	0.24
2019	952	16613	6.8	9.72	2.92	0.24
	16613				67.04	9.51
Mean					2.23	0.32

The Relative Growth Rate (RGR) experienced fluctuations throughout the study period, but it increased from 1.28 in 1991 to 2.92 in 2019. The mean RGR for the entire study period was 2.23.

The Doubling Time (DT) drastically decreased from 0.54 in 1991 to 0.24 in 2019. The mean DT value for the study period is 0.32.

D. Time Series Analysis: The Future Growth of Publications

TABLE IV TIME SERIES ANALYSIS OF SEED TECHNOLOGY PUBLICATIONS

Sl. No	Year	Publications (Y)	X	X^2	XY
1	1990	121	-14.5	210.25	-1754.5
2	1991	316	-13.5	182.25	-4266
3	1992	300	-12.5	156.25	-3750
4	1993	342	-11.5	132.25	-3933
5	1994	362	-10.5	110.25	-3801
6	1995	375	-9.5	90.25	-3562.5
7	1996	378	-8.5	72.25	-3213
8	1997	389	-7.5	56.25	-2917.5
9	1998	426	-6.5	42.25	-2769
10	1999	382	-5.5	30.25	-2101
11	2000	442	-4.5	20.25	-1989
12	2001	417	-3.5	12.25	-1459.5
13	2002	447	-2.5	6.25	-1117.5
14	2003	472	-1.5	2.25	-708
15	2004	508	-0.5	0.25	-254
16	2005	529	0.5	0.25	264.5
17	2006	514	1.5	2.25	771
18	2007	610	2.5	6.25	1525
19	2008	660	3.5	12.25	2310
20	2009	673	4.5	20.25	3028.5
21	2010	682	5.5	30.25	3751
22	2011	690	6.5	42.25	4485
23	2012	678	7.5	56.25	5085
24	2013	711	8.5	72.25	6043.5
25	2014	790	9.5	90.25	7505
26	2015	808	10.5	110.25	8484
27	2016	862	11.5	132.25	9913
28	2017	880	12.5	156.25	11000
29	2018	897	13.5	182.25	12109.5
30	2019	952	14.5	210.25	13804
		16613	0	2247.5	52483.5

It has been projected that the number of publications related to Seed technology research will increase in the years to come. The estimate for 2025 is 1044 publications, while for 2030, it is expected to increase to 1161.

By 2040, the projected number of publications is 1395, and by 2050, it's expected to reach 1628. These numbers indicate a significant upward trend in Seed technology research publications.

TABLE V AUTHORSHIP PATTERN IN SEED TECHNOLOGY RESEARCH

No. of Authors	No. of Publications	% of 16613	No. of Authors	% of Total Authors
1	1438	8.66	1438	2.19
2	3550	21.37	7100	10.8
3	3541	21.31	10623	16.16
4	2824	17	11296	17.18
5	2026	12.2	10130	15.41
6	1237	7.45	7422	11.29
7	736	4.43	5152	7.84
8	467	2.81	3736	5.68
9	277	1.67	2493	3.79
10	181	1.09	1810	2.75
11	118	0.71	1298	1.97
12	57	0.34	684	1.04
13	40	0.24	520	0.79
14	25	0.15	350	0.53
15	26	0.16	390	0.59
16	20	0.12	320	0.49
17	6	0.04	102	0.16
18	8	0.05	144	0.22
19	6	0.04	114	0.17
20	6	0.04	120	0.18
21	5	0.03	105	0.16
22	3	0.02	66	0.1
23	3	0.02	69	0.1
24	1	0.01	24	0.04
25	2	0.01	50	0.08
27	1	0.01	27	0.04
28	1	0.01	28	0.04
29	1	0.01	29	0.04
31	1	0.01	31	0.05
32	1	0.01	32	0.05
34	2	0.01	68	0.1
36	1	0.01	36	0.05
46	1	0.01	46	0.07
56	1	0.01	56	0.09
	16613	100	65853	100

The research on Seed technology showed a range of authorship patterns, with publications ranging from single-authored to up to fifty-six authors. The dominant authorship pattern was double authorship, which contributed to a maximum of 21.37% (3550 publications).

The three-authored pattern came second with a contribution of 16.59% (3541), followed by the four-author style with a 17% share, and the five-authored pattern with 12.20%. Therefore, collaborative multi-authorship was more popular among Seed technology researchers than single-authorship.

E. Highly Cited Authors

TABLE VI TOP 10 HIGHLY CITED AUTHORS IN SEED TECHNOLOGY

Sl. No.	Impacted Authors	Total Publications	Total Citations	% of 350561	Country	Institution	Rank
1	Shewry PR	37	3495	1.0	England	Rothamsted Research, Harpenden	1
2	Takaiwa F	42	2441	0.7	Japan	National Agriculture and Food Research Organization	2
3	Ashman TL	25	2274	0.65	USA	University of Pittsburgh	3
4	Lamont BB	50	2225	0.63	Australia	Curtin University, Perth, Western Australia	4
5	Tatham AS	22	1900	0.54	England	University of Bristol, IACR Long Ashton Research station	5
6	Eckert CG	22	1866	0.53	England	Queens University	6
7	Hara-Nishimura I	40	1781	0.51	Japan	Konan University	7
8	Shimada T	41	1750	0.5	Japan	Tohoku Research Center Forestry and Forest Products Research Institute	8
9	Nishimura M	35	1719	0.49	Japan	National Institute for Basic Biology	9
10	Agren J	31	1673	0.48	Sweden	Uppsala University, Department of Ecology and Genetics	10

According to the data, Shewry, PR affiliated with Rothamsted Research in Harpenden, England, has the highest number of citations with a total of 350561. Out of those citations, 37 publications by Shewry have garnered 3495 citations, which is 0.1%. In the second position is Takaiwa F from the National Agriculture and Food Research Organization in Japan, with a total of 42 publications and 2441 citations (0.7%). In third place is Ashman TL from the University of Pittsburgh in the USA, with 25 publications and 2274 citations (0.65%).

VII. DISCUSSION OF FINDINGS

This study analyzed the research output in the Web of Science multidisciplinary database from 1990 to 2019. The researchers aimed to identify general metrics, growth in literature, authorship patterns, and citations received by published papers. Over this period, the number of Seed technology publications showed a consistent rise, averaging 553.77 publications yearly. This growth aligns with a linear model, signifying a steady expansion. Notably, 2019 witnessed the highest publications at 952, indicating a promising upward trajectory. The citation patterns revealed dynamic trends, with variations in Annual Growth Rate (AGR) and Compound Annual Growth Rate (CAGR). The Relative Growth Rate (RGR) spiked from 1.28 in 1991 to 2.92 in 2019, showcasing a substantial surge in Seed technology literature. Doubling Time (DT) decreased, suggesting an accelerated pace of growth. The analysis forecasts a significant increase in Seed technology publications, reaching 1628 by 2050. Authorship patterns showcased a dominance of collaborative multi-authorship, notably double-authored papers at 21.37%. Top three highly cited authors were Shewry PR (England), Takaiwa F (Japan), and Ashman TL (USA), with Shewry PR amassing the highest total citations at 350,561.

VIII. CONCLUSION AND SUGGESTIONS

This comprehensive analysis of seed technology publications from 1990 to 2019, utilizing the Web of Science multidisciplinary database, sheds light on several key findings. The study's findings are helpful for policymakers and administrators to identify research strengths and weaknesses and understand the knowledge dissemination pattern of seed technology research. This information can assist them in developing seed policies at national and international levels. The economic growth and per capita income of any country are heavily dependent on the agriculture sector. This sector plays a vital role in ensuring the overall development of a country. Therefore, significant investment is required from the government to promote research and development activities in seed technology and increase research output. To achieve this, Indian scientists should be encouraged to collaborate with global seed technology research authors or institutions. Additionally, the most cited papers in seed technology research should be made available in open access mode for Indian scientists to access. It is important to encourage researchers to publish their research results in open access journals, as this can enhance the visibility of their research.

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