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Characterization and Quantification of Betasatellites Research from Google Scholar Using a Bibliometric Approach

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Abstract

Background: *Begomoviruses* belongs to the family *Geminiviridae*. These viruses are associated with various satellite DNA molecules (alpha satellites, delta satellites, and betasatellites).

Methods: The standardized search strategy was applied to get the research output regarding betasatellites worldwide for bibliometric analysis. Google scholar database was used to collect the data regarding betasatellites research from past 1997 to June 2018.

Results: A total of 213 documents regarding the studied subject were identified, out of which the maximum number of documents 153 (71.83%) were found to have been published in the form of original research articles. The common language of publications 208 (97.65%) was English. The results declare that the number of publications shows an increase from 1997 to 2014, with the maximum number of publications in 2014. The top 10 productive countries based on the maximum number of publications were India 83 (38.96%), Pakistan 66 (30.98%), China 26 (12.20%) followed by some other countries. USA and Oman were the top collaborative countries with Pakistan respectively.

Conclusion: For all the analyzed documents the total number of citations was 3564 with an average of 16.73 citations per document. The journal "*Virus Genes*" was the most prolific journal based on a maximum number of publications on the studied subject. Robert William Briddon and Shahid Mansoor were the most productive scientists, and the National Institute for Biotechnology and Genetic Engineering (NIBGE) was the most productive institute regarding the studied subject. This study shows that India, Pakistan, the USA, and China play an important role in the area of beta satellite research.

Introduction

Gemini viruses belong to the family *Geminiviridae* [1]. This family consists of circular, single-stranded DNA (ssDNA) genome and is economically the most important plant infecting DNA viruses. The genome of such viruses is enclosed in 22 capsomeres comprising capsid, their size is 20 nm diameter and 38 nm long and having incomplete icosahedral symmetry [2, 3]. This family of plant viruses is divided into nine different genera based on their genome organization, transmitting vector, host range, and genome-wide pairwise sequences similarities. These genera are *Begomovirus, Curtovirus, Topocovirus, Becurtovirus, Mastervirus, Turncurtovirus, Eragrovirus, Graglovirus,* and *Capulavirus* [4-6].

Begomovirus is the largest genus amongst the 9 genera of the family, consisting of 320 recognized species [1]. These are economically most destructive viruses infecting a wide range of plants including both monocots and dicots, in tropical and in subtropical regions around the world. These viruses have become a serious threat for several crops such as vegetables, cereal crops, ornamental plants, medicinal and aromatic plants, etc. during the last two decades. These viruses also infect weeds plants as a reservoir [1, 7]. The common symptoms include mottling, leaf stunting, curling, and yellowing, vein thickening, vein darkening, stunted growth, mosaic and foliar crinkling. Depending on the host plants, their cultivar, and age at infection time, and environmental factors, the symptoms and infection severity greatly vary [8, 9].

Begomoviruses are globally transmitted by their ubiquitous vector whitefly (*Bemisia tabaci*) [10]. The size of the viral circular ssDNA genome ranges from 2.5 to 2.9-kilobases (kb). As they cover a wide range of regions in the world, they are divided into two major biogeographic clades named New World (NW) and Old World (OW). The viruses of the NW are native to America and those of the OW are native to Australia, Europe, Africa, and Asia. *Begomoviruses* are also sub-divided based on their genome organization into Bipartite (composed of two separate circular ssDNA molecules, referred to as DNA-A and DNA-B) and Monopartite (contain only a single circular ssDNA molecule, similar to the DNA-A component of the bipartite Begomovirus) [1,7]. Satellite molecules are generally defined as any nucleic acid or virus that is associated with helper viruses and for replication depends upon them. Association of satellite complexes is mostly the common feature for RNA viruses [11] but it was just up to 1997. For the first time, a monopartite virus, Tomato leaf curl virus (ToLCV) from the genus *Begomovirus* of family *Geminiviridae* (a DNA virus) was investigated in association with satellite molecule [12]. After these continuous investigations proved the association of Begomoviruses with 2 kinds of satellite complexes, known as alpha satellite and beta satellite. Afterward, a new satellite called delta satellite is also discovered in combination with several Begomoviruses [12-15].

Betasatellites are more diverse, until now more than 400 full-length beta satellite sequences are present in the database [9]. The genomic size of betasatellites is approximately 1350 nucleotides (nts), considered half the size of their associated helper Begomovirus [5, 8]. Betasatellites are ssDNA molecules and are not significantly homologous in sequence with their associated Begomovirus [3]. They contain a potential stem-loop structure, only in which they share sequence homology with their helper *Begomovirus* because of the presence of universal non-nucleotide sequence (TAATATTAC) in this stem-loop structure [8, 12]. This sequence is typically considered as Ori for the virion strand [15]. In addition, beta satellites have a region that is highly conserved between all betasatellites thus called satellites conserved region (SCR) [7]. The length of the SCR is about 100 cents. Betasatellites contain a complementary orientated single ORF (βC1 gene) that encodes a βC1 protein. This protein is a multifunctional protein as it performs various functions including suppression of gene silencing at both transcriptional and post-transcriptional level e.g. transcriptional gene silencing (TGS) and post-transcriptional gene silencing (PTGS), suppression the defense responses of other plants, and also act as pathogenicity determinant. Betasatellites also contain Adenine-rich (A-rich) region. This region possesses approximately 65% of A-content and their size ranges from 160-180 nights in length [16, 17].

This study is based on a bibliometric approach using statistical and mathematical measures, which provides the quantitative and qualitative overview of the previous research data published on betasatellites. This study aims to collect all the dispersed knowledge on betasatellites into a proper condense shape, that could be used by the plant virologists for some useful purposes such as finding strong collaborative linkages amongst international scientists. leading countries in terms of research, leading institutions, and prolific journals regarding the betasatellites research. To the best of our knowledge, there are no bibliometric reports published on betasatellites research. However, there are several studies conducted on animals/ human diseases only but not like this [20].

Methods

Study design

The nature of this study was bibliometric analysis in which the previously published literature regarding betasatellites was analyzed based on certain bibliometric indicators according to the method used by [21, 22]. The concerned data were retrieved from the database and stored in a computer, then analyzed manually as well as through the use of statistical procedures for obtaining useful information.

Data source

As the bibliometric analysis is based on the previous literature, the secondary data betasatellites were completely obtained from Google scholar and the bibliometric analysis was performed in July 2018 based on the data from the past 1997 to June 2018. Various search engines were searched like PubMed, Web of Science, and Scopus, which can also be used for performing such studies. The retrieval of data from Google scholar is very easy and freely available, thus it was the main focus for this study.

Search strategy

The search strategy was based on the bibliometric approach used by [22]. The standardized search strategy was used in which the keyword "betasatellites" was used as a search item in the Google Scholar database and all the publications in which the keyword "betasatellites" was used in their title, abstract and keyword field were downloaded. Betasatellites related data were collected from past 1997 up to June 2018. From that collected data the following information was collected: (i) total number of publications (ii) type of the publication (iii) year of the publication (iv) institute of the author (v) country of the author (vi) language of the publication (vii) international collaboration (partnership) (viii) journal of the publications (ix) citation received by each publication (x) impact factor (If) and *h*-index.

Data analysis

The collected data were analyzed by various approaches. The total number of publications, publication year, publication type, country and institute name, international collaboration, and journal names were identified manually from the data. Microsoft excel 2013 was used to get the top 10 ranked countries through the standard competition ranking (SCR) procedure (1-2-2-4 rule) and were arranged in descending order from 1-10. For the growth of publications year-wise and percentage of international collaboration, descriptive statistical tools were used. For detecting the quality and quantity of research output *h*-index and IF were used. As the *h*-index covers both the impact (number of citations) and quantitative aspect (number of publications) therefore, in bibliometric analysis it is used to represents the scientific productivity of an individual scientist, an organization, or a country. For obtaining IF for the journals, data from (http://www.bioxbio.com/if/) Journal Citation Reports (JCR) were used. The results obtained from the data were presented in the tabulated and graphic form [22, 17].

Results

Total number of documents related to beta satellite, their types, and language

A total of 213 publications were detected in Google scholar regarding betasatellites research from the past 1997 up to June 2018. These publications were of different types. These include original research articles (153; 71.83%), short communications (16; 7.51%), reports (17; 7.98%), annotated sequence records (8; 3.75%) and review, notes, editorial letters and others (19; 8.93%) shown in Table 1. These documents were published in 4 different languages, among which the English language was most common. 208 articles out of 213 (97.65%) were published in the English language. 2 documents (0.93%) were published in French. 2 documents (0.93%) were published in the Chinese language as well. Only 1 document (0.46%) was published in the Persian language (Table 2).

S. No	Publication type	Number articles	Percentage
1	Original	153	71.83 %
2	Short communications	16	7.51 %
3	Reports	17	7.98 %
4	Annotated sequence record	8	3.75 %
5	Review, notes, editorial letters, and others	19	8.93 %
	Total	**213**	

Table 1: Types of research articles published related to beta satellites (n =213).

S. No	Language used	Number (%) of Articles
1	English	208 (97.65%)
2	French	2 (0.93%)
3	Chinese	2 (0.93%)
4	Persian	1 (0.46%)

Table 2: Types of languages in which articles related to beta satellites research were published (n =213).

Growth of betasatellites related publications year-wise (n =213)

There were no publications regarding betasatellites research before 1997 when for the first time an article was published in Australia regarding Begomovirus satellite complexes in 1997. As this field of research was new and less understood there was a fewer number of articles published related to betasatellites until 2008. The number of publications was then increased during 2009-2010 and onward. Out of the total (213 documents), 199 (93.42%) were published from 2009-2018, in which the maximum number of documents were

published in 2014 (n=28). The data show a little decrease in documents publication from 2015 to 2107 as compared to the previous five years (2010-2014). As the data for the year 2018 was collected up to June, not for the whole year, thus considered incomplete with possibilities of further increasing. The growth of publications (number of publications) along with the time (year wise) is shown in the graph (Figure 1).

Top 10 countries and their research productivity collaboration with other countries.

A total (213) documents related to betasatellites research were published by more than 35 different countries. Out of these, the top 10 countries based on the number of publications (research productivity) were India, Pakistan, China, United States of America (USA), Japan, Oman, Iran, Saudi Arabia, United Kingdom (UK), France, Spain, Sri Lanka, and Australia respectively. United Kingdom, France, and Spain got combined 9th position and Sri Lanka and Australia on combined 10th position due to their equal number of publications on the under discussion topic. India published 83 (38.96%), Pakistan 66 (30.98%), China 26 (12.20%), USA 22 (10.32%), Japan 9 (4.22%), Oman 8 (3.75%), Iran 7 (3.28%), Saudi Arabia 6 (2.81%), UK, France and Spain published 5 (2.34%) by each of them and Sri Lanka and Australia both published 3 (1.40%) of documents.

Out of all these countries, Pakistan has been found on the top in terms of collaboration with other countries. Pakistan collaborated with 19 different countries and published 31 (14.55%) documents in collaboration with foreign scientists, followed by the USA by collaborating with 14 different countries and publishing 18 (8.45%) documents in collaboration with foreign scientists. India collaborated with 6 different countries and published 9 (4.22%) documents in combination with multinational scientists. They published all of their 5 (2.34%) documents in collaboration with 10 different countries. China was found at 3rd position based on published documents, but China showed no effective partnership with foreign scientists. China published only 3 (1.40%) documents in collaboration with multinational scientists. This bibliometric study determines that Pakistan, the USA, and India play a significant role in research about betasatellites (Table 3). For all the 213 publications the total number of citations was 3564 till July 2018 showing 16.73 citations per publication by average. The *h*-index for the extracted documents was calculated as 64. The top*h*-index was achieved by India (37), followed by Pakistan (31), and the USA (17) respectively (Table3).

Top 10 collaborative countries with Pakistan

Pakistan got the second position in terms of a total number of published documents regarding betasatellites research, however, Pakistani researchers topped in terms of published documents in collaboration with foreign scientists. The top 10 collaborative countries with Pakistan were the USA, Oman, Japan, UK, Saudi Arab, Spain, India, China, France, and Nepal respectively. United States of America topped the list by collaborating in 14 documents with Pakistan followed by Oman by publishing 7 documents in collaboration with Pakistan, Japan (6), UK (5), Saudi Arabia (4), Spain, and India (each 3). China, France, and Nepal collaborated with Pakistan by 2 documents for each of them as shown in Figure 2.

Top 10 most frequently cited articles

All the documents were analyzed to find out the top 10 most cited articles. The number of citations for all the documents was recorded by June 2018. The article which was recorded as the top-cited article of the list had received 315 citations followed by an article by receiving 202 citations, then 184, 177, 155, 119, 78, 74, 63, and 59 respectively. The top-cited article of the top 10 most frequently cited documents list was published by [13] in 2000. This article was published in the journal "*Proceedings of National Academy of Sciences (PNAS)* has an Impact factor of (7.06). The two authors S. Mansoor and R.W. Briddon were found involved in most of the frequently cited articles, thus considered more productive authors regarding the studied subject (Table 4).

Top 10 most frequently cited articles

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Top 10 most productive journals

All the documents were published in more than 50 different journals, out of these the top 10 most productive journals were identified based on the number of published documents globally. The journal "*Virus*

SCR	Countries	Publications (%)	*h*-index	Collaboration with foreign countries	No. (%) of publications with international authors
1	India	83 (38.96%)	37	6	9 (4.22%)
2	Pakistan	66 (30.98%)	31	19	31 (14.55%)
3	China	26 (12.20%)	16	5	3 (1.40%)
4	United states of America	22 (10.32%)	17	14	18 (8.45%)
5	Japan	9 (4.22%)	5	6	8 (3.75%)
6	Oman	8 (3.75%)	4	4	6 (2.81%)
7	Iran	7 (3.28%)	3	1	1 (0.46%)
8	Saudi Arabia	6 (2.81%)	2	4	5 (2.34%)
9	United Kingdom	5 (2.34%)	3	10	6 (2.81%)
9	France	5 (2.34%)	2	2	4 (1.87%)
9	Spain	5 (2.34%)	2	9	5 (2.34%)
10	Sri Lanka	3 (1.40%)	1	2	2 (0.93%)
10	Australia	3 (1.40%)	2	1	1 (0.46%)

Standard competition ranking (SCR).

Table 3: Top 10 most prolific countries based on number of publications regarding beta satellites research globally from 1997-June 2018 (n =213)

SCR	Title	Publication year	Title source	Citation count	Authors
1	A unique virus complex causes Ageratum yellow vein disease	2000	PNAS	315	[13]
2	Recommendations for the classification and nomenclature of the DNA-b satellites of *Begomoviruses*	2008	Virology	202	[15]
3	Evolution of *Gemini*-viruses and their satellites	2009	FEBS LETTERS	184	[11]
4	A novel subviral agent associated with a *Geminiviruses*: The first report of a DNA satellite	1997	Plant Biology	177	[12]
5	A modified viral satellite DNA that suppresses gene expression in plants	2004	The Plant Journal	155	[17]
6	Suppression of Methylation-Mediated Transcriptional Gene Silencing by bC1-SAHH Protein Interaction during *Geminivirus*-betasatellite Infection	2011	PLoS Pathogens	119	[12]
7	Suppressors of RNA Silencing Encoded by the Components of the Cotton Leaf Curl *Begomovirus*-betasatellite Complex	2011	MPMI	78	[16]
8	Maintenance of an Old World Betasatellites by a New World Helper *Begomovirus* and Possible Rapid Adaptation of the Betasatellites	2009	Journal of Virology	74	[9]
9	Differential interaction between cassava mosaic *Geminiviruses* and *Geminiviruses* satellites	210	Journal of General Virology	63	[4]
10	Roles and interactions of *Begomoviruses*, satellite DNAs associated with okra leaf curl disease in Mali, West Africa	2008	Journal of General Virology	59	[24]

Table 4: Top 10 most frequently cited articles regarding betasatellites research until 2018.

SCR	Journals	IF	No. % of publications
1	Virus Genes	1.542	26 (12.20%)
2	Archives of Virology	2.610	24 (11.26%)
3	Virus Research	2.484	12 (5.63%)
4	Virology Journal	2.465	10 (4.69%)
5	Plant Disease	2.941	9 (4.22%)
6	Viruses	3.761	8 (3.75%)
7	Journal of Plant Pathology	1.267	7 (3.28%)
8	Journal of Phytopathology	0.823	6 (2.81%)
9	Canadian Journal of Plant Pathology	0.898	5 (2.34%)
9	Plant Pathology	2.303	5 (234%)
10	Journal of General Plant Pathology	0.741	4 (1.87%)
10	Journal of Virology	4.69	4 (1.87%)

Standard competition ranking (SCR)

Table 5: Top 10 most published journals regarding beta satellites research.

SCR	Institutions, Countries	No. of Publications (%)
1	National Institute for Biotechnology and Genetic Engineering Faisalabad, Pakistan (NIBGE), Pakistan.	56 (26.29%)
2	Indian Agricultural Research Institute, New Delhi, India.	20 (9.38%)
3	Zhejiang University, Hangzhou, China.	19 (8.92%)
4	Mody Institute of Technology and Science, India.	12 (5.63%)
5	University of Punjab, Pakistan.	10 (4.69%)
6	National Agri-Food Biotechnology Institute, Mohali 160071, Punjab, India.	9 (4.22%)
7	Sultan Qaboos University, Alkhod, 123 Muscat, Oman	8 (3.75%)
8	Jawaharlal Nehru University, New Delhi 110 067, India	7 (3.28%)
9	University of Arizona, USA	6 (2.81%)
10 (a)	Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan.	5 (2.34%)
10 (b)	Shiraz University, Shiraz, Iran	5 (234%)

Standard competition ranking (SCR)

Table 6: Top 10 most prolific institutions globally regarding beta satellites research.

Genes" was ranked 1st by publishing most documents (26, 12.20%) related to the topic under study. Followed by *Archives of Virology* (24, 11.26%) then *Virus Research* (12, 5.63%), *Virology Journal* (10, 4.69%), *Plant Disease* (9, 4.22%), *Viruses* (8, 3.75%), *Journal of Plant Pathology* (7, 3.28%), *Journal of Phytopathology* (6, 2.81%), *Canadian Journal of Plant Pathology* (5, 2.34%), *Plant Pathology* (5, 234%), *Journal of General Plant Pathology* (4, 1.87%) and *Journal of Virology* (4, 1.87%) respectively. The IF for all the journals in the list was also identified. All the data are shown in Table 5.

Top 10 most prolific institutions

The top 10 most productive institutions were ranked based on the most number of documents published regarding the under discussion topic worldwide. After the analysis of all documents for the most productive institute, National Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad, Pakistan got 1st position by publishing 56 (26.29%) documents regarding the under discussion subject. Indian Agricultural Research Institute, New Delhi, India published 20 (9.38%) articles and ranked as 2nd in the list. Zhejiang University, Hangzhou, China, and Mody Institute of Technology and Science, India published 19 (8.92%) and 12 (5.63%) articles respectively. All the data are shown in Table 6.

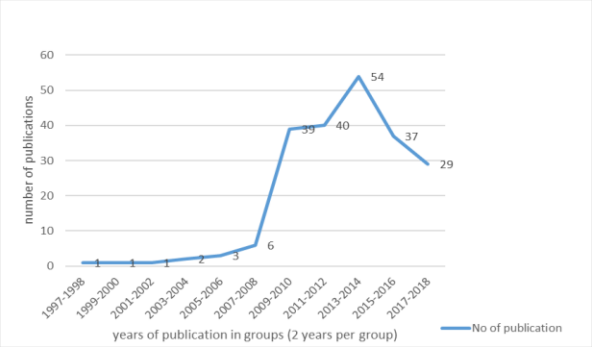

Figure 1: Several published documents regarding beta satellites trends in Google Scholar from 1997 to June 2018 (n =213).

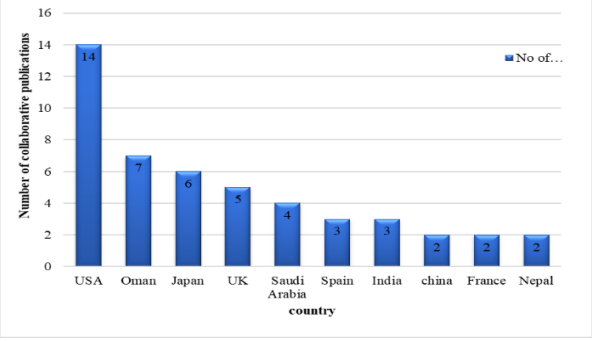

Figure 2: Top 10 international collaborated countries with Pakistan in research regarding beta satellites.

Discussion

Betasatellites are ssDNA molecules that play a very essential role in the production of symptomatic infection in combination with begomoviruses. Due to the association of betasatellites with these economically important viruses, betasatellites have become an interesting topic to study globally. In the current study, a bibliometric approach has been used for the analysis of beta satellite-related research output at the global level. This approach of bibliometrics has been already used for various infectious diseases like tuberculosis (TB), Acquired immune deficiency syndrome (AIDS), Ebola virus disease (EVD), and dengue disease. To the best of our knowledge, this is the first attempt to use the bibliometric analysis for betasatellites research output globally. As this is the first attempt of its nature, so there are no previous results for direct comparison of our results [22, 23].

In the current study, there is fluctuation in the growth of publications. From 1997 to 2014 there is a solid increase in the publications but then, the number of publications decreases. The results from this study show that India, Pakistan, the USA, and China play important role in research regarding betasatellites. The possible validation for these results is, begomoviruses are the economically most important destructor for agriculture in these countries. India topped the top 10 countries list in terms of a maximum number of publications regarding the topic under discussion. This maximum contribution of India to the studied subject might be due to its wide involvement in the field of agriculture and several epidemics of begomoviruses on agriculture in India. This analysis also shows that a maximum number of publications was in the form of original research articles and documents that were commonly published in the English language. Our results are in pattern with previous bibliometric analysis in other sectors [21, 24]. Pakistani scientists topped the top 10 list in terms of collaboration with foreign scientists and published the maximum number of documents in collaboration with foreigners among all participated countries in the studied subject. The possible reason for these results may be, Pakistan has faced various epidemics of begomovirus diseases and Pakistan wants to get rid of these diseases. So, Pakistan shares its efforts with foreigners for better control in the country. In addition, the USA was the most important collaborator with Pakistan, this might be due to their developed status and also spending of more money on research as well as helping the developing countries worldwide. Although China ranked at number 3rd in terms of a maximum number of publications in the list, China shows no impressive collaboration with foreigners. It is suggested

that China's partnership with foreigners especially with their neighboring countries will be helpful for the region.

Among all the institutions, NIBGE got the top position in terms of documents publication regarding the studied subject globally. The possible validation for these results is, the most productive scientists Dr. Shahid Mansoor and Dr. Robert William Briddon. These scientists are working at NIBGE in the area of begomoviruses/ CLCuD research. The current study also shows that the journal "Virus Genes" was the most prolific journal in terms of a maximum number of documents published on the studied subject. The IF of this journal is 1.542.

The current attempt is the first Bibliometric approach globally regarding betasatellites research output, intending to evaluate quantitative as well as qualitative research output regarding the studied subject worldwide. But still, this study has some limitations. As the data for this analysis was only extracted from the Google Scholar database, although this database is very large, the limitation is there must be data other than collected present in other databases. So the need for other databases is suggested for the extraction of data on the studied subject. In the present study, the research output regarding betasatellites was analyzed. In conclusion, a total of 213 extracted research documents provide qualitative and quantitative insight on the studied subject. The findings from this analysis demonstrate the solid increase in the number of publications year-wise. India, Pakistan, the USA, and China play a significant role regarding betasatellites research. This analysis also recognizes the significant collaborative role of Pakistan and the USA with other countries. International collaboration could increase the research interest related to betasatellites at the global level. In addition, this analysis is a helpful guideline for the scientists of those countries where begomoviruses are still endemic, to promote useful research projects for the investigation and control of begomoviruses. The productive journals recognized by this investigation are a helpful guideline for the researchers/ scientists for data extraction regarding betasatellites.

Competing Interests

The authors declare no conflicts of interest.

Author Contributions

Syed Ishfaq Ahmad conducted the study and performed the corresponding data analysis, prepared figures, and drafted the manuscript. Fazal Akbar and Nisar Ahmad supervised the study, performed the data analysis, prepared the figure, and contributed to writing. Zeeshan Nasar, Naeem Akhtar is responsible for writing, review & editing the manuscript. Zaib Ullah and Syed Ishfaq Ahmad were responsible for reviewing, and editing the final version of the manuscript. All authors approved the final version of the manuscript.

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