

Original Article



The International Natural Product Sciences Taskforce (INPST) and the power of Twitter networking exemplified through #INPST hashtag analysis

Rajeev K. Singla^{a,b}, Ronita De^d, Thomas Efferth^e, Bruno Mezzetti^f, Md. Sahab Uddin^{g,h}, Sanusiⁱ, Fidele Ntie-Kang^j, Dongdong Wang^k, Fabien Schultz^{l,m}, Kiran R. Kharatⁿ, Hari Prasad Devkota^{o,p}, Maurizio Battino^{q,r}, Daniel Sur^s, Ronan Lordan^t, Sourav S Patnaik^u, Christos Tsagkaris^v, Chandragiri Siva Sai^w, Surya Kant Tripathi^x, Mihnea-Alexandru Găman^{y,z}, Mosa E.O. Ahmed^{aa}, Elena González-Burgos^{ab}, Smith B. Babiaka^j, Shrvan Kumar Paswan^{ac}, Joy Ifunanya Odimegwu^{ad}, Faizan Akram^{ae}, Jesus Simal-Gandara^{af}, Mágali S. Urquiza^{ag}, Aleksei Tikhonov^{ah}, Himel Mondal^{ai}, Shailja Singla^c, Sara Di Lonardo^{aj}, Eoghan J Mulholland^{ak,al}, Merisa Cenanic^{am}, Abdulkadir Yusuf Maigoro^{an}, Francesca Giampieri^{ao,ap}, Soojin Lee^{an}, Nikolay T. Tzvetkov^{aq}, Anna Maria Louka^{ar}, Pritt Verma^{as}, Hitesh Chopra^{at}, Scarlett Perez Olea^{au}, Johra Khan^{av}, José M. Alvarez Suarez^{aw}, Xiaonan Zheng^{ax}, Michał Tomczyk^{ay}, Manoj Kumar Sabnani^{az,ba}, Christian Delfino Villanueva Medina^{au}, Garba M. Khalid^{bb}, Hemanth Kumar Boyina^{bc}, Milen I. Georgiev^{bd}, Claudiu T. Supuran^{be}, Eduardo Sobarzo-Sánchez^{bf,bg}, Tai-Ping Fan^{bh}, Valeria Pittala^{bi}, Antoni Sureda^{bj}, Nady Braidy^{bk}, Gian Luigi Russo^{bl}, Rosa Anna Vacca^{bm}, Maciej Banach^{bn,bo}, Gérard Lizard^{bp}, Amira Zarrouk^{bq}, Sonia Hammami^{bq}, Ilkay Erdogan Orhan^{br}, Bharat B. Aggarwal^{bs}, George Perry^{bt}, Mark JS Miller^{bu}, Michael Heinrich^{bv}, Anupam Bishayee^{bw}, Anake Kijjoa^{bx}, Nicolas Arkells^{by}, David Bredt^{bz}, Michael Wink^{ca}, Bernd I. Fiebich^{cb}, Gangarapu Kiran^{cc}, Andy Wai Kan Yeung^{cd}, Girish Kumar Gupta^{ce}, Antonello Santini^{cf}, Massimo Lucarini^{cg}, Alessandra Durazzo^{cg}, Amr El-Demerdash^{ch,ci}, Alben T. Dinkova-Kostova^{cj}, Alejandro Cifuentes^{ck}, Eliana B. Souto^{cl}, Muhammad Asim Masoom Zubair^{cm}, Pravin Badhe^{cn,co,cp}, Javier Echeverría^{cq}, Jarosław Olav Horbańczuk^{cr}, Olaf K. Horbanczuk^{cs}, Helen Sheridan^{ct}, Sadeeq Muhammad Sheshe^{cu}, Anna Maria Witkowska^{cv}, Ibrahim M. Abu-Reidah^{cw}, Muhammad Riaz^{cx}, Hammad Ullah^{cy}, Akolade R. Oladipupo^{cz,da}, Víctor Lopez^{db}, Neeraj Kumar Sethiya^{dc}, Bhupal Govinda Shrestha^{dd}, Palaniyandi Ravanan^{de}, Subash Chandra Gupta^{df,dg}, Qushmua E. Alzahrani^{dh}, Preethidan Dama Sreedhar^{di}, Jianbo Xiao^{dj}, Mohammad Amin Moosavi^{dk}, Parasuraman Aiya Subramani^{dl}, Amit Kumar Singh^{dm}, Ananda Kumar Chettupalli^{dn}, Jayanta Kumar Patra^{do}, Gopal Singh^{dp}, Tomasz M. Karpiński^{dq}, Fuad Al-Rimawi^{dr}, Rambod Abiri^{ds}, Atallah F. Ahmed^{dt,du}, Davide Barreca^{dv}, Sharad Vats^{dw}, Said Amrani^{dx}, Carmela Fimognari^{dy}, Andrei Mocan^{dz}, Lucian Hritcu^{ea}, Prabhakar Semwal^{eb}, Md. Shiblur Rahaman^{ec}, Mila Emerald^{ed}

Abbreviations: COVID-19, Coronavirus Disease 2019; DHPSP, Digital Health and Patient Safety Platform; FDA, Food and Drug Administration; HIV/AIDS, Human Immunodeficiency Virus/ Acquired ImmunoDeficiency Syndrome; INPST, International Natural Product Sciences Taskforce; ICNPU-2019, The 4th International Conference on Natural Products Utilization from Plants to Pharmacy Shelf, 2019; LDCs, Least Developed Countries; MDPI, Multidisciplinary Digital Publishing Institute; ROS, Reactive Oxygen Species; SARS-CoV-2, Severe Acute Respiratory Syndrome Coronavirus 2; STEM, Science Technology Engineering and Mathematics.

* Corresponding authors.

E-mail addresses: Atanas.Atanasov@dhps.lbg.ac.at (A.G. Atanasov), bairong.shen@scu.edu.cn (B. Shen).

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Akinleye Stephen Akinrinde^{ee}, Abhilasha Singh^{ef}, Ashima Joshi^{eg}, Tanuj Joshi^{eh}, Shafaat Yar Khan^{ei}, Gareeballah Osman Adam Balla^{ej}, Aiping Lu^{ek}, Sandeep Ramchandra Pai^{el}, Imen Ghzaïel^{em,en}, Niyazi Acar^{eo}, Nour Eddine Es-Safi^{ep}, Gokhan Zengin^{eq}, Azazahemad A. Kureshi^{er}, Arvind Kumar Sharma^{es}, Bikash Baral^{et}, Neeraj Rani^{eu}, Philippe Jeandet^{ev}, Monica Gulati^{ew}, Bhupinder Kapoor^{ew}, Yugal Kishore Mohanta^{ex}, Zahra Emam-Djomeh^{ey}, Raphael Onuku^{ez}, Jennifer R. Depew^{fa}, Omar M. Atrooz^{fb}, Bey Hing Goh^{fc,fd}, Jose Carlos Andrade^{fe}, Bikramjit Konwar^{ff}, VJ Shine^{fg}, João Miguel Lousa Dias Ferreira^{fh}, Jamil Ahmad^{fi}, Vivek K. Chaturvedi^{fj}, Krystyna Skalicka-Woźniak^{fk}, Rohit Sharma^{fl}, Rupesh K. Gautam^{fm}, Sebastian Granica^{fn}, Salvatore Parisi^{fo}, Rishabh Kumar^{fp}, Atanas G. Atanasov^{fq,fr,fs,*}, Bairong Shen^{a,*}

^a Institutes for Systems Genetics, Frontiers Science Center for Disease-Related Molecular Network, West China Hospital, Sichuan University, Xinchuan Road 2222, Chengdu, Sichuan, China

^b School of Pharmaceutical Sciences, Lovely Professional University, Phagwara, Punjab-144411, India

^c iGlobal Research and Publishing Foundation, New Delhi, India

^d ICMR-National Institute of Cholera and Enteric Diseases, P-33, CIT Rd, Subhas Sarobar Park, Phool Bagan, Belegata, Kolkata, West Bengal 700010, India

^e Department of Pharmaceutical Biology, Institute of Pharmaceutical and Biomedical Sciences, Johannes Gutenberg University, Mainz, Germany

^f Department of Agriculture, Food and Environmental Sciences (D3A) Università Politecnica Delle Marche Ancona, IT, Italy

^g Department of Pharmacy, Southeast University, Dhaka, Bangladesh

^h Pharmakon Neuroscience Research Network, Dhaka, Bangladesh

ⁱ Research Center for Population - Indonesian Institute of Sciences, Indonesia

^j Department of Chemistry, Faculty of Science, University of Buea, Buea P.O. Box 63, Cameroon

^k Centre for Metabolism, Obesity, and Diabetes Research, Department of Medicine, McMaster University, HSC 4N71, 1280 Main Street West, Hamilton, ON L8S 4K1, Canada

^l Technical University of Berlin, Institute of Biotechnology, Faculty III - Process Sciences, Gustav-Meyer-Allee 25, Berlin 13355, Germany

^m Neubrandenburg University of Applied Sciences, Department of Agriculture and Food Sciences, Brodaer Str. 2, Neubrandenburg 17033, Germany

ⁿ KETs, V.G.Vaze College, Mulund, Mumbai 400081, India

^o Graduate School of Pharmaceutical Sciences, Kumamoto University, 5-10e-honmachi, Kumamoto 862-0973, Japan

^p Program for Leading Graduate Schools, HIGO Program, Kumamoto University, Japan

^q Department of Clinical Sciences, Faculty of Medicine, Polytechnic University of Marche, Ancona 60131, Italy

^r International Research Center for Food Nutrition and Safety, Jiangsu University, Zhenjiang 212013, China

^s Department of Medical Oncology, "Iuliu Hatieganu" University of Medicine and Pharmacy Cluj-Napoca, Romania

^t Institute for Translational Medicine and Therapeutics, Perelman School of Medicine, University of Pennsylvania, PA, United States

^u Department of Bioengineering, University of Texas at Dallas, Richardson, TX, United States

^v University of Crete, Faculty of Medicine, Heraklion, Greece

^w Amity Institute of Pharmacy, Amity University, Uttar Pradesh, Lucknow Campus, Gomati Nagar, Lucknow, Uttar Pradesh 226010, India

^x Cancer Drug Resistance Laboratory, National Institute of Technology Rourkela, Odisha-769008, India

^y "Carol Davila" University of Medicine and Pharmacy, 8 Eroii Sanitari Boulevard, Bucharest, Romania

^z Center of Hematology and Bone Marrow Transplantation, Fundeni Clinical Institute, 258 Fundeni Road, Bucharest, Romania

^{aa} Department of Pharmacognosy, Faculty of Pharmacy, Al Neelain University, Khartoum, Sudan

^{ab} Department of Pharmacology, Pharmacognosy and Botany, University Complutense of Madrid, Spain

^{ac} Department of Pharmacology, AIIMS, New Delhi, India

^{ad} Department of Pharmacognosy, Faculty of Pharmacy, University of Lagos, Nigeria

^{ae} Bahawalpur College of Pharmacy (BCP), Bahawalpur Medical and Dental College (BMDC), Bahawalpur, Pakistan

^{af} Universidade de Vigo, Nutrition and Bromatology Group, Department of Analytical Chemistry and Food Science, Faculty of Science, Ourense E-32004, Spain

^{ag} Universidad de Buenos Aires (UBA), Argentina

^{ah} Translational Research Laboratory in Immunotherapy, Gustave Roussy, Villejuif, France

^{ai} Department of Physiology, All India Institute of Medical Sciences, Deoghar, Jharkhand, India

^{aj} Research Institute on Terrestrial Ecosystems-Italian National Research Council (IRET-CNR), Via Madonna del Piano 10, Sesto Fiorentino Fi 50019, Italy

^{ak} Gastrointestinal Stem Cell Biology Laboratory, Wellcome Trust Centre for Human Genetics, University of Oxford, Oxford, United Kingdom

^{al} Somerville College, University of Oxford, Oxford, United Kingdom

^{am} Independent Researcher, Sarajevo, Bosnia and Herzegovina

^{an} Department of Bioscience and Biotechnology, Chungnam National University, Republic of Korea

^{ao} Department of Biochemistry, Faculty of Sciences, King Abdulaziz University, Jeddah, Saudi Arabia

^{ap} Research Group on Food, Nutritional Biochemistry and Health, Universidad Europea del Atlántico, Santander, Spain

^{aq} Department of Biochemical Pharmacology and Drug Design, Institute of Molecular Biology "Roumen Tsanev", Bulgarian Academy of Sciences, Bulgaria

^{ar} University of Thessaly, Greece

^{as} Department of Pharmacology, CSIR-NBRI, Lucknow, India

^{at} Chitkara College of Pharmacy, Chitkara University, Punjab, India

^{au} MOL2NET 2021, 7th edition, Mexico

^{av} Department of Medical Laboratory Sciences, College of Applied Medical Sciences, Majmaah University, Al Majmaah 11952, Saudi Arabia

^{aw} Departamento de Ingeniería en Alimentos, Colegio de Ciencias e Ingenierías, Universidad San Francisco de Quito, Quito, Ecuador

^{ax} Department of Urology, West China Hospital, Sichuan University, Chengdu, Sichuan, China

^{ay} Department of Pharmacognosy, Faculty of Pharmacy with the Division of Laboratory Medicine, Medical University of Białystok, ul. Mickiewicza 2a, Białystok 15-230, Poland

^{az} The University of Texas at Arlington, United States

^{ba} Alloy Therapeutics, United States

^{bb} Pharmaceutical Engineering Group, School of Pharmacy, Queen's University, Belfast BT9, United Kingdom

^{bc} School of Pharmacy, Department of Pharmacology, Anurag University, Venkatapur, Medchal, Hyderabad, Telangana 500088, India

^{bd} Laboratory of Metabolomics, Stephan Angeloff Institute of Microbiology, Bulgarian Academy of Sciences, 139 Ruski Blvd., Plovdiv 4000, Bulgaria

^{be} University of Florence, Neurofarba Dept., Italy

^{bf} Instituto de Investigación y Postgrado, Facultad de Ciencias de la Salud, Universidad Central de Chile, Santiago 8330507, Chile

^{bg} Department of Organic Chemistry, Faculty of Pharmacy, University of Santiago de Compostela, Santiago de Compostela 15782, Spain

^{bh} Key Laboratory of Resource Biology and Biotechnology in Western China, Ministry of Education, Faculty of Life Science and Medicine, Northwest University, Xi'an, China

- ^{bi} Department of Drug and Health Sciences, University of Catania, Catania, Italy
- ^{bj} Research Group in Community Nutrition and Oxidative Stress, University of the Balearic Islands-IUNICS, Health Research Institute of Balearic Islands (IdISBa), and CIBEROBN (Physiopathology of Obesity and Nutrition), Palma, Balearic Islands E-07122, Spain
- ^{bk} Centre for Healthy Brain Ageing (CHEBA), School of Psychiatry, University of New South Wales, Sydney, Australia
- ^{bl} National Research Council, Institute of Food Sciences, Avellino 83100, Italy
- ^{bm} Institute of Biomembranes, Bioenergetics and Molecular Biotechnologies, National Council of Research, Bari 70126, Italy
- ^{bn} Department of Preventive Cardiology and Lipidology, Medical University of Lodz (MUL), Lodz, Poland
- ^{bo} Cardiovascular Research Centre, University of Zielona Gora, Zielona Gora, Poland
- ^{bp} Université de Bourgogne / Inserm, Laboratoire Bio-PeroxiL, Faculté des Sciences Gabriel, 6 Boulevard Gabriel, Dijon 21000 France
- ^{bq} University of Monastir (Tunisia), Faculty of Medicine, LR-NAFS 'Nutrition - Functional Food & Vascular Health', Tunisia
- ^{br} Department of Pharmacognosy, Faculty of Pharmacy, Gazi University, Ankara 06330, Türkiye
- ^{bs} Inflammation Research Center, San Diego, California, United States
- ^{bt} Department of Neuroscience, Developmental, and Regenerative Biology, University of Texas, United States
- ^{bu} Kaiviti Consulting, LLC, United States
- ^{bv} UCL School of Pharmacy, London, United Kingdom
- ^{bw} College of Osteopathic Medicine, Lake Erie College of Osteopathic Medicine, Bradenton, FL 34211, United States
- ^{bx} Instituto de Ciências Biomédicas Abel Salazar e CIIMAR, Universidade do Porto, Portugal
- ^{by} International Natural Product Sciences Taskforce (INSPT), United States
- ^{bz} Independent Researcher, United States
- ^{ca} Heidelberg University, Institute of Pharmacy and Molecular Biotechnology (IPMB), Heidelberg 69120, Germany
- ^{cb} Neurochemistry and Neuroimmunology Research Group, Department of Psychiatry and Psychotherapy, Medical Center – University of Freiburg, Faculty of Medicine, University of Freiburg, Freiburg, Germany
- ^{cc} School of Pharmacy, Anurag University, India
- ^{cd} Oral and Maxillofacial Radiology, Applied Oral Sciences and Community Dental Care, Faculty of Dentistry, University of Hong Kong, Hong Kong, China
- ^{ce} Department of Pharmaceutical Chemistry, Sri Sai College of Pharmacy, Badhani, Pathankot, Punjab, India
- ^{cf} University of Napoli Federico II, Department of Pharmacy. Via D Montesano 49, Napoli 80131, Italy
- ^{cg} CREA—Research Centre for Food and Nutrition, Via Ardeatina 546 00178 Rome, Italy
- ^{ch} Metabolic Biology & Biological Chemistry Department, John Innes Centre, Norwich Research Park, Norwich NR4 7UH, United Kingdom
- ^{ci} Organic Chemistry Division, Chemistry Department, Faculty of Science, Mansoura University, Mansoura 35516, Egypt
- ^{cj} Division of Cellular Medicine, University of Dundee School of Medicine, United Kingdom
- ^{ck} Foodomics Lab, CIAL, CSIC, Madrid, Spain
- ^{cl} Department of Pharmaceutical Technology, Faculty of Pharmacy, University of Porto, Rua de Jorge Viterbo Ferreira, 228, Porto 4050-313, Portugal
- ^{cm} Department of Pharmaceutics, Faculty of Pharmacy, The Islamia University of Bahawalpur, Pakistan
- ^{cn} Swalife Foundation, India
- ^{co} Swalife Biotech Ltd, Ireland
- ^{cp} Sinhgad College of Pharmacy, Vadgaon (BK) Pune Maharashtra India
- ^{cq} Departamento de Ciencias del Ambiente, Facultad de Química y Biología, Universidad de Santiago de Chile, Chile
- ^{cr} Institute of Genetics and Animal Biotechnology of the Polish Academy of Sciences, Jastrzębiec 05-552, Poland
- ^{cs} Department of Technique and Food Product Development, Warsaw University of Life Sciences (WULS-SGGW) 159c Nowoursynowska, Warsaw 02-776, Poland
- ^{ct} The NatPro Centre. Trinity College Dublin. Dublin 2, Ireland
- ^{cu} Kano University of Science & Technology Wudil, Kano, Nigeria
- ^{cv} Medical University of Białystok, Department of Food Biotechnology, Poland
- ^{cw} School of Science and the Environment, Grenfell Campus, Memorial University of Newfoundland, Corner Brook A2H 5G4, Canada
- ^{cx} Department of Pharmacy, Shaheed Benazir Bhutto University, Sheringal 18050, Pakistan
- ^{cy} Department of Pharmacy, University of Naples Federico II, Naples 80131, Italy
- ^{cz} Department of Pharmaceutical Chemistry, Faculty of Pharmacy, University of Lagos, Nigeria
- ^{da} Department of Chemistry, Nelson Mandela University, Port Elizabeth, South Africa
- ^{db} Department of Pharmacy, Universidad San Jorge, Villanueva de Gállego (Zaragoza), Spain
- ^{dc} Faculty of Pharmacy, DIT University, Dehradun, India
- ^{dd} Dept of Biotechnology, Kathmandu University, Nepal
- ^{de} Department of Microbiology, School of Life Sciences, Central University of Tamil Nadu, Thiruvavur, India
- ^{df} Department of Biochemistry, Institute of Science, Banaras Hindu University, Varanasi, India
- ^{dg} Department of Biochemistry, All India Institute of Medical Sciences, Guwahati, Assam, India
- ^{dh} Department of Pharmacy/Nursing Medicine Health and Environment, University of the Region of Joinville (UNIVILLE) Brazil, Sana Catarina, Joinville, Brazil
- ^{di} Hermian Foundation for Neuro Research & Innovation, Kannur, India
- ^{dj} University of Vigo, Vigo, Spain
- ^{dk} Molecular Medicine Department, Institute of Medical Biotechnology, National Institute of Genetics Engineering and Biotechnology, Tehran P.O. Box: 14965/161, Iran
- ^{dl} Independent Researcher, Vels Institute of Science, Technology and Advanced Studies (VISTAS), Chennai, India - 600048. formerly, Pallavaram, Chennai 600117, India
- ^{dm} Department of Biochemistry, University of Allahabad, Prayagraj 211002 India
- ^{dn} Center for Nanomedicine, School of Pharmacy, Anurag University, Hyderabad 500088, India
- ^{do} Research Institute of Integrative Life Sciences, Dongguk University-Seoul, Goyangsi 10326, Republic of Korea
- ^{dp} Department of Plant Functional Metabolomics, Institute of Bioorganic Chemistry, Polish Academy of Sciences, Poznan, Poland
- ^{dq} Chair and Department of Medical Microbiology, Poznań University of Medical Sciences, Wieniawskiego 3, Poznań 61-712, Poland
- ^{dr} Al-Quds University, Palestine
- ^{ds} Department of Forestry Science and Biodiversity, Faculty of Forestry and Environment, Universiti Putra Malaysia, UPM Serdang, Selangor 43400, Malaysia
- ^{dt} Department of Pharmacognosy, College of Pharmacy, King Saud University, Riyadh 11451, Saudi Arabia
- ^{du} Department of Pharmacognosy, Faculty of Pharmacy, Mansoura University, Mansoura 35516, Egypt
- ^{dv} Department of Chemical, Biological, Pharmaceutical and Environmental Sciences, Università degli Studi di Messina, Messina, Italy
- ^{dw} Department of Bioscience and Biotechnology, Banasthali Vidyapith, Rajasthan 304022, India
- ^{dx} Laboratoire de Biologie et de Physiologie des Organismes, Faculté des Sciences Biologiques, USTHB, Bab Ezzouar, Alger, Algeria
- ^{dy} Department for Life Quality Studies, University of Bologna, Italy
- ^{dz} Department of Pharmaceutical Botany, Iuliu Hațieganu University of Medicine and Pharmacy, Cluj-Napoca, Romania
- ^{ea} Department of Biology, Alexandru Ioan Cuza University of Iasi, Bd. Carol I, No. 11, Iasi 700506, Romania
- ^{eb} Department of Life Sciences, Graphic Era Deemed to be University, Dehradun, Uttarakhand 248002, India
- ^{ec} Department of Environmental and Preventive Medicine, Jichi Medical University School of Medicine, 3311-1 Yakushiji, Shimotsuke, Tochigi 329-0498, Japan
- ^{ed} PHYTOCEUTICALS International™ & NOVOTEK Global Solutions™, Canada
- ^{ee} Department of Veterinary Physiology and Biochemistry, Faculty of Veterinary Medicine, University of Ibadan, Ibadan, Nigeria
- ^{ef} MGH[Harvard Medical School], Boston, MA, United States
- ^{eg} Sardar Bhagwan Singh University, Balawala, Dehradun, India

- ^{eh} Department of Pharmaceutical Sciences, Bhimtal, Kumaun University (Nainital), India
- ^{ei} Research Lab III, Hematology & Vascular Biology, Department of Zoology, University of Sargodha, Sargodha, Pakistan
- ^{ej} Department of Pharmacology, College of Veterinary Medicine, Sudan University of Science and Technology, Hilat Kuku, Khartoum North P.O. Box No. 204, Sudan
- ^{ek} School of Chinese Medicine, Hong Kong Baptist University, HongKong, China
- ^{el} Department of Botany, Rayat Shikshan Sanstha's, Dada Patil Mahavidyalaya, Karjat, Maharashtra, India
- ^{em} Université de Bourgogne, Inserm, Laboratoire Bio - PeroxIL, Faculté des Sciences Gabriel, 6 Boulevard Gabriel, Dijon 21000 France
- ^{en} University Tunis El Manar, Tunis, Tunisia
- ^{eo} INRAe, rue Sully, Dijon 21000, France
- ^{ep} Mohammed V University in Rabat, LPCMIO, Materials Science Center (MSC), Ecole Normale Supérieure, Rabat, Morocco
- ^{eq} Department of Biology, Science Faculty, Selcuk University, Konya, Turkey
- ^{er} Department of Chemistry, Sardar Vallabhbhai National Institute of Technology, Surat, India
- ^{es} Center of Biotechnology, Anna University, Chennai, India
- ^{et} Institute of Biological Resources, Nepal
- ^{eu} Department of Pharmaceutical Sciences, Chaudhary Bansilal University, Bhiwani, Haryana, India
- ^{ev} University of Reims, Research Unit Induced Resistance and Plant Bioprotection, USC INRAe 1488, Reims, France
- ^{ew} School of Pharmaceutical Sciences, Lovely Professional University, Jalandhar-Delhi G.T. Road (NH 1) Phagwara, Punjab 144411 India
- ^{ex} Department of Applied Biology, School of Biological Sciences, University of Science and Technology Meghalaya (USTM), Techno City, Kling Road, Baridua, Ri-Bhoi, Meghalaya 793101, India
- ^{ey} University of Tehran, Iran
- ^{ez} Department of Pharmaceutical and Medicinal Chemistry, Faculty of Pharmaceutical Sciences, University of Nigeria, Nigeria
- ^{fa} Independent Researcher, United States
- ^{fb} Department of Biological Sciences, Mutah University, Jordan
- ^{fc} College of Pharmaceutical Sciences, Zhejiang University, Hangzhou, China
- ^{fd} Biofunctional Molecule Exploratory (BMEX) Research Group, School of Pharmacy, Monash University Malaysia, Subang Jaya, Malaysia
- ^{fe} TOXRUN – Toxicology Research Unit, University Institute of Health Sciences, CESPU, Gandra, Portugal
- ^{ff} Independent, Guwahati, Assam, India
- ^{fg} Cancer Research Program, Rajiv Gandhi Centre for Biotechnology (RGCB), Thiruvananthapuram, Kerala 695014, India
- ^{fh} Faculdade de Medicina, Universidade do Porto, Alameda Prof. Hernâni Monteiro, Porto 4200-319, Portugal
- ^{fi} Department of Human Nutrition, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan
- ^{fj} Department of Gastroenterology, Institute of Medical Sciences, Banaras Hindu University, Varanasi 221005, India
- ^{fk} Department of Natural Products Chemistry, Medical University of Lublin, Poland
- ^{fl} Department of Rasa Shastra and Bhaishajya Kalpana, Faculty of Ayurveda, Institute of Medical Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh 221005, India
- ^{fm} Department of Pharmacology, Indore Institute of Pharmacy, IIST Campus, Rau-Indore-453331, India
- ^{fn} Microbiota Lab, Department of Pharmacognosy and Molecular Basis of Phytotherapy, Medical University of Warsaw, Poland
- ^{fo} Lourdes Matha Institute of Hotel Management and Catering Technology, Kerala State, India
- ^{fp} School of Medical and Allied Sciences, K.R. Mangalam University, Sohna Road, Gurugram, Haryana 122103, India
- ^{fq} Ludwig Boltzmann Institute for Digital Health and Patient Safety, Medical University of Vienna, Spitalgasse 23, Vienna 1090, Austria
- ^{fr} Department of Pharmaceutical Sciences, University of Vienna, Althanstraße 14, Vienna 1090, Austria
- ^{fs} Institute of Genetics and Animal Biotechnology of the Polish Academy of Sciences, Jastrzebiec, Magdalenka 05-552, Poland

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ABSTRACT

Background: The development of digital technologies and the evolution of open innovation approaches have enabled the creation of diverse virtual organizations and enterprises coordinating their activities primarily online. The open innovation platform titled “International Natural Product Sciences Taskforce” (INPST) was established in 2018, to bring together in collaborative environment individuals and organizations interested in natural product scientific research, and to empower their interactions by using digital communication tools.

Methods: In this work, we present a general overview of INPST activities and showcase the specific use of Twitter as a powerful networking tool that was used to host a one-week “2021 INPST Twitter Networking Event” (spanning from 31st May 2021 to 6th June 2021) based on the application of the Twitter hashtag #INPST.

Results and Conclusion: The use of this hashtag during the networking event period was analyzed with Symplur Signals (<https://www.symplur.com/>), revealing a total of 6,036 tweets, shared by 686 users, which generated a total of 65,004,773 impressions (views of the respective tweets). This networking event’s achieved high visibility and participation rate showcases a convincing example of how this social media platform can be used as a highly effective tool to host virtual Twitter-based international biomedical research events.

Introduction

Significance of natural products and natural product research

Nature offers multiple solutions to almost all the challenges faced by mankind. In particular, natural products represent a sustainable bio-resource with the potential to treat and manage various diseases and disorders (Durazzo et al., 2018a; Durazzo and Lucarini, 2021, 2019; Ghareeb et al., 2020; Uhrin et al., 2018). Globally, a fast and dynamically growing body of evidence is continuously emerging from computational level to the clinical level, enabling translational aspects and diverse applications of a wide range of bioactive natural products (Apoorva et al., 2021; Bankar et al., 2011; Bansal et al., 2021; Dangar and Patel, 2021; Igoli et al., 2014a, 2014b; Madaan et al., 2022;

Marzocco et al., 2021; Okoh et al., 2021; Singla, 2021; Singla et al., 2021a, 2021b, 2021c; Singla et al., 2021d). Plants, animals, and microbes serve as natural resources and goldmines for therapeutics, supplements, and nutraceuticals discovery (Capó et al., 2021; Dai et al., 2021; Durazzo et al., 2018b, 2020; Mironczuk-Chodakowska et al., 2021; Santini et al., 2018; Santini and Novellino, 2014, 2017, 2018; Santini et al., 2017; Singla and Dubey, 2019; Singla et al., 2019; Wink, 2015; Yang et al., 2019a). Not only do the traditional medicinal systems rely on natural products, but the modern medicinal systems also heavily rely on using multiple natural product scaffolds for drug development, in an unmodified state or for-property optimization achieved by modifying the starting natural product scaffold (Atanasov et al., 2015; Chaturvedi et al., 2020; Ravula et al., 2021; Tewari et al., 2021). For clinical purpose, there are already a lot of highly successful natural

product-based medicines, including but not limited to antibacterials such as streptomycin (Waksman and Schatz, 1945), antifungals such as amphotericin B (Cavassin et al., 2021), antimalarials such as artemisinin (Wang et al., 2019b), anticancer agents such as vinca alkaloids (Ehrhardt et al., 2011), camptothecin (Wang et al., 2021), and paclitaxel (Rowinsky et al., 1995), or antidiabetic agents such as acarbose (Kumar Singla et al., 2016; Tupas et al., 2020). Chemical modification of natural product molecules has also yielded multiple clinically relevant drugs such as caspofungin (Walsh et al., 2004), artemether (Hien et al., 1996), or etoposide (Cragg and Pezzuto, 2016; O'Dwyer et al., 1985). As a reflection of the high significance of natural products for the discovery and development of new pharmaceuticals, a high number of natural products or their derivatives are currently in clinical trials for a range of diverse diseases (Ahmad et al., 2021; Lima et al., 2021; Nile and Kai, 2020; Singla et al., 2022a, 2022b). Moreover, multi-component natural product mixtures are also studied to explore their therapeutic potential and used clinically (Wink, 2015). Examples of botanical drugs based on such complex mixtures of natural products approved by the United States Food and Drug Administration (FDA) include sinecatechins (marketed as Veregen® by Fougere Pharmaceuticals Inc.), an extract of green tea leaves [*Camellia sinensis* (L.) Kuntze] approved for the treatment of genital and anal warts in 2006, and crofelemer (marketed as Mytesi™ by Napo Pharmaceuticals), an oligomeric proanthocyanidin-enriched extract from the latex of the Dragon's blood tree (*Croton lechleri* Müll.Arg.) that was approved for human immunodeficiency virus/ acquired immunodeficiency syndrome (HIV/AIDS)-related diarrhea in 2012 (Chen et al., 2008; Crutchley et al., 2010; Kleindl et al., 2017). Natural products are also been intensively investigated for prevention or treatment of coronavirus disease 2019 (Devpura et al., 2021; Lordan et al., 2021; Silveira et al., 2020; Singla et al., 2021b; Wang et al., 2020b). Aside of medicinal plants, many mushrooms are also exhibiting therapeutic potential, and for example in China numerous medicinal mushrooms have been included in the Chinese Pharmacopoeia (Dai et al., 2021). Along this line, it is important to underline that multiple herbal preparations are used in complementary and alternative medicine around the world. For example, plants with antioxidant phytoconstituents, such as phenolics, carotenoids, allicin, mustard oil and vitamins C and E, are widely employed as phytopharmaceuticals and nutraceuticals and help prevent diseases caused from an overdose of reactive oxygen species (ROS) including cancer, cardiovascular and neurodegenerative health conditions (Wink, 2022). To reduce the financial strain on the public from poorer countries undergoing rapid (economic) development (LDCs), it is essential to focus on such sustainable resources for therapeutic management as they will be cost-effective, accessible, and in most cases safe (Chaturvedi et al., 2018; Heinrich et al., 2021; Singla et al., 2021d; Suryanarayana Raju et al., 2015).

In addition to therapeutic uses, natural products and materials have many other (non-medical) applications in different areas. Cellulose nanofibers with improved photothermal stability, for example, have potential in the fields of coating and packaging (Deng et al., 2022). Rice husk can be applied as a green coagulant (Tan et al., 2022), and hydrophobically modified agarose as hydrogels (Evans et al., 2022). Sweeteners (Pawar et al., 2013; Yeung et al., 2019d), biosurfactants (Liu et al., 2022), bioremediators (Xue et al., 2022), adsorbents (Etim et al., 2016), biofuels (Murillo et al., 2021; Sirigeri et al., 2019), fuel cells (Chen et al., 2018), carbon electrodes (Xi et al., 2021), carbon fertilizers (Xiang et al., 2021), paper industry uses (Haunreiter et al., 2021), cosmetics (Alves et al., 2020), and pesticides (Yang et al., 2021; Zaccardelli et al., 2020) are just a couple of examples out of the broad spectrum applications of various natural products and materials.

Scientific open innovation in the era of digital communications

The traditional approach for the generation of industrial innovation (including the development of new products and services) has been

relying on internal resources and company employees. A newer concept, “open innovation”, moved the focus on a more substantial reliance on innovation generated externally, and its interaction with the company's resources (Chesbrough and Crowther, 2006; Hodson, 2016). The open innovation concept has an advantage that it can tap into newly developed technologies and ideas without the need to entirely depend on own resources and expertise, the maintenance of which is complex and costly. In this model of innovation generation, industrial entities move their priority out of intellectual property protection to pursue external collaboration-oriented strategies, whereby collaborating partners could be other companies, academic units, or the general public as a whole. In analogy to the industrial approach where the concept was first created, the “Open Innovation in Science” approach in academia emerges as a set of practices with the focus shifted to openness and collaborative, interactive, integrated, and often interdisciplinary work involving more vital interaction with external parties from academia, industry, and society (Beck et al., 2020), realized for example by creating collaborative networks and research infrastructures in the perspective of interoperability (Dwyer et al., 2021). In the arena of medical and pharmaceutical research, which is of relevance to the focus of the open innovation platform described in the present manuscript, a recent total-scale literature analysis identified 384 scientific papers dealing with open innovation, with the first publications starting to appear in the literature in the middle of the 2000s (Yeung et al., 2021a). The later analysis also revealed that, so far, most research on open innovation in the arena of medical and pharmaceutical research was done in North America and Europe, and that the pharmaceutical sector was the most active industrial stakeholder.

Digital communication tools have the potential to empower significantly open innovation approaches. Historically, some of the first applications of open innovation took place exactly in the area of information technologies and computer technologies (in addition to the above-mentioned pharmaceutical industry sector) (Chesbrough and Crowther, 2006). With the use of digital communication tools, open innovation practitioners can reach quickly and easily large audiences of relevant stakeholders, which is of high importance for the application of key open innovation techniques such as crowdsourcing (Wazny, 2018). Moreover, digital technologies have enabled the emergence of a variety of virtual organizations that coordinate their activities primarily online, one of which is the International Natural Product Sciences Taskforce (INPST) (Atanasov et al., 2021; Camarinha-Matos and Afsarmanesh, 2005) that we present in detail in the current manuscript.

The International Natural Product Sciences Taskforce (INPST), an open innovation platform to invigorate the natural product research field

The International Natural Product Sciences Taskforce (INPST) was initiated in the early 2018, aiming to bring together in a collaborative environment individuals and organizations interested in natural products science, and empower them through the application of open innovation approaches and digital communication tools (for both networking and dissemination of credible scientific information). Envisaging the diverse applications of natural products in many areas of industry and healthcare, new natural product-related scientific findings could be of high importance in addressing some key societal problems, such as the search for new medicines, the establishment of innovative technologies that are friendlier to the environment, and the development of better food and dietary supplements. Along this line, both the continuous exploration of the existing natural biodiversity is of benefit, but also cultivated biodiversity, involving improvements mediated through modern genetic techniques, which allow to specifically increase the content of substances of high nutritional and even pharmaceutical interest (Sabbadini et al., 2021).

As the major entry point for accessing INPST-curated content, INPST website (<https://inpst.net/>) has been established. The INPST platform integrates several social media channels (Table 1) and presents in

Table 1
Major INPST social media channels.

Social media	Audience (as of April 2021)- Pre INPST Networking Event	Audience (as of January 2022) Post INPST Networking Event	Web address
Facebook	7672	8171	https://www.facebook.com/INPST/
Twitter	3113	4084	https://twitter.com/_INPST
ResearchGate	561	889	https://www.researchgate.net/project/International-Natural-Product-Sciences-Taskforce-INPST
LinkedIn	573	725	https://www.linkedin.com/company/international-natural-product-sciences-taskforce/

diverse subsections, contents that might be of interest to the visitors, including links to relevant conferences, job offers, publications, funding opportunities, and special issues of scientific journals. The INPST has attracted strong attention, and over 1500 people from more than 50 countries have joined the platform as members or email subscribers as of April 2021. In addition, large audiences have followed the major INPST social media channels (Facebook, Twitter, ResearchGate, and LinkedIn), as detailed in Table 1.

Aside from the INPST email list and social media channels, another tool for direct communication between INPST members and web visitors was provided through the INPST forum tool (<https://inpst.net/other-topics-and-announcements/>). Representative examples of different INPST-based activities (Table 2) are aligned with the multiple dissemination and outreach activities. INPST-based networking has proven to be an excellent catalyst for new collaborative integrated scientific research (Banach et al., 2018; Horbanczuk et al., 2019; Jozwik et al., 2018; Ruscica et al., 2021; Tancheva et al., 2020; Tewari et al., 2020; Tzvetkov et al., 2019; Yang et al., 2019b; Zhubi-Bakija et al., 2021), including joint work conducting meta-analysis of the published literature (Durazzo et al., 2021a, 2021b; Yeung et al., 2018, 2019a, 2020a; Yeung et al., 2019b, 2020b, 2020c; Yeung et al., 2019c, 2021c, 2019d), and the preparation of scientific collaborative review publications (Khan et al., 2020; Li et al., 2021; Mondal et al., 2021, 2019; Tewari et al., 2018; Vacca et al., 2019; Wang et al., 2022, 2018, 2019a; Wang et al., 2021) utilizing broadly-international collaborative work. In the latest example of collaborative work type, a special mention deserves a 2021 article from *Nature Reviews Drug Discovery* entitled “Natural products in drug discovery: advances and opportunities,” in which the International Natural Product Sciences Taskforce was used for the first time as an author group designation (Atanasov et al., 2021).

Twitter as a tool for science communication and networking

Twitter represents one of the comparably large social media platforms with an estimated more than 300 million monthly active users (<https://www.statista.com/>). The major feature of the platform is that it enables users to share publicly short messages (tweets), with the current characters limit (since 2017) for a single tweet being 280 characters (Boot et al., 2019). Furthermore, tweets can optionally include hyperlinks to other content on the web, photo images, short video clips, and hashtags (broadly used tags in social media used to label and grouping together thematically linked social media posts).

Twitter represents a social media platform widely used by scientists (Soragni and Maitra, 2019) and the general public. It empowers scientists to disseminate their research both to their peers (who are also the users of the platform) and directly to the general public (without the

Table 2
Representative examples of different categories of INPST-based activities.

Category	Example	Weblink
Conference support	ICNPU-2019: The 4th International Conference on Natural Products Utilization from Plants to Pharmacy Shelf, supported by INPST (29 May – 01 June 2019, Albena resort, Bulgaria)	https://inpst.net/4th-international-conference-on-natural-products-utilization-from-plants-to-pharmacy-shelf-supported-by-inpst/
News entries dissemination	INPST collaborative work analyzes about 300,000 scientific papers to outline trends in antioxidants research	https://inpst.net/antioxidant-phytochemicals-takeover-scientific-attention-replacing-antioxidant-vitamins-and-minerals/
Research project features	Multitarget peptide-fragment hybrids for the treatment of neurodegenerative diseases	https://inpst.net/multitarget-peptide-fragment-hybrids-for-the-treatment-of-neurodegenerative-diseases/
Popularization of scientific publications	Marine natural products	https://inpst.net/marine-natural-products/
Funding announcements	Government of Ireland International Education Scholarship Programme	https://inpst.net/government-of-ireland-international-education-scholarship-program/
Online lectures	SARS-CoV-2 and COVID-19: Basic knowledge on a novel pandemic (Special Online Lecture by Prof. Thomas Efferth, on 9th of March 2021)	https://inpst.net/sars-cov-2-and-covid-19-basic-knowledge-on-a-novel-pandemic/
Job offers	Non-academic Executive Director at Natural Product Research center (at Trinity College Dublin, Ireland)	https://inpst.net/non-academic-executive-director-at-natural-product-research-center-at-trinity-college-dublin-ireland/
Collaborative research calls	Collaboration call: Root of <i>Althea officinalis</i> (marsh-mallow)	https://inpst.net/collaboration-call-root-of-althea-officinalis-marsh-mallow/
Award announcements	INPST Young Scientist Award 2019	https://inpst.net/inpst-young-scientist-award-2019/
Blogging	Pomegranate for heart health and the science behind it	https://inpst.net/blog/pomegranate-for-heart-health-and-the-science-behind-it/
Dissemination of journal special issues	Natural Products and Their Applications	https://inpst.net/crbitech-special-issue-natural-products-and-their-applications/

need for involvement of journalists or science communication professionals). Moreover, Twitter represents a fertile ground for networking of professionals and finding new collaboration partners, with multiple examples in the scientific literature of fruitful research partnerships starting through Twitter interactions (Baker, 2015; Doxtader et al., 2019; Guralnick et al., 2016; Lurie et al., 2020).

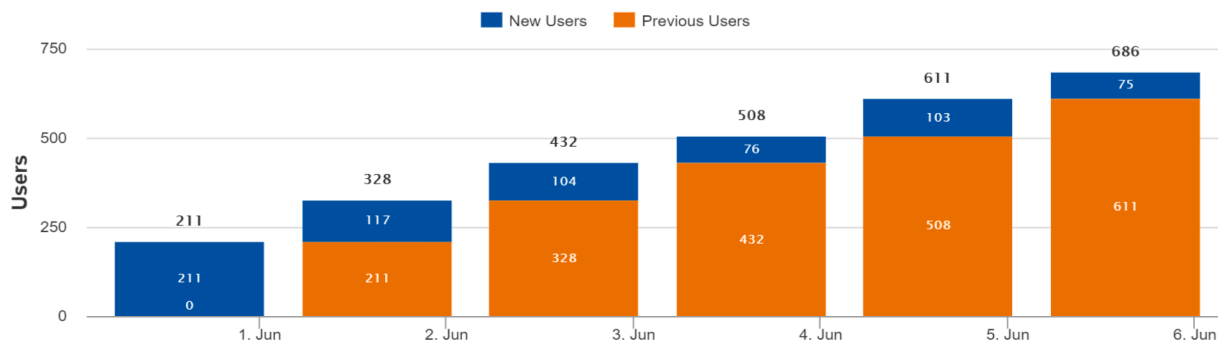
Hashtags, which were mentioned above as one of the commonly used tweet components, are designed as keyword-terms (usually thematically related to the content of the tweet) that are missing spaces (in case the term consists of several words) and have a hash sign (#) in front (particular example: #NaturalProducts). Hashtags afford tagging and thematic grouping of tweets and hashtag analysis has been widely used as a research tool that allows different quantifications (Cheung et al., 2018; Gardhouse et al., 2017; Grabbert et al., 2019; Kudchadkar and Carroll, 2020). In this context, relevant visibility parameters associated with tweets that could be analyzed, include retweets (re-shares) and impressions (views). Consequently, in this work, we aimed to evaluate visibility-associated features of the INPST Twitter networking event 2021 (detailed in the next section) by #INPST Twitter hashtag analysis.

Methodology

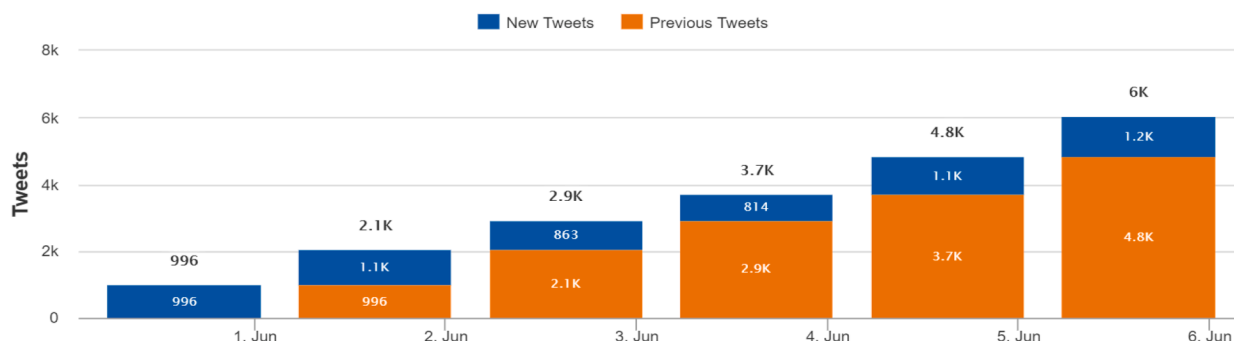
The use of the #INPST hashtag was assessed through a one-week event, highlighted and promoted as “2021 INPST Twitter Networking Event”, which spanned from 31st May 2021 to 6th June 2021. Twitter users were encouraged to use the #INPST hashtag, while doing any relevant scientific communication on Twitter. Contributions that were being encouraged included: showcasing individual research, collaboration calls, job postings, journal special issue announcements,

networking messages, conference announcements, Twitter polls, seminar announcements, links of relevant new publications, and job searches. Readers can refer to <https://inpst.net/inpst-twitter-networking-event-2021/> for more details. Utilization of the hashtag #INPST through the study period was analyzed with the aid of Symplur Signals (<https://www.symplur.com/>).

A



B



C

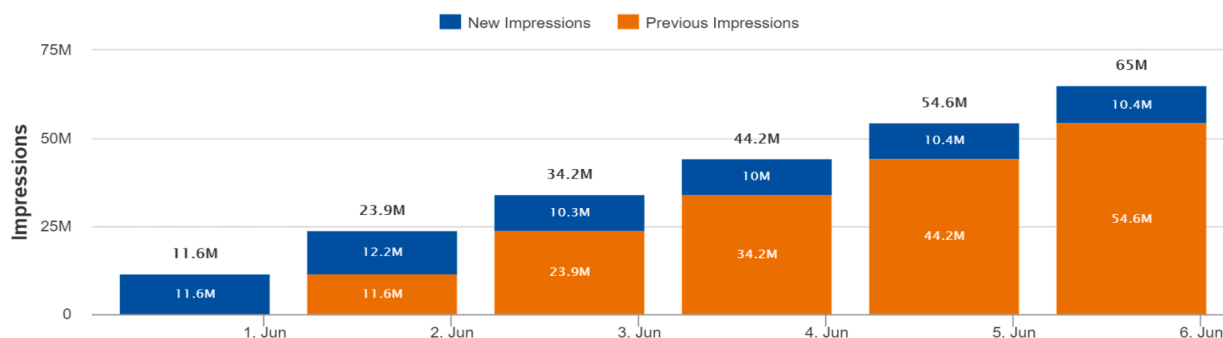


Fig. 1. Cumulative increase in the number of #INPST-posting users (A), #INPST-containing tweets (B), and impressions/views (C) during the networking event timeline (31st May to 6th June 2021).

Results and discussion

A total of 6036 tweets were posted by 686 users in that one-week networking event, generating a total of 65,004,773 impressions (views of the respective tweets). Of these 6036 tweets, 4272 tweets (70.8%) contained links, while only 319 tweets (5.28%) contained different attached images. Strategic usage of links, related hashtags, and images are in general relevant in strengthening tweets' visibility (Mishori et al., 2019). Mishori and the team, in their study published in 2019, have covered seven hashtags such as #ilooklikeasurgeon, #WomenInMedicine, #SheLeads2017, #seetibeit, #BlackMenInMedicine, #QuoteHer, and #diversityinmedicine, and analyzed them for one year. For each tweet, the volume of tweets recorded on a monthly basis (Mishori et al., 2019) was less than the tweets yielded in our one week #INPST campaign. This indicates that the tweets number obtained in the conducted "2021 INPST Twitter Networking Event" was comparably higher than weekly tweets reported in the literature for many other hashtags with biomedical significance.

Out of the 686 Twitter users who posted #INPST-containing tweets, 399 (58.2%) made only one tweet during the networking event period; 95 (13.8%) posted two tweets, while 192 (28.0%) users made three or more tweets. This suggested that close to two hundred users have regularly used the hashtag #INPST while promoting their scientific content on Twitter. It has been observed that during the one week of this hashtag networking event, new users kept on joining in the tweeting and sharing (Fig. 1A). On the first day, only 211 Twitter users joined the networking event, and the participant number gradually increased in the next few days, reaching 686 users by the last day of the networking event. During the study period, new tweets number also gradually increased, with daily tweet numbers in the range 814–1200 (Fig. 1B). On the first day of the networking event 996 tweets and 11.6 million impressions were recorded. Each day, there was an increase of around 10 million of new impressions, and by the end of the networking event week, there were more than 65 million impressions (Fig. 1C). For comparison, in a one-year period (from 1st of March 2021 to 1st of March 2022), there have been 49,300 tweets using the hashtag #INPST that have been shared by 4209 users and generated 610,157,622 impressions. Considering that there are around 52 weeks in a year, it becomes obvious that the "2021 INPST Twitter Networking Event" that took place in one single week (from 31st May 2021 to 6th June 2021) generated hugely increased weekly activity reflected in the number of shared tweets (6036 tweets in a single week) participating users (686 users) and generated impressions (65,004,773 impressions). In a previous study, a Twitter campaign focused on the hashtag #DHPSP was executed for five weeks, yielding a total of 151,984,378 impressions (Kletecka-Pulker et al., 2021). Benjamin and Royer in 2018, have performed analytics of a six months-interval to track the significance of the @AACAnatomy Twitter account. Total impressions gained by the posts from that account were calculated to be 60,510 from September 2016 to February 2017 (Benjamin and Royer, 2018). These comparative data illustrate that the #INPST networking event, with its 65,004,773 impressions (views) achieved very high visibility in just one week in comparison to other biomedical Twitter-based campaigns. Similar conclusions can be also reached by comparing to the Spanish pro-vaccine Twitter campaign focused on the hashtag #yomevacuno, which was monitored for two weeks (between 14 December and 28 December 2020) and yielded 915,736 impressions (Herrera-Peco et al., 2021).

Further, as per the user information publicly available on Twitter, the top 5 locations of the users who had used the #INPST hashtag while posted during the one-week networking event was the United States (73 users), India (38), the United Kingdom (22), Canada (18), and Spain (14). Although English remains the most frequently used language with 4068 of the tweets being in English, other languages such as Japanese (26 tweets), Romanian (14), Welsh (10), and Slovenian (6) are also noteworthy. During the one-week #INPST networking event, the most widely shared tweet featured the publication "Big impact of

nanoparticles: analysis of the most cited nanopharmaceuticals and nanonutraceuticals research", and gathered 66 retweets, 6 quoted tweets and 69 likes (Fig. 2). Furthermore, Twitter Analytics revealed that this tweet generated 23,426 impressions and 211 engagements (equaling the total number of times a user has interacted with a Tweet, including all clicks, retweets, replies, follows, and likes). The article featured in this tweet was published in Current Research in Biotechnology (Elsevier) in 2020. As per the Google Scholar record dated January 18 2022, this article has been cited a total of 25 times. Although, the follow-up time was too short to investigate whether the visibility-boost achieved through Twitter during the #INPST networking event might translate into more widespread readership and increasing citation rate for this paper, it is interesting to mention that previous works have indicated that on average widely tweeted manuscripts receive more citations (Luc et al., 2021).

The most frequently used words, which were found in the #INPST tweets shared during the networking event, were also analyzed. The top 10 words were "read", "twitter", "research", "paper", "natural", "event", "analysis", "review", "published", and "networking" (Fig. 3). All of these words have meanings that can be linked to the scope of the #INPST Twitter networking event and scientific research in general. The frequency of these words is quite high, ranging from 200 to more than 400 uses.

As the co-hashtag usage also influences the visibility of tweets, we additionally analyzed the hashtags that were co-occurring with #INPST. The top 10 hashtags that co-occurred with #INPST were also all related and relevant to the focus of the Twitter networking event (Fig. 4). The hashtag #DHPSP (an acronym for Digital Health and Patient Safety Platform) is officially registered with the Symplur Healthcare Hashtag Project and meant to be used with tweets related to "digital health, open innovation, patient safety, personalized medicine" (Kletecka-Pulker et al., 2021). #NPMND is a hashtag officially registered with the Symplur Healthcare Hashtag Project and is meant to be used with tweets related to "cancer, diabetes, metabolic disorders, natural products, neurological disorders, obesity, pain, Parkinson's disease" (Singla, 2021). #AcademicTwitter, is a widely used hashtag to label various academy-related Twitter discussions (Fuller and Potvin, 2020; Gomez-Vasquez and Romero-Hall, 2020). #SciComm hashtag is used with tweets related to "Medical Education, scientific communication, scientific posters" (Kaczmarczyk, 2015). #cancer is broadly used in tweets related to cancer. #AcademicChatter is dedicated to broader academic community chatting (Davies, 2021; Stillwell, 2021). #OpenScience is a hashtag from the accounts @open_science_ and @open-science, and is related to "promoting the discussion/dissemination of open science, equality, inclusivity, and fairness". #womeninstem is a hashtag related to "gender equity, gender parity, STEM, women in healthcare, women in medicine, women in research, women in science" (Woolston, 2015). #meded is linked to medical education (Jaswal et al., 2021), and #STEM is related to science and technology related communications (abbreviation from science, technology, engineering, and mathematics). Thus, all the co-hashtags in the top 10 list were related to science and health.

Special issues in various journals have also been widely promoted during the #INPST networking event. Among the three most shared images (Fig. 5), two illustrations (left and right) are related to journal special issues. At the same time, the third (in the center) presents an overview of a specific drug discovery research project, "Multitarget peptide-fragment hybrids for the treatment of neurodegenerative diseases" lead by Dr. Nikolay T. Tzvetko. The first special issue (the image on the left) is entitled "Plant-Derived Functional Foods, Nutraceuticals, and Cosmeceuticals: From Basic to Applied Science." This special issue is being handled by the guest editor, Dr. Hari Prasad Devkota for the journal, *Applied Sciences*, MDPI publisher. The second special issue was about "Pharmacology of Plant Polyphenols in Human Health and Diseases". This special issue was handled by five guest editors, including Dr. Hari Prasad Devkota, Dr. Atanas G. Atanasov (the founder of INPST and

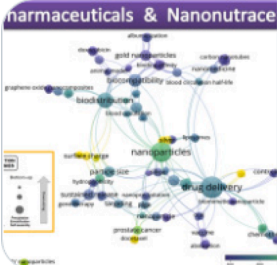


Atanas G. Atanasov
@_atanas_



Big impact of nanoparticles: analysis of the most cited nanopharmaceuticals and nanonutraceuticals research

#INPST #Nanoparticles #Nanopharmaceuticals
#Nanonutraceuticals #scicomm #100DaysOfCode
#globalhealth #nutrition #WomenInSTEM
#OpenScience #STEM



Big impact of nanoparticles: analysis of the most cited nano...
Nanopharmaceuticals and nanonutraceuticals research has been lately receiving a lot of scientific attention. We aimed t...
[sciedirect.com](https://www.sciencedirect.com)

6:58 AM · Jun 5, 2021 · Buffer

66 Retweets 6 Quote Tweets 69 Likes

Fig. 2. The most shared tweet of the #INPST Twitter networking event.

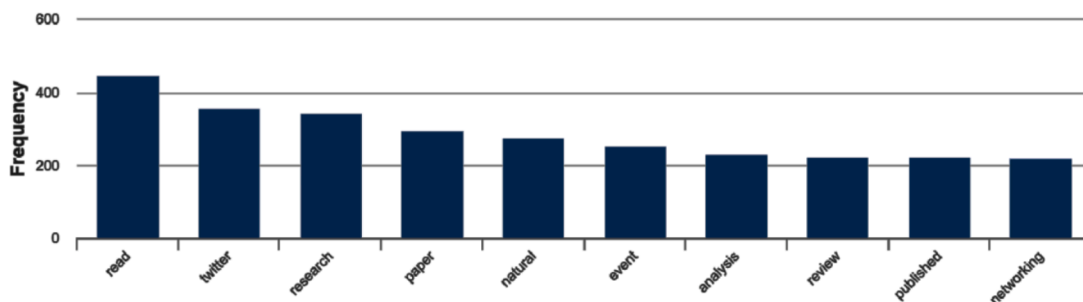


Fig. 3. . Top 10 words of the #INPST tweets posted during the networking event.

the #INPST hashtag), Dr. Keshav Raj Paudel, Dr. Namrita Lall, and Dr. Michał Tomczyk, for the journal *Frontiers in Pharmacology* (Frontiers Publisher).

Other journal special issues promoted during the event (edited by Dr. Anupam Bishayee) were “Molecular Mechanisms Underlying Cancer Prevention and Intervention with Bioactive Food Components” (in *Cancers*), “Molecular insights into natural compounds in oncoprevention and oncotherapy” (in *Pharmacological Research*), and “Molecular pharmacology of anticancer natural products” (in *Phytomedicine*). Additionally, a special collection E-book at the interface of *Frontiers in Plant Science*, *Frontiers in Pharmacology* and *Frontiers in Physiology*, entitled “Lignans: Insights into Their Biosynthesis, Metabolic Engineering,

Analytical Methods and Health Benefits” was published in early 2021. It was edited by Christophe F Hano, Albena T. Dinkova-Kostova, Norman G Lewis, John R Cort, and Laurence B. Davin, and has been viewed more than 18,700 times to date (<https://www.frontiersin.org/research-topics/9159/lignans-insights-into-their-biosynthesis-metabolic-engineering-analytical-methods-and-health-benefit#overview>) (Hano et al., 2021).

In their randomized-controlled trial “Three Facts and a Story”, Tapper and co-workers have also evaluated the use of Twitter for research dissemination, finding a significant increase in engagement for the papers published in the *Journal of Hepatology*, if relevant tweets featuring these papers were posted on Twitter (Tapper et al., 2021).

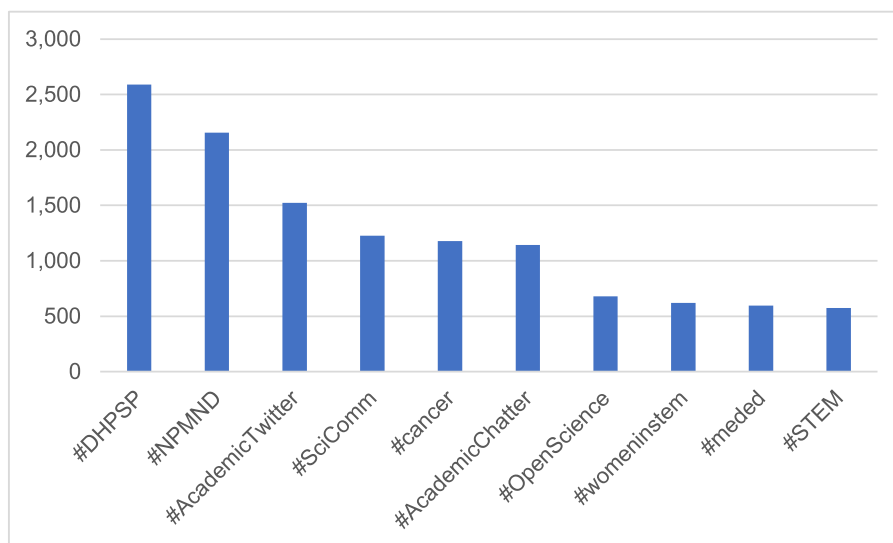


Fig. 4. Top 10 hashtags co-occurring with #INPST.

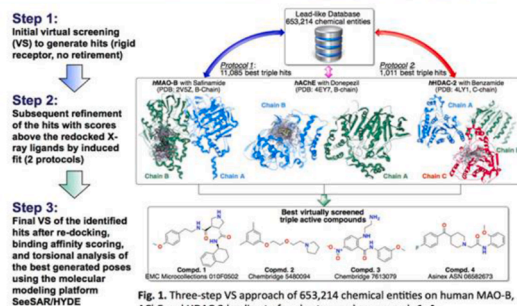


Fig. 1. Three-step VS approach of 653,214 chemical entities on human MAO-B, AChE and HDAC-2 leading to four best scored compounds 1–4.

Drugs	Structure	K _i ranges		
		MAO-B (PDB: 2V5Z)	AChE (PDB: 4EY7)	HDAC-2 (PDB: 4LY1)
Safinamide (SAF)		4.06 nM < K _i < 403 nM 5.18 ± 0.04 nM ¹¹	69.0 μM < K _i < 403 nM	2209 μM < K _i < 22 nM
Compd. 1 EMC Microcollections 010F0502		0.04 nM < K _i < 4.0 nM	6.89 nM < K _i < 684 nM	2.36 μM < K _i < 234 μM
Compd. 2 Chembright 5480094		0.23 nM < K _i < 23.1 nM	81.7 μM < K _i < 8.12 nM	1.52 mM < K _i < 151 nM
Compd. 3 Chembright 7613079		114 nM < K _i < 11.3 μM	4.63 μM < K _i < 460 μM	312 nM < K _i < 30.9 μM
Compd. 4 Asinex ASN 06582673		947 nM < K _i < 94.0 μM	358 nM < K _i < 35.6 μM	22.3 nM < K _i < 2.21 μM

Table 1. Estimated with HYDE/SeeSAR binding affinity (K_i ranges) of reference safinamide and compounds 1–4 towards MAO-B, AChE, and HDAC-2 leading to four best scored commercially available drugs. ¹¹ Experimental value (Ref. [5]).

Fig. 5. The three most shared images during the #INPST Twitter Networking Event 2021 (with 27, 20, and once again 20 retweets, for the images displayed left, center-bottom, and right, respectively).

Exploring another application of the social media platform, Bennett and co-workers have utilized Twitter to identify COVID-19 vaccine-associated hematological adverse events (Bennett et al., 2022). Further, Eibensteiner and co-workers have utilized the Twitter poll analysis

methodology to assess the people’s willingness to vaccinate against COVID-19 (Eibensteiner et al., 2021). As yet another application of Twitter, Lyu et al. have utilized the social media platform to identify topics and perform sentiment analysis in public for COVID-19

vaccine-related discussions (Lyu et al., 2021). Kwok and co-workers did the same but focused only on Australian users and by machine learning analysis (Kwok et al., 2021). As further examples of Twitter hashtag-based studies, Kauffman and colleagues have analyzed the role of Twitter in online radiology education by assessing the hashtag #RadEd (Kauffman et al., 2021), and Robertson et al. have analyzed the hashtags #RadialFirst and #RadialForNeuro on Twitter referring to transradial access for neurointerventional procedures (Robertson et al., 2021). While Twitter-applications have the limitation that they just reach this segment of the population who are users of the platform, the above-described research studies leave no scope for doubting for the value of Twitter use and Twitter-based analysis for the scientific community. Moreover, since social media platforms are a fertile ground for the dissemination of science and health-related misinformation (Yeung et al., 2021b, 2022), scientists-driven activities and events hosted on social media platforms such as Twitter can benefit the general public by providing credible and easy-accessible science-based information. Nevertheless, it should be noted that using specifically Twitter for scientific communication-based initiatives such as the here-described #INPST networking event has one important limitation: Twitter is not popularly used in some countries, which results in excluding a large group of researchers in Asia, particularly in China, who are engaging in natural product research. Envisaging this limitation, it might be recommended that for better international coverage future events from that kind might be executed with the simultaneous use of several diverse social media platforms to better reach and involve scientists located in different countries.

Conclusions

This study demonstrated how Twitter networking event attracted a large number of scientists across the world to showcase their scientific content and gained high visibility for the participants and the INPST platform as a whole, as clearly demonstrated especially by the archived high number (65,004,773) of impressions/views archived in just a single week. This work sets an example of how Twitter can be used as a highly efficient and fascinating channel to host virtual campaigns, disseminate credible scientific information, and host virtual international biomedical research events. Importantly, such digital networking events also provide platform for intensifying of interactions between scientists from different parts of the world, which might potentially yield the formation of new scientific collaborations benefiting future biomedical research. The wider implications of this analysis relate to the potential of better understanding scientific communication both within the scientific community as well as with the wider public enabling a better understanding of science.

CRedit author statement

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and accuracy.

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Availability of data and materials

All the key information is already available in the manuscript; still, the authors are ready to provide any further data if the inquiry will be routed through journal and affiliation authorities, and follow the standard process.

Ethical approval and consent to participate

Not applicable.

Human and animal rights

Not applicable.

Consent for publication

Authors duly provide the consent for publication.

Conflict of Interest

Authors Dr. Rajeev K. Singla and Shailja Singla have an honorary-based associations with the iGlobal Research and Publishing Foundation (iGRPF), New Delhi, India. Dr. Bernd Fiebich is associated with VivaCell Biotechnology GmbH. RKS, SS and BF along with the remaining authors, declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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