

A Quantitative and Qualitative Assessment of *Aegle marmelos* Global Publications during 2004-18

B.M.Gupta¹, K.K. Mueen Ahmed², Jivesh Bansal³, Madhu Bansal^{4,*}

¹Formerly with CSIR-NISTADS, New Delhi, INDIA.

²Phcog.Net, Bengaluru, Karnataka, INDIA.

³Panjab University, A.C. Joshi Library, Chandigarh, INDIA.

⁴Department of Mathematics Library, Panjab University, Chandigarh, INDIA.

ABSTRACT

The present study examined 962 global publications on *Aegle marmelos*, as covered in Scopus database during 2004-18, with a view to understand its growth rate, global share, citation impact, international collaborative papers share, distribution of publications by broad subjects, productivity and citation profile of top organizations and authors, preferred communication media and characteristics of high cited papers. *Aegle marmelos* global output registered 36.37% annual growth and averaged 16.0 citations per paper during the period. 43 countries participated in the global *Aegle marmelos* research output during 2004-18, of which the top 10 most productive countries contributed 98.97% global publication share and more than 100.0% global citation share. India alone contributed 82.30% of the global publication share, while all other 9 top countries contributed from 1.34% to 3.29% during 2004-18. Pharmacology, toxicology and pharmaceuticals was the most followed subject with 47.71% global share, followed by medicine (29.0%), biochemistry, genetics and molecular biology (22.35%), agricultural and biological sciences (21.41%), etc. during 2004-18. Top 15 productive organizations and authors accounted for 19.65% and 12.79% global publications share and 22.85% and 21.30% global citations share in global *Aegle*

marmelos research output. Top 15 most productive journals accounted for 19.68% of global publication share in journals. Only 32 publications registered high citations with 100-427 citations per paper and collectively averaging to 166.56 citations per paper. Suggest that the above analysis will help the policy-makers and scholars to explore the full potential of *Aegle marmelos* in preventing and treating diseases and also to identify future research areas in this field.

Key words: *Aegle marmelos*, Medicinal plant, Global publications, Scientometrics, Bibliometrics.

Correspondence

Madhu Bansal,

Department of Mathematics Library, Panjab University, Chandigarh-160014, INDIA.

Phone no: +91 9465528460

Email: madhu@pu.ac.in.

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INTRODUCTION

Aegle marmelos L., tree known by different names in different languages, such as Bel, Beli and Belgiri in Hindi, Bilva, Shivadrums, Shivaphala and Vilva in Sanskrit and Bael, Bengal quince and golden apple in English and also Japanese bitter orange, stone apple or wood apple. It is the only member of the monotypic genus *Aegle* and belongs to Rutaceae family, the family of citrus fruits.^{1,2}

It is a deciduous shrub or small to medium-sized tree, up to 13m tall with slender drooping branches and rather shabby crown. *Aegle marmelos* is a spinous deciduous and aromatic shrub or small to medium size tree with long, strong and axillary spines. This tree grows up to 18 mt in height and thickness of tree is about 3-4 ft. Its bark is pale brown or grayish, smooth or finely fissured and flaking, armed with long straight spines, 1.2 - 2.5 cm singly or in pairs, often with slimy sap oozing out from cut parts. The gum is also described as a clear, gummy sap, resembling gum arabic, which exudes from wounded branches and hangs down in long strands, becoming gradually solid. It is sweet at first taste and then irritating to the throat. The leaf or leaves is trifoliate, alternate, each leaflet 5-14 x 2-6 cm, ovate with tapering or pointed tip and rounded base, untoothed or with shallow rounded teeth. Young leaves are pale green or pinkish, finely hairy while mature leaves are dark green and completely smooth. Each leaf has 4-12 pairs of side veins which are joined at the margin. The leaves have typical aroma. Flowers are greenish white in color and sweet scented. Bael fruits typically has a diameter of between 5 and 12 cm. It is globose or slightly pear-shaped with a thick, hard rind and does not

split upon ripening. The woody shell is smooth and green, gray until it is fully ripe when it turns yellow. Inside are 8 to 15 or 20 sections filled with aromatic orange pulp, each section with 6 (8) to 10 (15) flattened-oblong seeds each about 1 cm long, bearing woolly hairs and each enclosed in a sac of adhesive, transparent mucilage that solidifies on drying. Seeds are compressed, oblong and numerous found in aromatic pulp.^{3,4}

This plant has tremendous uses listed in Indian system of medicine (Ayurvedic, Unani and Siddha Systems of medicine) and in various folk medicine to treat myriad ailments. Almost every part of this plant (viz. stems, barks roots, leaves, flowers seeds and fruits at all stages of maturity) bears one or more of the medicinal properties or virtues utilized through preparation of different formulations either alone or in combination with other herbal plants.⁴Bilva is a very common herbaceous plant native and it is grown in Bangladesh, Sri Lanka, Thailand, Malaysia and India. It grows in most parts of the Indian sub-continent, Myanmar and South – East Asia. Forests on hills and Rajasthan is suitable climate for this tree. This herb is also distributed in other countries such as Pakistan, Nepal, Philippines, Fiji, Cambodia and Thailand.³

Besides having medical properties, it has number of other uses. Its fruit can be eaten either fresh from trees or after being dried and produced into candy, toffee, pulp powder or nectar. If fresh, the juice is strained and sweetened to make a drink similar to lemonade. It can be made into sharbat or Bela pana, a beverage. If the fruit is to be dried, it is usually

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sliced and sun-dried. The hard leathery slices are then immersed in water. The leaves and small shoots are eaten as salad, It is also an important environmental protector as leaves and bark act as a sink by absorbing dust and foul and poisonous gases from surrounding atmosphere and makes them clean. Leaves are also used as a veterinary medicine for wound and fodder for animals and stimulation of denervated nictitating membrane in anesthetized cats.⁵The *Aegle marmelos* plant act as “sink” for chemical pollutants as it absorbs poisonous gases from atmosphere and make them inert or neutral. Owing to its environment friendly nature, *Aegle marmelos* is being placed among plant species group called “climate purifiers” which emit a greater percentage of oxygen in sunlight as compared to other plants. The tree is also considered under the category of “Fragrant” species”, whose flowers and volatile vapour neutralize bad smell of pterfied organic matter or decaying refuse and thus saving from bacterial attack. This herb has great spiritual and religious significance. Its fruits and leaves are considered sacred and used as offerings to the Hindu Gods like Lord Shiva. This is why it is also known as “Shiva druma” or the tree of Shiva in ancient scriptures.^{2,5}

Various chemical constituents like alkaloids, coumarins and steroids have been isolated and identified from different parts of the tree. Some of the important phytochemical compounds isolated from different plant parts of *Aegle marmelos* are: Leaf - Skimmianine, Aegeline, Lupeol, Cineol, Cuminaldehyde, Eugenol, Marmesinine, Citronella; Bark - Skimmianine, Fagarine, Marmine and Fruit-Marmelosin, Luvangetin, Auraptin, Psoralen, Marmelide, Tannin. The biological activities of the phenolic compounds present in *Aegle marmelos* is shown indicating the wide-spread therapeutic effect of the plant.⁶ Among the traditional uses of *Aegle marmelos*, it helps in the management of diabetes mellitus. It is traditionally used to treat jaundice, constipation, chronic diarrhoea, dysentery, stomachache, stomachic, fever, asthma, inflammations, febrile delirium, acute bronchitis, snakebite, abdominal discomfort, acidity, burning sensation, epilepsy, indigestion, leporsy, myalgia, smallpox, spermatorrhoea, leucoderma, eye disorders, ulcers, mental illnesses, nausea, sores, swelling, thirst, thyroid disorders, tumors, ulcers and upper respiratory tract infections. It is also used to treat anaemia, fractures, healing of wounds, swollen joints, high blood pressure, diarrhoea, healthy mind and brain typhoid troubles during pregnancy.⁶ *Aegle marmelos* is known for its modern medicinal values because of the presence of numerous phytochemical constituents. Researchers reported pharmacological potential of various parts such as fruits, leaves and stems of *Aegle marmelos* as antioxidant, antimicrobial, hypoglycemic, anti-inflammatory, analgesic, nephroprotective, hepatoprotective etc.⁶The extract prepared by boiling the bark, leaves or roots in water is useful as laxative, febrifuge and expectorant. The extract is also useful in ophthalmia, deafness, inflammations, catarrh, diabetes and asthmatic complaints. The fruits are used in treating diarrhoea, dysentery, stomach ache and cardiac ailments.

Extensive experimental and clinical studies have validated many of *Aegle marmelos*'s ethnomedicinal properties and its potential antimicrobial effects, hypoglycemic, astringent, antidiarrheal, antidysenteric, demulcent, analgesic, anti-inflammatory, antipyretic, wound-healing, insecticidal and gastroprotective properties, which help it to be useful in prevention and treatment of many diseases. In addition, studies have also shown that *Aegle marmelos* phytochemical compounds possess antineoplastic, radioprotective, chemoprotective and chemopreventive effects, properties efficacious in the treatment and prevention of cancer.^{6,7}Bael fruits are of dietary use and the fruit pulp is used to prepare delicacies like murabba, puddings and juice. Bael fruits are also used in the treatment of chronic diarrhoea, dysentery and peptic ulcers, as a laxative and to recuperate from respiratory affections in various folk medicines. Leaves of this plant used to cause infertility/abortion in women. The fruit possesses broad range of therapeutic effects that includes free radical scaveng-

ing, antioxidant, inhibition of lipid peroxidation, antibacterial, antiviral, anti-diarrheal, gastroprotective, anti-ulcerative colitis, hepatoprotective, anti-diabetic, cardioprotective and radioprotective effects.⁶

Overall in terms of health benefits in Ayurveda, it is used for the treatment of tuberculosis. The regular consumption of Bael helps to prevent gynecological related issues. Use of bel leads you to overcome the problems of urinary diseases. It has bitter pungent, full of antioxidants and helps to stimulate the pancreas to secrete insulin, which leads to lowering of blood sugar. The leaves can be used against diabetes. It supports intestinal biological formulations and protects the digestive system from ulceration, reduces the frequency of Irritable Bowel Syndrome (IBS), intestinal spasm thus beneficial in treating of diarrhoea, dysentery and other infections of Elementary canal. The leaf juice with honey is helpful in prevention of fever. Its flowers are uses as epilepsy tonic. The extract of unripe bel fruit is helpful in curing of piles and hemorrhoids. Due to its soothing effects on the digestive system, it leads to reduce the acidity level in the stomach thus useful in combating ulcers like gastric ulcers, gastroduodenal ulcers, etc.⁸

Despite the global importance of *Aegle marmelos* plant research for diverse medical applications, no bibliometric study about publications on this subject is available in the literature. However, few other similar studies are available, which quantitatively and qualitatively analyze global and Indian literature on individual medicinal plants, such as on *Aloe vera*,⁹ *Azadirachta indica*,¹⁰ *Curcuma longa*,¹¹ *Glycyrrhiza glabra*,¹² *Nigella sativa*,¹³ *Ocimum santum*,¹⁴ *Phyllanthus emblica*,¹⁵ *Tinospora cordifolia*,¹⁶ *Withania somnifera*,¹⁷ *Rhodiola rosea*¹⁸ and *Terminalia arjuna*.¹⁹

In order to fill this existing gap in the literature, the authors decided to scrutinize and analyze the global publications on *Aegle marmelos* plant during 2004-18 with the aim to study the distribution of its global publication output and of 10 most productive countries; by document type and source type, growth rate of its annual and cumulative output, the share of international collaborative publications, broad subject-wise scatter across sub-fields, identification of significant keywords depicting trends in research, publication output and citation impact of top 15 global organizations, authors and journals and characteristics of its high cited publications.

METHODS

Aegle marmelos global publications and of top 10 leading countries data was derived from indexed publications in the Scopus database (<http://www.scopus.com>) during 2004-18. Keywords, such as “*Aegle marmelos*” or “Bael” were searched in “KEY”(Keyword) or “TITLE” (Title of the paper) tags during 2004-18 to get publication data on global output (962 records). The search string was subsequently refined, using analytical tags in Scopus database, by “subject area tag”, “country tag”, “source title tag”, “journal title name” and “affiliation tag”, to get data/information on the distribution of publications output by subject, collaborating countries, author-wise, organization-wise and journal-wise, etc. Citations to publications were also collected from date of publication till 25 August 2019.

(KEY (“*Aegle marmelos*” or “Bael”) OR TITLE (“*Aegle marmelos*” or “Bael”)) AND PUBYEAR > 2003 AND PUBYEAR < 2019

ANALYSIS

The global research community published 962 publications on *Aegle marmelos* during 2004-18 as indexed in Scopus database. Its annual publication output registered average growth rate 36.37%, up from 26 in the year 2004 to 88 in the year 2018. Its cumulative global output registered 47.30% growth, up from 389 during 2004-11 to 573 during 2012-18. *Aegle marmelos* cumulative research output registered the citation impact

per paper (CPP) of 16.00 during 2004-18, which, however, decreased from 29.68 CPP to 6.72 CPP from 2004-11 to 2012-18. Among document types, articles (810, 84.30%) and reviews (115, 11.95%) constitute 96.25% of the global output. Conference papers (1.56%), book chapters (0.73%), editorials (0.52%), letters (0.31%) and notes (0.21) constitute only 3.33% of the total output (Table 1). The rest document types con-

stitute data paper, erratum, short survey and undefined with 0.10% contribution each.

Top 10 Most Productive Countries in *Aegle marmelos* research

43 countries evenly participated in global *Aegle marmelos* research during 2004-18. 33 and 6 countries contributed 1-10 and 11-20 papers each, as against 3 and 1 countries contributing 21-50 and 800 papers each. The top 10 most productive countries contributed 13 to 800 publications each on *Aegle marmelos* during 2004-18 (Table 2). 98.97% of global publications and more than 100.0% of the global citations have been contributed by the top 10 countries during 2004-18. India alone contributed 82.30% share of the global output, while all other 9 top countries contributed global share from 1.34% to 3.29% during 2004-18. The global publication share registered decreasing trend in Italy, Japan, U.K., India and Bangladesh (from 0.46% to 1.70%), as against increase in Malaysia, USA, Pakistan, Indonesia and Thailand (from 0.05% to 0.72%) from 2004-11 to 2012-18. Six countries, among top 10, registered relative citation index above the world average of 1.08: U.K. (4.29), Italy (2.21), USA (1.69), Bangladesh (1.65), Japan (1.27) and Thailand (1.14) during 2004-18. India has though emerged as one of the world most significant and leading contributor on *Aegle marmelos* research, its performance in terms of relative citation index has been slightly below the world average (0.98).

As a national share in the country-wise output, the international collaborative output of top 10 most productive countries on *Aegle marmelos* varied widely from 6.63% (India) to 93.33% (Japan), with the average share of 13.89% during 2004-18. Most surprisingly, India's international collaborative share in its national output in *Aegle marmelos* research has, however, been comparatively the lowest.

Subject-Wise Distribution of Research Output

The global *Aegle marmelos* research output (as reflected in Scopus database classification) published during 2004-18 is distributed across seven sub-fields. Pharmacology, toxicology and pharmaceuticals have contributed the most significant publications share (47.71%). Medicine (29.0%), biochemistry, genetics and molecular biology (22.35%) and agricultural

Table 1: *Aegle marmelos* Plant Annual Publications during 2004-18.

Publication Period	World		
	TP	TC	CPP
2004	26	1338	51.46
2005	29	1233	42.52
2006	23	1558	67.74
2007	34	2103	61.85
2008	48	1207	25.15
2009	66	1753	26.56
2010	64	991	15.48
2011	99	1361	13.75
2012	99	1529	15.44
2013	91	808	8.88
2014	91	553	6.08
2015	78	302	3.87
2016	63	235	3.73
2017	63	236	3.75
2018	88	188	2.14
2004-11	389	11544	29.68
2012-18	573	3851	6.72
2004-18	962	15395	16.00

TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper

Table 2: Top 10 Most Productive Countries Global Publication Output on *Aegle marmelos* during 2004-18.

S.No	Name of the Country	Number of Papers			Share of Papers			TC	CPP	ICP	%ICP	RCI
		2004-11	2012-18	2004-18	2004-11	2012-18	2004-18					
1	India	325	475	800	83.55	83.04	82.30	12601	15.75	53	6.63	0.98
2	USA	12	20	32	3.08	3.50	3.29	866	27.06	17	53.13	1.69
3	Bangladesh	12	15	27	3.08	2.62	2.78	712	26.37	8	29.63	1.65
4	Thailand	10	15	25	2.57	2.62	2.57	456	18.24	4	16.00	1.14
5	Pakistan	6	11	17	1.54	1.92	1.75	256	15.06	2	11.76	0.94
6	Italy	10	5	15	2.57	0.87	1.54	530	35.33	9	60.00	2.21
7	Japan	8	7	15	2.06	1.22	1.54	304	20.27	14	93.33	1.27
8	Indonesia	5	9	14	1.29	1.57	1.44	101	7.21	9	64.29	0.45
9	Malaysia	4	10	14	1.03	1.75	1.44	74	5.29	12	85.71	0.33
10	U.K.	8	5	13	2.06	0.87	1.34	892	68.62	7	53.85	4.29
	Total	400	572	972	102.83	100.00	100.00	16792	17.28	135	13.89	1.08
	World	389	573	962	100.00	100.17	98.97	15395	16.00			
	Share of 10 Countries in World Total							109.07				

TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper; ICP=International Collaborative Papers; RCI=Relative Citation Index

and biological sciences (21.41%) showed medium - level contributions. Other three sub-fields namely chemistry, environment science and immunology and microbiology showed the least contribution (from 5.61% to 8.0%) during 2004-18. On measuring the change in research activity (as reflected in activity index) from 2004-11 to 2012-18, all subjects except chemistry, showed decline during the above periods. Biochemistry, genetics and molecular biology (21.03), medicine (19.08), immunology and microbiology (17.70) and pharmacology, toxicology and pharmaceuticals (17.15) registered citation impact per paper above the global average of 16.0 during 2004-18 (Table 3).

Most Productive Global Organizations

In *Aegle marmelos* global research, two hundred ninety one (291) organizations evenly participated during 2004-18. 251 and 27 organizations contributed 1 - 5 and 6-10 papers each, as against only 13 organizations contributing 11-18 papers. Among 291 organizations, the top 15 publication productivity varied from 9 to 18 papers. Together these top 15 contributed 19.65% global publication and 22.85% global citation share, respectively during 2004-18. Among top 15 organizations, 13 were from India and 1 each from Malaysia and Indonesia.

On further analysis, it was found that only five organizations among top 10, namely Banaras Hindu University, Varanasi, India and Annamalai

Table 3: Distribution of Global Publications on *Aegle marmelos* by Broad Subject during 2004-18.

S.No	Subject*	Number of Papers (TP)			Activity Index		TC	CPP	%TP
		2004-11	2012-18	2004-18	2004-11	2012-18			
1	Pharmacology, Toxicology and Pharmaceutics	202	257	459	108.83	94.00	7871	17.15	47.71
2	Medicine	125	154	279	110.80	92.67	5322	19.08	29.00
3	Biochemistry, Genetics and Molecular Biology	90	125	215	103.52	97.61	4522	21.03	22.35
4	Agricultural and Biological Sciences	92	114	206	110.45	92.91	2614	12.69	21.41
5	Chemistry	23	54	77	73.87	117.74	1179	15.31	8.00
6	Environment Science	31	45	76	100.87	99.41	1091	14.36	7.90
7	Immunology and Microbiology	31	23	54	141.97	71.51	956	17.70	5.61
	World Output	389	573	962			15395	16.00	

There is overlapping of literature covered under various subjects

TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper

Table 4: Top 15 Most Productive Global Organizations on *Aegle marmelos* Research during 2004-18.

S.No	Name of the Organization	TP	TC	CPP	HI	ICP	%ICP	RCI
1	Banaras Hindu University, Varanasi, India	18	460	25.56	8	3	16.67	1.60
2	Annamalai University, India	18	281	15.61	10	0	0.00	0.98
3	University of Madras	17	488	28.71	10	4	23.53	1.79
4	Government College of Technology, Vellore, India	13	39	3.00	3	0	0.00	0.19
5	Sathyabama University, Madras, India	13	38	2.92	3	0	0.00	0.18
6	G.B. Pant University of Agriculture and Technology, India	12	22	1.83	2	1	8.33	0.11
7	Kasturba Medical College, Manipal, India	12	626	52.17	10	2	16.67	3.26
8	Loyola College, Madras, India	12	429	35.75	10	4	33.33	2.23
9	C. Abdul Hakeem College, Melvisharam, India	12	470	39.17	10	0	0.00	2.45
10	Vellore Institute of Technology, India	11	118	10.73	6	1	9.09	0.67
11	University of Rajasthan, Jaipur, India	11	61	5.55	4	1	9.09	0.35
12	Universitas Gadjah Mada, Indonesia	11	63	5.73	4	8	72.73	0.36
13	Panjab University, Chandigarh, India	10	129	12.90	7	1	10.00	0.81
14	National Institute of Technology, Rourkela, India	10	240	24.00	6	0	0.00	1.50
15	Universiti Patra Malaysia	9	54	6.00	3	7	77.78	0.38
	Total of 15 organizations	189	3518	18.61	6	32	16.93	1.16
	Total of World	962	15395	16.00				
	Share of top 15 organizations in World total output	19.65	22.85					

TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper; HI=h-index; ICP=International Collaborative Papers; RCI=Relative Citation Index

University, India (18 papers each), University of Madras, India (17 papers), Government College of Technology, Vellore, India and Sathyabama University, Madras, India (13 papers each) registered publications output greater than the group average of 12.6 during 2004-18; Seven organizations, namely Kasturba Medical College, Manipal, India (52.17 and 3.26), C. Abdul Hakeem College, Melvisharam, India (39.17 and 2.45), Loyola College, Madras, India (35.75 and 2.23), University of Madras, Chennai, India (28.71 and 1.79), Banaras Hindu University, Varanasi, India (25.56 and 1.60) and National Institute of Technology, Rourkela, India (24.0 and 1.50) registered citation impact above the group average of 18.61 citations per publication and 1.16 relative citation index during 2004-18; and Four organizations, namely Universiti Patra Malaysia (77.78%), Universitas Gadjah Mada, Indonesia (72.73%), Loyola College, Madras, India (33.33%) and University of Madras, Chennai, India (23.53%) contributed international collaborative publications share above the group average of 16.93% during 2004-18 (Table 4).

Most Productive Global Authors

In *Aegle marmelos* global research, Four hundred fifty six (456) authors evenly participated during 2004-18. 437 and 27 authors contributed 1-5 and 6-10 papers each, as against only 2 authors contributing 11-12 papers each. Among 456 authors, the top 15 publication productivity varied from 6 to 12 papers. Together these top 15 authors contributed 12.79% global publications and 21.30% global citation share, respectively during 2004-18. Among top 15 authors, 10 were from India, 3 from Italy and 2 from Indonesia.

On further analysis, it was found that only five authors among the top 10, namely M.S. Baliga (12 papers), S. Riyanto (11 papers), R. Venkatesh (10 papers), G.C. Jagetia and A.E. Nugroho (9 papers) registered publication output above the group average of 8.2 during 2004-18; Seven authors, G.C. Jagetia (61.89 and 3.87), M.S. Baliga (37.17 and 2.32), S. Ignocimuthu (37.0 and 2.31), G. Elango (32.63 and 2.04), A. Bagavan (31.86 and 1.99), C. Kamaraj (31.86 and 1.99), R. Venkatesh (27.86 and 1.96) and A.A. Rahuman (27.86 and 1.74) registered citation impact above the group average of 26.66 citations per paper and relative citation index

Table 5: Top 15 Most Productive Authors on *Aegle marmelos* Research during 2004-18.

S. No	Name of the Author	Affiliation of the Author	TP	TC	CPP	HI	ICP	%ICP	RCI
1	M.S.Baliga	Kasturba Medical College, Manipal, India	12	446	37.17	9	3	25.00	2.32
2	S.Riyanto	Universitas Gadjah Mada, Indonesia	11	63	5.73	4	8	72.73	0.36
3	R.Venkatesh	Kasturba Medical College, Manipal, India	10	314	31.40	9	3	30.00	1.96
4	G.C. Jagetia	Kasturba Medical College, Manipal, India	9	557	61.89	9	1	11.11	3.87
5	A.E.Nugroho	Universitas Gadjah Mada, Indonesia	9	60	6.67	4	6	66.67	0.42
6	G.Elango	C.Abdul Hakeem College, Melvishara, India	8	261	32.63	8	0	0.00	2.04
7	R.Gambari	University of Ferrara, Italy	8	202	25.25	7	3	37.50	1.58
8	I.Lampronti	University of Ferrara, Italy	8	202	25.25	7	3	37.50	1.58
9	A.Bagavan	C.Abdul Hakeem College, Melvishara, India	7	223	31.86	7	0	0.00	1.99
10	M. Borgatti	University of Ferrara, Italy	7	173	24.71	6	2	28.57	1.54
11	C.Kamaraj	C.Abdul Hakeem College, Melvishara, India	7	223	31.86	7	0	0.00	1.99
12	M.Krishnamoorthi	Government College of Technology, Coimbatore, India	7	69	9.86	4	0	0.00	0.62
13	R.Malayala	Government College of Technology, Coimbatore, India	7	69	9.86	4	0	0.00	0.62
14	A.A.Rahuman	C.Abdul Hakeem College, Melvishara, India	7	195	27.86	7	0	0.00	1.74
15	S. Ignocimuthu	Loyola College, Madras, India	6	222	37.00	6	2	33.33	2.31
		Total of 15 authors	123	3279	26.66	6.53	31	25.20	1.67
		Total of World	962	15395	16.00				
		Share of top 15 authors in World total output	12.79	21.30					

TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper; HI=h-index; ICP=International Collaborative Papers; RCI=Relative Citation Index

of 1.67; and Seven authors, namely S. Riyanto (72.73%), A.E. Nugroho (66.67%), R. Gambari and I. Lampronti (37.5% each), S. Ignocimuthu (33.33%), R. Venkatesh (30.0%) and M. Borgatti (28.57%) contributed international collaborative publications share above the group average of 25.20% during 2004-18 (Table 5).

Medium of Research Communication

97.71% (940 papers) share of *Aegle marmelos* global research output appeared in journals and the rest as book series (1.64%), books (0.62%) and conference proceedings (0.52%) during 2004-18. 940 journal papers appeared in 437 journals and they are evenly distributed. 437 journals published 1-5 papers each, as against 27 and 2 journals 6-10 and 11-12 papers each during 2004-18. The top 15 most productive journals reported 12 to 31 papers each on *Aegle marmelos*; together they accounted for 19.68% (185 papers) share of total *Aegle marmelos* output published in journals during 2004-18. Their output share have shown increase from 13.98% to 23.53% between 2004-11 and 2012-18. The top ranking journal is *Journal of Ethnopharmacology* (with 31 papers), followed by *International Journal of Pharmacy and Pharmaceutical Science* (30 papers), *Asian Journal of Pharmaceutical and Clinical Research* and *International Journal of Pharmaceutical Science Review and Research* (20 papers each), *International Journal of Green Pharmacy* (16 papers each), etc. during 2004-18 (Table 6).

Significant Keywords

Around 48 significant keywords have been identified from the literature which through light on the research trends in *Aegle marmelos* research including on its biological and pharmacological properties and medicinal uses. These keywords are listed in Table 7 in the decreasing order of the frequency of their occurrence in the literature during 2004-18.

Highly Cited Papers

Thirty Two (32) papers were identified as highly cited as each having 100 to 427 citations (25 papers each in citation range 100-200, 5 papers each in 201-300 citations range each, 1 paper each with 377 and 427 citations) in 15 years during 2004-18. These 32 papers together cumulated a total of 5330 citations, averaging 166.56 citations per paper. Of the 32 highly cited papers, 17 resulted from the participation of research organizations in their role as stand-alone (non-collaborating) and remaining 15 from

two or more research organizations working in their role as collaborating partners per paper (6 national collaborative and 9 international collaborative). Among 32 highly cited papers, the largest participation was seen from India (26 papers), followed by the USA, U.K. and Italy (2 papers each), Australia, Bangladesh, Brazil, China, France, Germany, Japan, Pakistan, Singapore and Sri Lanka (1 paper each) during 2004-18. These 32 highly cited papers involved the participation of 139 authors and 57 research organizations in total across the globe. Of the 32 highly cited papers, 22 were published as articles and 10 as review papers. These 32 highly cited papers were published in 16 journals, with 11 papers in *Journal of Ethnopharmacology*, 3 papers each in *Journal of Clinical Biochemistry and Nutrition* and *Phytotherapy Research*, 2 papers in *Journal of Hazardous Materials* and 1 paper each in 12 other journals.

SUMMARY AND CONCLUSION

The publications data on *Aegle marmelos* considered for the present study for the last 15 years (2004-18) were derived from the Scopus database with a view to study its quantitative and qualitative aspects in the form of bibliometric indicators. It was observed that the annual and cumulative global output of *Aegle marmelos* research registered 36.37% and 47.30% growth. Its global citation impact averaged to 16.0 citations per paper in 15 years, which decreased from 29.68 CP to 6.72 CP from 2004-11 to 2012-18. *Aegle marmelos* global research output came from 43 countries during 2004-18 and the distribution was quiet even. 98.97% of global publication share and more than 100.0% of the global citation share have come from top 10 countries alone during 2004-18. On one hand 82.30% of the global publication share came from India, while on the hand 9 other top countries contributed from 1.34% to 3.29% global share during 2004-18. South Korea (2.55), Bangladesh (2.10), USA (1.61), Malaysia (1.36), Iran (1.21), Thailand (1.16) and Pakistan (1.11) registered relative citation index above the world average of 1.0 among the top 10 countries during 2004-18. The international collaborative share of these top 10 countries varied from 6.70% to 85.71%, with Saudi Arabia registering the highest and India the least share.

Pharmacology, toxicology and pharmaceuticals was the most priority subject on *Aegle marmelos*, contributing 47.71% publications share, followed by medicine (29.0%), biochemistry, genetics and molecular biology (22.35%) and agricultural and biological sciences. Other three sub-fields namely chemistry, environment science and immunology and microbi-

Table 6: Top 15 Most Productive Journals on *Aegle marmelos* Research during 2004-18.

S.No	Name of the Journal	Number of Papers		
		2004-11	2012-18	2004-18
1	Journal of Ethnopharmacology	17	14	31
2	International Journal of Pharmacy and Pharmaceutical Sciences	6	24	30
3	Asian Journal of Pharmaceutical and Clinical Research	2	18	20
4	International Journal of Pharmaceutical Science Review and Research	6	14	20
5	International Journal of Green Pharmacy	1	15	16
6	International Journal of Pharma and Bio Sciences	2	13	15
7	Pharmaceutical Biology	10	5	15
8	Asian Pacific Journal of Tropical Diseases	0	13	13
9	International Journal of Pharmatech Research	5	8	13
10	Asian Pacific Journal of Tropical Medicine	4	8	12
	Total of 15 journals	53	132	185
	Total global journal output	379	561	940
	Share of top 15 journals in global journal output	13.98	23.53	19.68

Table 7: List of Significant Keywords on Global *Aegle marmelos* Research Literature during 2004-18.

S.No	Keyword	Frequency	S.No	Keyword	Frequency
1	<i>Aegle marmelos</i>	850	25	Anti-Diabetic Activity	51
2	Plant Extract	532	26	Diarrhea	51
3	Medicinal Plant	296	27	Antimicrobial Activity	48
4	Plant Leaf	243	28	Enzyme Activity	48
5	Fruit	152	29	Anti-inflammatory Activity	
6	Herbaceous Agent	124	30	Staphylococcus Auras	45
7	Antioxidant Activity	122	31	Ethno botany	44
8	Phytochemistry	111	32	Anti-fungal Activity	42
9	Diabetes Mellitus	107	33	Anti-infective Agents	42
10	Traditional Medicine	98	34	Anti-neoplastic Activity	41
11	Drug Screening	94	35	Bael	41
12	<i>In vitro</i> Study	88	36	Plant Stem	41
13	Plant Root	87	37	Diabetes	39
14	Anti-bacterial Activity	85	38	Liver Protection	36
15	Drug Efficacy	78	39	Tannins	35
16	Bark	77	40	Ascorbic Acid	34
17	Phytotherapy	77	41	Non-Insulin Dependent Diabetes Mellitus	34
18	Plant Seed	73	42	Drug Safety	33
19	Flavonoids	68	43	Fever	32
20	Drug Mechanism	67	44	Flower	32
21	Drug Isolation	65	45	<i>In vivo</i> Study	31
22	Plant Leaves	64	46	Drug Potency	28
23	Alkaloids	56	47	Ascorbic Acid	34
24	Ayurveda	56	48	Non-Insulin Dependent Diabetes Mellitus	34
25	Escherichia Coli	53			

ology showed the least contribution (from 5.61% to 8.0%) during 2004-18. Among broad subjects, the research activities registered increase in chemistry, while in all other subjects it showed decline from 2004-11 to 2012-18. Biochemistry, genetics and molecular biology (21.03), medicine (19.08), immunology and microbiology (17.70) and pharmacology, toxicology and pharmaceuticals (17.15) registered citation impact per paper above the global average of 16.0 during 2004-18.

291 organizations and 456 authors participated in global *Aegle marmelos* research output during 2004-18, of which the top 15 most productive research organizations and the authors collectively contributed 19.65% and 12.79% global publication share and 22.85% and 13.14% global citation share respectively during 2004-18. The leading organizations in terms of publication productivity were: Banaras Hindu University, Varanasi, India and Annamalai University, India (18 papers each), University of Madras, India (17 papers), Government College of Technology, Vellore, India and Sathyabama University, Madras, India (13 papers each) during 2004-18. The leading organizations in terms of citation impact per paper and relative citation index were: Kasturba Medical College, Manipal, India (52.17 and 3.26), C. Abdul Hakeem College, Melvisharam, India (39.17 and 2.45), Loyola College, Madras, India (35.75 and 2.23), University of Madras, Chennai, India (28.71 and 1.79), Banaras Hindu University, Varanasi, India (25.56 and 1.60) and National Institute of Technology, Rourkela, India (24.0 and 1.50) during 2004-18.

The journals medium accounted for 97.71% global share in *Aegle marmelos* research with top 15 most productive journals accounting for 19.68% share of total publications output in journals during 2004-18. Journal of

Ethnopharmacology contributed the largest number of papers (31), followed by International Journal of Pharmacy and Pharmaceutical Science (30 papers), Asian Journal of Pharmaceutical and Clinical Research and International Journal of Pharmaceutical Science Review and Research (20 papers each), International Journal of Green Pharmacy (16 papers each), etc. during 2004-18

Of the total *Aegle marmelos* global research output, only 32 publications registered high citations, in the range of 100-427 citations per paper and collectively these highly cited papers received a total of 5330 citations, averaging to 166.56 citations per paper. These 32 highly cited papers involved the participation of 139 authors and 57 organizations and were published in 16 journals, of which 11 papers in Journal of Ethnopharmacology, 3 papers each in Journal of Clinical Biochemistry and Nutrition and Phytotherapy Research, 2 papers in Journal of Hazardous Materials and 1 paper each in 12 other journals.

Concludes that *Aegle marmelos* is an important Indian plant, conserved since centuries has enormous traditional uses as a food source and against various diseases. Focus on plant research has increased in recent times with an aim towards exploring its edible, medicinal and amelioration properties in animal and human welfare globally. Over the last few years, researchers have aimed at identifying and validating plant derived substances for the treatment of various diseases and amelioration of toxicity. It has been proved that various parts of plants such as leaves, fruits, seeds, provide health and nutrition, promoting compounds in the human diet and which has enormous traditional uses against various diseases. The above analysis indicates the traditional uses, phytochemistry

and pharmacology activity of *Aegle marmelos*, which is incomparable source of a varied range of chemical compounds having diverse medicinal properties. The pharmacology studies on this plant are mainly focused on the antimicrobial, hypoglycemic, anti-inflammatory, analgesic, nephron-protective, neuro-protective, hepato-protective activity. Suggests that more mechanistic studies are required before *Aegle marmelos* can be considered for further clinical use. Suggest that research output on *Aegle marmelos* may serve as the baseline data to explore the full potential of *Aegle marmelos* in preventing and treating diseases and carry extensive studies further for the discovery of new potent compounds.

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