AGROSYM

BOOK OF PROCEEDINGS

XVI International Scientific Agriculture Symposium
"Agrosym 2025"
Jahorina, October 2-5, 2025

agrosym 2025

BOOK OF PROCEEDINGS

XVI International Scientific Agriculture Symposium
“AGROSYM 2025”

Jahorina, October 2 - 5, 2025

Impressum

XVI International Scientific Agriculture Symposium „AGROSYM 2025“

Book of Proceedings Published by

Faculty of Agriculture, University of East Sarajevo, Republic of Srpska, Bosnia and Herzegovina
Faculty of Agriculture,University of Belgrade, Serbia
Mediterranean Agronomic Institute of Bari (CIHEAM - Bari) Italy
International Society of Environment and Rural Development, Japan
Balkan Environmental Association (B.EN.A), Greece
Centre for Development Research, University of Natural Resources and Life Sciences (BOKU), Austria
Perm State Agro-Technological University, Russia
Voronezh State Agricultural University named after Peter The Great, Russia
Tokyo University of Agriculture, Japan
Jiangsu University, People's Republic of China
Shinshu University, Japan
Faculty of Agriculture, University of Western Macedonia, Greece
Arid Agricultural University, Rawalpindi, Pakistan
National School of Agriculture, Meknes, Morocco
Enterprise Europe Network (EEN)
Faculty of Agriculture, University of Akdeniz - Antalya, Turkey
Selçuk University, Turkey
Department of Agriculture, Food, and Environment, University of Catania, Italy
University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
Slovak University of Agriculture in Nitra, Slovakia
Ukrainian Institute for Plant Variety Examination, Kyiv, Ukraine
National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine
Valahia University of Targoviste, Romania
National Scientific Center „Institute of Agriculture of NAAS“, Kyiv, Ukraine
Saint Petersburg State Forest Technical University, Russia
Northwest Normal University, People's Republic of China
University of Valencia, Spain
Faculty of Agriculture, Cairo University, Egypt
Tarbiat Modares University, Iran
Chapingo Autonomous University, Mexico
Cangzhou Normal University, People's Republic of China
Department of Agricultural, Food and Environmental Sciences, University of Perugia, Italy
Higher Institute of Agronomy, Chott Mariem-Sousse, Tunisia
Watershed Management Society of Iran
Institute of Animal Science - Kostinbrod, Bulgaria
University Joseph Ki-Zerbo, Burkina Faso
University Abdou Moumouni, Niger
SEASN- South Eastern Advisory Service Network, Croatia
Faculty of Economics Brcko, University of East Sarajevo, Bosnia and Herzegovina
Biotechnical Faculty, University of Montenegro, Montenegro
Faculty of Agriculture, University of Zagreb, Croatia
Institute of Field and Vegetable Crops, Serbia
Institute of Lowland Forestry and Environment, Serbia

Institute for Science Application in Agriculture, Serbia
Agricultural Institute of Republic of Srpska - Banja Luka, Bosnia and Herzegovina
Maize Research Institute “Zemun Polje”, Serbia
Faculty of Agriculture, University of Novi Sad, Serbia
Institute for Animal Science, Ss. Cyril and Methodius University in Skopje, Northern Macedonia
Academy of Engineering Sciences of Serbia, Serbia
Balkan Scientific Association of Agricultural Economics, Serbia
Institute of Agricultural Economics, Serbia

Editor in Chief

Hamid El Bilali

Tehnical editors

Sinisa Berjan
Milan Jugovic
Rosanna Quagliariello

Website:
http://agrosym.ues.rs.ba

CIP - Каталогизација у публикацији
Народна и универзитетска библиотека
Републике Српске, Бања Лука

631(082)(0.034.2)

INTERNATIONAL Scientific Agriculture Symposium "AGROSYM" (16 ; 2025 ; Jahorina)
Book of Proceedings [Електронски извор] / XVI International Scientific Agriculture Symposium "AGROSYM 2025", Jahorina, October 2- 5, 2025 ; [editor in chief Hamid El Bilali]. - Onlajn izd. - El. zbornik. - East Sarajevo : Faculty of Agriculture, 2025

Системски захтјеви: Нису наведени. - Način pristupa (URL): Način pristupa (URL): https://agrosym.ues.rs.ba/article/showpdf/BOOK_OF_PROCEEDINGS_2025_FINAL.pdf. - Ел. публикација у ПДФ формату опсега 1121 стр. - Насл. са насловног екрана. - Опис извора дана 20.11.2025. - Библиографија уз сваки рад. - Регистар.

ISBN 978-99976-070-5-8

COBISS.RS-ID 14353894

XVI International Scientific Agricultural Symposium “Agrosym 2025”
Jahorina, October 2-5, 2025, Bosnia and Herzegovina

HONORARY COMMITTEE

President: **Prof. dr. Dusan Kovacevic**, Honorary president of AGROSYM Agriculture Symposium, Serbia
Mrs. Andjelka Kuzmic, Minister of Agriculture, Water Management and Forestry of Republic of Srpska, Bosnia and Herzegovina
Prof. dr. Sinisa Karan, Minister of Scientific-Technological Development, Higher Education and Information Society of Republic of Srpska, Bosnia and Herzegovina
Prof. dr Mario T. Tabucanon, President of the International Society of Environment and Rural Development, Japan
Prof. dr Milan Kulic, Rector of the University of East Sarajevo, Bosnia and Herzegovina
Prof. dr Vladan Bogdanovic, Dean of the Faculty of Agriculture, University of Belgrade, Serbia
Dr. Biagio Di Terlizzi, Director of the Mediterranean Agronomic Institute of Bari, Italy
Prof. Dr. Hüseyin Yilmaz, Rector of the Selcuk University, Turkey
Prof. dr Aleksey Andreev, Rector of the Perm State Agro-Technological University, Russia
Prof. dr Alexander Agibalov, Rector of the Voronezh State Agricultural University named after Peter The Great, Russia
Prof. dr Xing Weihong, President of Jiangsu University, People’s Republic of China
Prof. dr Barbara Hinterstoisser, Vice-Rector of the University of Natural Resources and Life Sciences (BOKU), Austria
Prof. dr Sorin Mihai Cimpeanu, Rector of the University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
Prof. Shinichi Yonekura, Vice-President of the Shinshu University, Japan
Doc. Ing. Klaudia Halászová, Rector of the Slovak University of Agriculture in Nitra, Slovakia
Prof. dr Calin D. Oros, Rector of the Valahia University of Targoviste, Romania
Prof. Dr Katerina Melfou, Dean of the Faculty of Agriculture, University of Western Macedonia, Greece
Prof. dr Amr Ahmed Mostafa, Dean of the Faculty of Agriculture, Cairo University, Egypt
Prof. dr José Sergio Barrales Domínguez, Rector of the Chapingo Autonomous University, Mexico
Prof. dr Davut Karayel, Dean of Faculty of Agriculture, University of Akdeniz - Antalya, Turkey
Prof. Dr EGUCHI Fumio, Rector of the Tokyo University of Agriculture, Japan
Prof. dr Muhammad Naeem, Vice-Chancellor of Arid Agricultural University, Rawalpindi, Pakistan
Prof. dr Zhang Zhanping, President of Cangzhou Normal University, People's Republic of China
Prof. dr Wang Zhanren, President of Nortwest Normal University, People's Republic of China
Dr Chokri Thabet, the General Director of the High Agronomic Institute of Chott Mariem, Sousse, Tunisia
Prof. dr Maya Ignatova, Director of the Institute of Animal Science- Kostinbrod, Bulgaria
Prof. dr Seyed Hamidreza Sadeghi, Professor at Tarbiat Modares University and the President of the Watershed Management Society of Iran, Iran
Prof. Jean-Francois Silas Kobiane, President of the University Joseph Ki-Zerbo, Burkina Faso
Prof. dr Francesco Tei, Director of the Department of Agricultural, Food and Environmental Sciences, University of Perugia, Italy
Prof. dr Viktor Kaminskyi, Director of National Scientific Center „Institute of Agriculture of NAAS“, Kyiv, Ukraine
Dr. Igor Hrovatič, President of South Eastern Advisory Service Network, Croatia
Prof. dr Mirza Dautbasic, Dean of the Faculty of Forestry, University of Sarajevo, Bosnia and Herzegovina
Prof. dr Bozidarka Markovic, Dean of the Biotechnical Faculty, University of Podgorica, Montenegro
Prof. dr Rade Jovanovic, Director of the Institute for Science Application in Agriculture, Serbia
Prof. dr Srdjan Lalic, Dean of the Faculty of Economics Brcko, University of East Sarajevo, Bosnia and Herzegovina
Prof. dr Vojislav Trkulja, Director of Agricultural Institute of Republic of Srpska - Banja Luka, Bosnia and Herzegovina
Dr. Miodrag Tolimir, Director of the Maize Research Institute “Zemun Polje”, Serbia
Prof. Dr. Dragana Latkovic, Director of the Institute of Field and Vegetable Crops, Serbia
Prof. dr Nenad Magazin, Dean of the Faculty of Agriculture, University of Novi Sad, Serbia
Prof. dr Rodne Nastova, Director of the Institute for Animal Science, Skoplje, Northern Macedonia
Prof. dr Sasa Orlovic, Director of the Institute of Lowland Forestry and Environment, Serbia
Prof. dr Jonel Subic, Director of the Institute of Agricultural Economics, Serbia
Prof. dr Branko Kovacevic, President of the Academy of Engineering Sciences of Serbia, Serbia
Prof. dr Radovan Pejanovic, President of Balkan Scientific Association of Agricultural Economics, Serbia

SCIENTIFIC COMMITTEE

President: **Dr. Hamid El Bilali**, Mediterranean Agronomic Institute of Bari, Italy
Vice-president: **Prof. dr Sinisa Berjan**, Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
Vice-president: **Prof. dr Zeljko Dolijanovic**, Faculty of Agriculture, University of Belgrade, Serbia
Prof. dr Machito Mihara, Tokyo University of Agriculture, Japan
Prof. dr John Brayden, Norwegian Agricultural Economics Research Institute (NILF), Norway
Prof. dr Steve Quarie, Visiting Professor, School of Biology, Newcastle University, United Kingdom
Prof. dr Andreas Melcher, CDR, University of Natural Resources and Life Sciences (BOKU), Vienna, Austria
Prof. dr Dieter Trautz, University of Applied Science, Germany
Prof. dr Mustafa Harmankaya, Dean of Faculty of Agriculture, University of Selçuk- Konya, Turkey
Prof. dr Sergei Eliseev, Perm State Agro-Technological University, Russia
Prof. dr Dani Shtienberg, full professor, Department of Plant pathology and Weed Research, ARO, the Volcani Center, Bet Dagan, Israel
Prof. dr William Meyers, Howard Cowden Professor of Agricultural and Applied Economics, University of Missouri, USA
Prof. dr Markus Schermer, Department of Sociology, University of Innsbruk, Austria
Prof. dr Carmelo Rapisalda, Department of Agriculture, Food and Environment; University of Catania, Italy
Prof. dr Thomas G. Johnson, University of Missouri – Columbia, USA
Prof. dr Fokion Papathanasiou, School of Agricultural Sciences, University of Western Macedonia, Greece
Prof. dr Sabahudin Bajramovic, Faculty of Agriculture and Food Sciences, University of Sarajevo, Bosnia and Herzegovina
Prof. dr Hiromu Okazawa, Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan
Prof. dr Tatiana Sivkova, Faculty for Veterinarian Medicine and Zootechny, Perm State Agro-Technological University, Russia
Prof. dr Aleksej Lukin, Voronezh State Agricultural University named after Peter The Great, Russia
Prof. dr Matteo Vittuari, Faculty of Agriculture, University of Bologna, Italy
Prof. Katsuharu Saito, Faculty of Agriculture, Shinshu University, Japan
Prof. dr. Ebrahim Sepehr, Faculty of Agriculture, Urmia University, Iran
Prof. dr. Andrea Criscione, Department of Agriculture, Food and Environment, University of Catania, Italy
Prof. Giorgio Testa, Department of Agriculture, Food and Environment, University of Catania, Italy
Prof. Gabriella Vindigni, Department of Agriculture, Food and Environment, University of Catania, Italy
Prof. dr Seyed Mohsen Hosseini, Faculty of Natural Resources, Tarbiat Modares University, Iran
Prof. dr Ardian Maci, Faculty of Agriculture and Environment, Agricultural University of Tirana, Albania
Prof. dr Regucivilla A. Pobar, Bohol Island State University, Philippines
Prof. dr Azeem Khalid, Arid Agriculture University, Rawalpindi, Pakistan
Prof. dr Aayesha Riaz, Arid Agriculture University, Rawalpindi, Pakistan
Prof. dr Munir Ahmad, Arid Agriculture University, Rawalpindi, Pakistan
Prof. dr Sudheer Kundukulangara Pulissery, Kerala Agricultural University, India
Prof. dr EPN Udayakumara, Faculty of Applied Sciences, Sabaragamuwa University, Sri Lanka
Prof. dr Vladimir Smutný, full professor, Mendel University, Faculty of agronomy, Czech Republic
Prof. dr Franc Bavec, full professor, Faculty of Agriculture and Life Sciences, Maribor, Slovenia
Prof. dr Natalija Bogdanov, Faculty of Agriculture, University of Belgrade, Serbia
Prof. dr Richard Barichello, Faculty of Land and Food Systems, University of British Columbia, Canada
Prof. dr Francesco Porcelli, University of Bari Aldo Moro, Italy
Prof. dr Vasilije Isajev, Faculty of Forestry, University of Belgrade, Serbia
Prof. dr Elazar Fallik, Agricultural Research Organization (ARO), Volcani, Israel
Prof. dr Junaid Alam Memon, Pakistan Institute of Development Economics, Pakistan
Prof. Aziz Abouabdillah, National School of Agriculture, Meknes, Morocco
Prof. dr. Jorge Batlle-Sales, Department of Biology, University of Valencia, Spain
Prof. dr Pandi Zdruli, Land and Water Resources Department; IAMB, Italy
Prof. dr Mladen Todorovic, Land and Water Resources Department; IAMB, Italy
Prof. dr Maksym Melnychuk, National Academy of Agricultural Science of Ukraine, Ukraine
Prof. dr Borys Sorochynskyi, Ukrainian Institute for Plant Variety Examination, Kyiv, Ukraine
Dr. Lorenz Probst, CDR, University of Natural Resources and Life Sciences (BOKU), Vienna, Austria
Prof. Dragana Sunjka, Faculty of Agriculture, University of Novi Sad, Serbia
Prof.dr Miodrag Dimitrijevic, Faculty of Agriculture, University of Novi Sad, Serbia
Prof. dr Mohsen Boubaker, High Institute of Agronomy of Chott Meriem, Sousse, Tunisia
Prof. dr Ion Viorel, University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
Prof. dr. Chuleemas Boonthai Iwai, Faculty of Agriculture, Khon Kaen University, Thailand

Prof. dr Wathuge T.P.S.K. Senarath, Department of Botany, University of Sri Jayewardenepura, Colombo, Sri Lanka
Dr. Hamada Abdelrahman, Soil Science Dept., Faculty of Agriculture, Cairo University, Egypt
Prof. dr Maya Ignatova, Director of the Institute of Animal Science- Kostinbrod, Bulgaria
Prof. dr Ioannis N. Xynias, School of Agricultural Technology & Food Technology and Nutrition, Western Macedonia University of Applied Sciences, Greece
PhD ing. Artur Rutkiewicz, Department of Forest Protection, Institute of Forest Sciences, Warsaw University of Life Sciences - SGGW, Poland
Prof. dr Mohammad Sadegh Allahyari, Islamic Azad University, Rasht Branch, Iran
Dr. Lalita Siriwattananon, Faculty of Agricultural Technology, Rajamangala University of Technology Thanyaburi (RMUTT), Thailand
Prof. dr Konstantin Korlyakov, Perm Agricultural Research Institute, Russia
Dr. Larysa Prysiazhniuk, Ukrainian Institute for Plant Variety Examination, Kyiv, Ukraine
Prof. dr Oksana Kliachenko, National University of Life and Environmental Science of Ukraine, Ukraine
Dr. Abid Hussain, International Centre for Integrated Mountain Development (ICIMOD), Nepal
Dr. Amrita Ghatak, Gujarat Institute of Development Research (GIDR), India
Prof. dr Naser Sabaghnia, University of Maragheh, Iran
Dr. Karol Wajszczuk, Poznan University of Life Sciences, Poland
Prof. dr Penka Moneva, Institute of Animal Science - Kostinbrod, Bulgaria
Prof. dr Mostafa K. Nassar, Animal husbandry Dept., Faculty of Agriculture, Cairo University, Egypt
Prof. dr Andrzej Kowalski, Director of the Institute for Agricultural and Food Economy, Warzawa-Poland
Prof. dr Yalcin Kaya, The Director of the Plant Breeding Research Center, University of Trakya, Turkey
Prof. dr Sanja Radonjic, Biotechnical Faculty, University of Montenegro, Montenegro
Prof. dr Ionela Dobrin, Department for Plant Protection, University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
Prof. dr Inocencio Buot Jr., Institute of Biological Sciences, College of Arts and Sciences, University of the Philippines Los Banos, Philippines
Prof. dr Monica Paula Marin, Department for Animal Husbandry, University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
Prof. dr Nedeljka Nikolova, Institute for Animal Science, Ss. Cyril and Methodius University in Skopje, Republic of Macedonia
Prof. dr Mohammad Al-Mamun, Department of Animal Nutrition, Bangladesh Agricultural University, Bangladesh
Prof. dr Anucha Wittayakorn-Puripunpinyoo, School of Agriculture and Co-operatives, Sukhothai Thammathirat Open University, Nonthaburi, Thailand
Dr. Redouane Choukr-Allah, International Center for Biosaline Agriculture (ICBA), United Arab Emirates
Prof. dr Ignacio J. Díaz-Maroto, High School Polytechnic, University of Santiago de Compostela, Spain
Prof. dr Nidal Shaban, University of Forestry Sofia, Bulgaria
Prof. dr Mehdi Shafaghati, Faculty of Geography, Tarbiat Moalem (kharazmi) University, Iran
Prof. dr Youssif Sassine, Lebanese University Beirut, Lebanon
Prof. dr Cafer Topaloglu, Faculty of Tourism, Mugla Sitki Kocman University, Turkey
Prof. dr Seyed Hamidreza Sadeghi, Faculty of Natural Resources, Tarbiat Modares University, Iran
Prof. Zain Ul Abdin, Department of Entomology, University of Agriculture, Faisalabad, Pakistan
Prof. dr Mohsen Mohseni Saravi, University of Teheran and Member of WMSI Management Board, Iran
Prof. dr Branislav Draskovic, Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
Prof. dr Mahmood Arabkhedri, Soil Conservation and Watershed Management Research Institute and Member of WMSI Management Board, Iran
Prof. dr Ataollah Kavian, Sari Agricultural Science and Natural Resources University and Member of WMSI Management Board, Iran
Prof. dr Tugay Ayasan, Department of Organic Farming Business Management, Osmaniye, Applied Science School of Kadirli, Osmaniye Korkut Ata University, Turkey
Prof. dr Sakine Özpınar, Department of Farm Machinery and Technologies Engineering, Faculty of Agriculture, Çanakkale Onsekiz Mart University, Çanakkale, Turkey
Prof. dr Sherein Saeide Abdelgayed, Faculty of Veterinary Medicine, Cairo University, Cairo, Egypt
Prof. dr Zohreh Mashak, Islamic Azad University, Karaj Branch, Iran
Dr. Khalid Azim, National Institute of Agriculture Research, Morocco
Dr. Mario Licata, Department of Agricultural, Food and Forest Sciences, University of Palermo, Italy
Prof. Fatiha Addyoubah, Moulay Ismail University, Morocco
Prof. dr Muhammad Ovais Omer, Faculty of Bio-Sciences, University of Veterinary & Animal Sciences, Lahore, Pakistan
Dr. Edouard Musabanganji, School of Economics/CBE, University of Rwanda, Rwanda

Prof. dr Kubilay Baştaş, Department of Plant Protection, Faculty of Agriculture, Selçuk University, Turkey
Dr. Branka Kresovic, Maize Research Institute “Zemun Polje”, Serbia
Dr. Milan Stevanovic, Maize Research Institute “Zemun Polje”, Serbia
Prof. Violeta Babic, Faculty of Forestry, University of Belgrade, Serbia
Dr. Svetlana Balesevic-Tubic, Institute of Field and Vegetable Crops Novi Sad, Serbia
Dr. Ana Marjanovic Jeromela, Institute of Field and Vegetable Crops Novi Sad, Serbia
Prof. dr Tatjana Krajisnik, Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
Prof. dr Aleksandra Govedarica-Lucic, Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
Prof. dr Desimir Knezevic, University of Pristina, Faculty of Agriculture, Kosovska Mitrovica - Lesak, Kosovo i Metohija, Serbia
Dr. Snezana Mladenovic-Drinic, Maize Research Institute “Zemun Polje”, Serbia
Prof. dr Nebojsa Momirovic, Faculty of Agriculture, University of Belgrade, Serbia
Prof. dr Osman Mujezinovic, Faculty of Forestry, University of Sarajevo, Bosnia and Herzegovina
Prof. dr Dalibor Ballian, Faculty of Forestry, University of Sarajevo, Bosnia and Herzegovina
Prof. dr Zoran Jovovic, Biotechnical Faculty, University of Montenegro, Montenegro
Prof. dr Danijel Jug, Faculty of Agriculture, University of Osijek, Croatia
Prof. dr Milan Markovic, Biotechnical Faculty, University of Montenegro, Montenegro
Prof. Mirjana Jovovic, Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
Prof. dr Dejana Stanic, Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
Prof. Goran Marinkovic, Faculty of Technical Sciences, University of Novi Sad, Serbia
Dr Dejan Stojanovic, Institute of Lowland Forestry and Environment, Serbia
Dr Dobrivoj Postic, Institute for plant protection and environment, Belgrade, Serbia
Dr Srdjan Stojnic, Institute of Lowland Forestry and Environment, Serbia
Dunja Demirović Bajrami, Research Associate, Geographical Institute “Jovan Cvijić,” Serbian Academy of Sciences and Arts, Belgrade, Serbia

ORGANIZATION COMMITTEE

President: **Prof. dr Vesna Milic**, Dean of the Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
Prof. Dr Marko Gutalj, Vice rector of the University of East Sarajevo, Bosnia and Herzegovina
Prof. Dr Jelena Krunic, Vice rector of the University of East Sarajevo, Bosnia and Herzegovina
Dr. Maroun El Moujabber, Mediterranean Agronomic Institute of Bari, Italy
Dr Milic Curovic, The journal “Agriculture and Forestry”, Biotechnical Faculty Podgorica, University of Montenegro, Montenegro
Dr. Tatiana Lysak, International Relations Office, Voronezh State Agricultural University named after Peter The Great, Russia
Dr. Oksana Fotina, International Relations Center, Perm State Agro-Technological University, Russia
Prof. dr Fokion Papathanasiou, School of Agricultural Sciences, University of Western Macedonia, Greece
Dr Ana Marjanović Jeromela, Institute of Field and Vegetable Crops, Serbia
Prof. dr Engr. Teodora Popova, Institute of Animal Science - Kostinbrod, Bulgaria
Dr Daniela Spina, Department of Agriculture, Food and Environment, University of Catania, Italy
Prof. dr Mehmet Musa Ozcan, Faculty of Agriculture, Selçuk University, Turkey
Prof. dr Arfan Yousaf, Arid Agricultural University, Rawalpindi, Pakistan
Dr. Abdulvahed Khaledi Darvishan, Faculty of Natural Resources, Tarbiat Modares University, Iran
Prof. dr Nikola Pacinovski, Institute for Animal Science, Ss. Cyril and Methodius University in Skopje, Northern Macedonia
MSc. Erasmo Velázquez Cigarroa, Department of Rural Sociology, Chapingo Autonomous University, Mexico
Dr. Ecaterina Stefan, University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
Dr. Jeeranuch Sakkhamduang, The International Society of Environmental and Rural Development, Japan
Prof. Irfan Ozturk, Trakya Agriculture Research Institute in Edirne, Turkey
Dr. Raoudha Khanfir Ben Jenana, High Institute of Agronomy of Chott Meriem, Sousse, Tunisia
Dr. Romaric Kiswendsida Nanema, University Joseph Ki-Zerbo, Burkina Faso
Dr. Hamada Abdelrahman, Soil Science Dept., Faculty of Agriculture, Cairo University, Egypt
Prof. Dragana Sunjka, Faculty of Agriculture, University of Novi Sad, Serbia
MSc. Aleksandra Susnjar, Faculty of Agriculture, University of Novi Sad, Serbia
MSc. Dragana Boskovic, Faculty of Agriculture, University of Novi Sad, Serbia
Dr. Antonije Zunic, Faculty of Agriculture, University of Novi Sad, Serbia
Dr. Vedran Tomic, Institute for Science Application in Agriculture, Serbia

MSc. Vojin Cvijanovic, Institute for Science Application in Agriculture, Serbia
MSc. Mladen Petrovic, Institute of Agricultural Economics, Serbia
Dr. Milan Stevanovic, Maize Research Institute “Zemun Polje”, Serbia
Dr. Andrej Pilipovic, Institute of Lowland Forestry and Environment, Serbia
Dr. Sc. Morteza Behzadfar, Tarbiat Modares University, Tehran, Iran
Dr. Larysa Prysiazhniuk, Ukrainian Institute for Plant Variety Examination, Kyiv, Ukraine
Doc. dr Sead Ivojevic, Faculty of Forestry, University of Sarajevo, Bosnia and Herzegovina
Dr. Nenad Markovic, Enterprise E. N. (EEN) Coordinator, University of East Sarajevo, Bosnia and Herzegovina
Domagoj Group, SEASN - South Eastern Advisory Service Network, Croatia
Dr. Milan Ninkovic, Scientific Institute of Veterinary Medicine of Serbia
Prof. dr Zeljko Lakic, Agricultural Institute of Republic of Srpska - Banja Luka, Bosnia and Herzegovina
Dr. Milan Jugovic, Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
Prof. dr Dejana Stanic, Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
Dr. Milena Stankovic, Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
Prof. dr. Stefan Stjepanovic, Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
MSc. Stefan Bojic, Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
Dr. Tanja Jakisic, Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
Dr. Boban Miletic, Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
Dr. Nedeljka Elez, Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
MSc. Selena Kovacevic, Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
Dr. Branka Govedarica, Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
Dr. Igor Djurdjic, Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina, **General Secretary**

FOREWORD

The world is facing a range of crises that require policymakers to base their decisions on scientific data and evidence to effectively address them. Issues such as climate change, loss of biodiversity, degradation of natural resources (e.g. land and water), ongoing conflicts, persistent inequalities, and economic disruptions are progressively weakening the ability of agri-food systems to ensure food security and nutrition for all. Research plays a vital role in providing evidence and technical expertise, acting as a facilitator and policy broker in the development of agri-food strategies, investment planning, innovation policies, and other important policy processes. Additionally, research is essential for generating the knowledge, evidence, and resources required to promote responsible and inclusive innovation. It also offers support to a range of stakeholders, including farmers' organizations, businesses, and civil society groups. Integrating research with long-term policy strategies can enhance the acceptance and adoption of innovations in the agri-food sector, particularly when these innovations are promoted through inclusive platforms. To achieve a sustainable impact at scale, it is essential to improve collaboration in agri-food research and innovation. Scientific events and gatherings can be crucial in reaching this objective.

The International Agriculture Symposium AGROSYM has served as an annual forum for sixteen years, facilitating global scientific discussions on agriculture, food, rural development, the environment, and forestry. This symposium offers an excellent opportunity to share ideas, strengthen existing networks, establish new academic connections, and stimulate dialogue among academia, public institutions, the private sector, and civil society organizations. Participants engage in discussions about recent global and regional trends in the agri-food sector. The multidisciplinary findings presented at AGROSYM contribute to the dissemination of knowledge and best practices among all stakeholders in the agri-food chain, including farmers, extension agents, researchers, and policymakers. Additionally, the symposium emphasizes the importance of agriculture and food science as vital components of many national research strategies, impacting the broader community as well.

This Book of Proceedings from the 16th International Scientific Agricultural Symposium “AGROSYM 2025” encompasses articles which illustrate a wide range of research and insights across the comprehensive spectrum of agricultural disciplines. These articles address the following themes: 1) Plant production, 2) Plant protection and food safety, 3) Organic agriculture and agroecology, 4) Environmental protection and natural resources management, 5) Animal husbandry, 6) Rural development and agro-economy, and 7) Forestry and agroforestry.

We wish to express our heartfelt appreciation to all authors, reviewers, and colleagues who assisted in preparing this Book of Proceedings. Our special thanks go to co-organizers, partners, and sponsors for their unwavering support and collaboration.

We hope this multidisciplinary and international collection of research findings serves as a valuable resource for all stakeholders and encourages continuous dialogue and exchange to facilitate the transition towards sustainable, resilient, and inclusive agri-food systems.

East Sarajevo, 1 November 2025

Dr. Hamid El Bilali, CIHEAM Bari, Italy – Editor in Chief, President of the Scientific Committee
Prof. Dr. Sinisa Berjan, University of East Sarajevo, Bosnia and Herzegovina & **Prof. Dr. Zeljko Dolijanovic**, University of Belgrade, Serbia – Vice-presidents of the Scientific Committee

CONTENT

ENVIRONMENTAL BEHAVIOR AND TRACER POTENTIAL OF FLUORIDE IN GROUNDWATER

Marija PEROVIĆ*[1], Tatjana MITROVIĆ[2]

[1]Jaroslav Cerni Water Institute, Jaroslava Cernog 80, 11226 Belgrade, Serbia
[2]Institute of Physics Belgrade, University of Belgrade, Pregrevica 118, 11080 Belgrade, Serbia
*Corresponding author: marija.perovic@jcerni.rs

Abstract

Understanding tracer behavior in groundwater is crucial for accurately interpreting flow dynamics, residence times, and hydrogeochemical processes, thereby supporting effective aquifer recharge and potential pollution sources. Fluoride (F-) in groundwater is a significant geochemical constituent which mobility and distribution are governed by a range of hydrogeochemical factors. This paper reviews the behavior of fluoride in groundwater and evaluates its potential as an environmental tracer. Although fluoride in groundwater predominantly occurs because of natural geochemical processes, mainly the dissolution of F-bearing minerals such as fluorite and apatite, it can also originate from anthropogenic sources. These include industrial emissions, phosphate fertilizer application, and mining or processing of phosphate and fluorite ores, particularly in oxic shallow aquifers near contaminated sites. It is generally not redox-sensitive, remaining as fluoride across a range of redox conditions. Key controls on fluoride concentrations include pH, alkalinity, calcium availability, mineralogy, and the presence of competitive anions like bicarbonate and phosphate. Owing to its conservative behavior under many conditions, fluoride has been used as a natural tracer to infer groundwater origin. The conducted literature review concludes that fluoride, though usually considered as a contaminant of health concern, can serve as an informative geochemical tracer in hydrogeology when its controlling factors are known and examined.

Keywords: *fluoride, groundwater.*

Introduction

Fluoride in groundwater represents both a valuable resource and a potential contaminant, depending on its concentration and hydrogeochemical context. As an anion (F^-), fluoride is primarily introduced into groundwater through the weathering and dissolution of fluorine-bearing minerals, usually fluorite (CaF_2), fluorapatite ($Ca_5(PO_4)_3F$), and certain silicate minerals such as biotite and hornblende (Nordstrom & Jenne, 1977; Edmunds & Smedley, 2013). The release of fluoride is enhanced by extended water–rock interaction, elevated temperatures, and geochemical conditions that increase mineral solubility. Globally, fluoride concentrations in groundwater typically range from just a few micrograms to several milligrams per liter. In some regions with specific geological settings and climatic conditions, concentrations can exceed 10 mg/L (WHO, 2017). Elevated levels are particularly common in arid and semi-arid regions, where low recharge rates, prolonged groundwater residence time, and evaporative concentration favor fluoride enrichment (WHO, 2006). The global median fluoride concentration in groundwater is about 0.3 mg/L, but roughly 10% of tested sources exceed the World Health Organization (WHO) guideline value of 1.5 mg/L for safe drinking water (WHO, 2017). Chronic exposure to such concentrations has been linked to dental and skeletal fluorosis, making fluoride both a geochemical concern and a public health issue. While the health impacts of fluoride contamination have been widely studied, less attention has been paid to its geochemical behavior as a tracer of groundwater processes. Unlike redox-sensitive elements, fluoride remains stable across a broad range of conditions, often behaving conservatively in aquifers. Its concentration is influenced by factors such as pH, alkalinity, calcium availability, mineralogy, and the presence of competing anions like bicarbonate and phosphate. Because of these characteristics, fluoride can provide valuable insights into groundwater origin, residence time, and flow dynamics, as well as potential anthropogenic influences from industrial emissions, fertilizer use, or mining activities. Understanding the dual role of fluoride, as both a contaminant of concern and a potential geochemical tracer, offers opportunities to better link hydrogeochemical research with groundwater management. Tracer studies are increasingly used in hydrogeology to improve aquifer characterization, assess recharge processes, and identify pollution pathways. Positioning fluoride within this framework can contribute to a more detailed understanding of groundwater systems, especially in regions where its concentrations are naturally elevated. The objective of this paper is to review the hydrogeochemical behavior of fluoride in groundwater and to evaluate its potential use as an environmental tracer. In doing so, the paper aims to bridge the gap between studies that treat fluoride solely as a contaminant and those that consider its broader geochemical significance for understanding groundwater origin, flow, and contamination pathways.

Materials and Methods

Fluoride's only stable oxidation state in aqueous environments is –1, and it remains as the fluoride ion (F^-) under both oxic and anoxic conditions (Langmuir,1997; Edmunds & Smedley, 2013; Smedley & Kinniburgh, 2002). Therefore, fluoride mobility in groundwater is governed by mineral solubility equilibrium and adsorption–desorption processes, rather than redox chemistry. Its behavior is particularly sensitive to pH, calcium concentration, and the presence of competing anions such as bicarbonate and phosphate (Smedley & Kinniburgh, 2002; Edmunds & Smedley, 2013; Kim & Jeong, 2005).

Fluoride solubility is controlled by equilibrium with fluorite (CaF_2), a poorly soluble mineral. In calcium-rich waters with near-neutral to slightly alkaline pH, fluoride concentrations in water may be limited by fluorite precipitation. Conversely, in sodium-bicarbonate type waters, often characterized by low calcium content, high alkalinity, and elevated pH, fluoride tends to accumulate due to reduced precipitation and enhanced desorption from mineral surfaces (Apambire et al., 1997; Edmunds & Smedley, 2013).

In this study, the key geochemical controls on fluoride mobility in groundwater are explored and its use as a tracer of subsurface processes is evaluated. Selected case studies from varied geological settings illustrate the applicability of fluoride as a tool for understanding groundwater flow, origin, and evolution.

Results and Discussion

Fluoride concentrations in groundwater can be in a wide range of variability globally, with values ranging from below 0.5 mg/L in fresh recharge zones to well above 5 mg/L in arid, geothermal, or anthropogenically influenced regions (McMahon et al., 2020; Podgorski & Berg, 2022). These concentrations are governed by a complex interplay of natural geochemical factors and, to a lesser extent, anthropogenic activities.

Under oxic conditions, fluoride occurs primarily as a product of mineral weathering. Geogenic sources include fluorite, fluorapatite, and micas, particularly in igneous and metamorphic rocks (Edmunds & Smedley, 2013; Apambire et al., 1997). In such environments, groundwater with high pH and low Ca^{2+} content, commonly $Na–HCO_3$ type waters, exhibit enhanced fluoride mobility due to desorption and suppressed fluorite precipitation (Cao et al., 2023). These conditions are typical in arid and semi-arid zones, such as the East African Rift, North China

Plain, and parts of India and Argentina (Rango et al., 2012; Cao et al., 2023; Aullón Alcaine et al., 2020).

Anthropogenic sources also contribute to elevated fluoride in localized areas. Industrial emissions (e.g., aluminum smelting), phosphate rock mining, and the use of phosphate fertilizers can result in fluoride enrichment, particularly in oxic settings (Cronin et al., 2000; Schlesinger et al., 2020). These contributions are typically limited in spatial extent and secondary to geogenic controls. Under anoxic conditions, fluoride remains stable due to its redox-independence, but its concentrations may increase with longer residence times, mineral dissolution, and lack of adsorption capacity. Confined aquifers, particularly those with elevated bicarbonate and depleted calcium, may accumulate fluoride to levels exceeding 1.5 mg/L, as documented in parts of China’s Datong Basin (Edmunds & Smedley, 2013). Fluoride’s co-occurrence with elements such as arsenic, boron, and lithium, especially under alkaline and oxidizing conditions, further supports its use as a geochemical tracer (Aullón Alcaine et al., 2020; McMahon et al., 2020). Because it is unaffected by redox processes, does not biodegrade, and reflects cumulative geochemical interaction, fluoride is effective for tracing groundwater origin, flow paths, and evolution.

The combined evidence indicates that fluoride’s utility as both a contaminant and a tracer depend on understanding the mineralogy, water chemistry, redox status, residence time and recharge of groundwater. Fluoride quantification alongside other geochemical indicators allows identification of different aquifer zones with distinct recharge origin or lithological signatures, especially in complex hydrogeological settings. In arid and semi-arid regions, evaporation further concentrates fluoride, often alongside sodium and chloride (Edmunds & Smedley, 2013). High fluoride levels in these conditions are indicative of both evaporative concentration and geochemical maturity. In oxic aquifers, particularly in shallow and well-recharged settings, fluoride is primarily geogenic. Although fluoride is redox-independent, elevated concentrations are often found under anoxic conditions particularly in deep, stagnant, or confined aquifers with long residence times, due to extended water–rock interaction rather than redox-driven processes (Smedley & Kinniburgh, 2002). Under reducing conditions, fluoride can be released via desorption from iron and manganese oxides or through sustained dissolution of F-bearing minerals, especially when Ca^{2+} is removed through calcite precipitation (Cao et al., 2023; Edmunds & Smedley, 2013). Anthropogenic fluoride in anoxic aquifers is less frequent but can result from industrial leachates (e.g., phosphate effluents, coal ash ponds) that infiltrate into confined zones. These pollution plumes are often limited in extent and are more difficult to remediate due to slow flow and minimal dilution in confined settings. Figure 1 presents fluoride concentrations in groundwater from reviewed representative aquifer types. Volcanic settings (e.g., East African Rift) show the highest levels (around 10 mg/L), followed by sedimentary–evaporative basins (e.g., China, Texas, around 6 mg/L) and crystalline aquifers (e.g., India, Sri Lanka, around 4 mg/L). These variations reflect the influence of geology and water–rock interaction on fluoride concentration and mobilization.

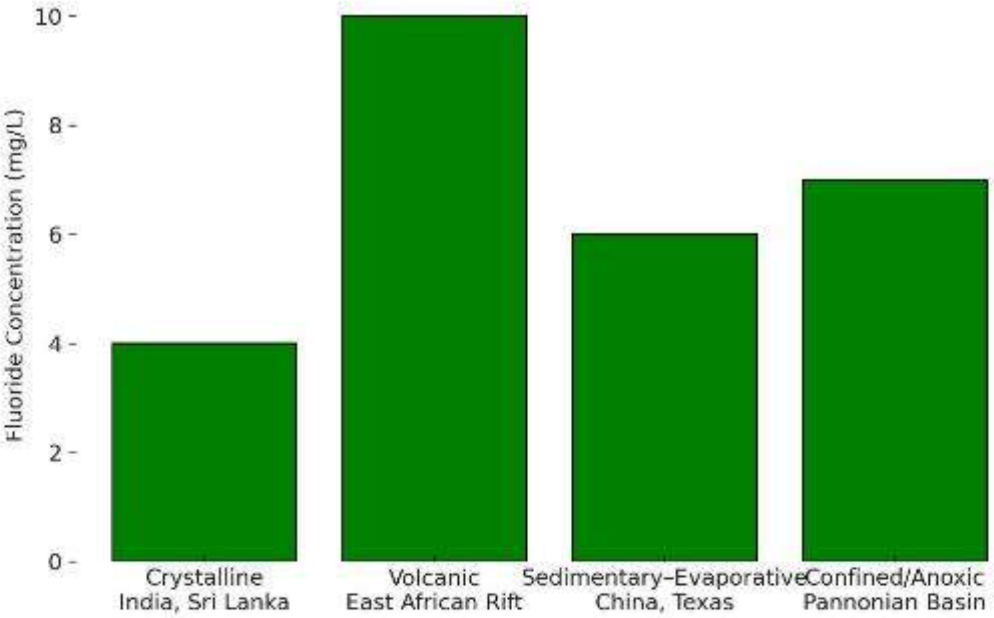

Figure 1. Typical Fluoride Concentrations in Groundwater by Aquifer Type

In the Republic of Serbia, the maximum allowable concentration of fluoride in drinking water is set at 1.2 mg/L, as stipulated in List IIIa of the Rulebook on the Hygienic Safety of Drinking Water (Official Gazette RS, No. 42/98, 44/99, 28/19), while for bottled water, the permitted limit is 1.0 mg/L. According to the Decree on Limit Values of Pollutants in Water, fluoride is also classified as a pollutant in groundwaters, listed under Annex II. Furthermore, the Decree on Emission Limit Values for Pollutants in Wastewater prescribes a maximum discharge concentration of 30 mg/L of total fluoride into surface waters from wastewater treatment processes (Annex 4a.1). In addition, the Rulebook on Permitted Quantities of Hazardous and Harmful Substances in Soil and Irrigation Water (Official Gazette RS, No. 23/94) defines the maximum fluoride content as up to 300 mg/kg in soil and 1.5 mg/L in irrigation water. In the Republic of Serbia, fluoride is not included in the official program for regular monitoring of surface and groundwater quality, although it is classified as a pollutant under national environmental legislation.

Conclusions

Fluoride's occurrence in groundwater is governed by well-defined geochemical processes, particularly its mobilization under alkaline, low-calcium conditions and its conservative behavior in the absence of redox sensitivity (Edmunds & Smedley, 2013; Jayawardana et al., 2010; Smedley & Kinniburgh, 2002). These same properties that make fluoride a contaminant also make it useful as a natural groundwater tracer. Elevated fluoride levels are frequently associated with prolonged water–rock interaction, ion exchange, evaporative concentration, and geothermal influences (Apambire et al., 1997; Podgorski & Berg, 2022). When used in conjunction with other hydrochemical parameters, fluoride can help identify sources of recharge, and reveal subsurface processes such as lithological influence or mixing of geochemically distinct waters (Rao, 1997; McMahon et al., 2020). It is important to emphasize that secondary processes (e.g., calcium influx or pH changes) may alter fluoride concentrations, its widespread measurement and sensitivity to geochemical conditions make it an accessible and powerful tracer (Belitz et al., 2022).

References

Apambire, W. B., Boyle, D. R., & Michel, F. A. (1997). Geochemistry, genesis, and health implications of fluoriferous groundwaters in the Upper Regions of Ghana. Environmental Geology, 33(1), 13–24.

Aullón Alcaine, A., Schulz, C., Bundschuh, J., Jacks, G., Thunvik, R., Gustafsson, J. P., & Bhattacharya, P. (2020). Hydrogeochemical controls on the mobility of arsenic, fluoride and other geogenic co-contaminants in the shallow aquifers of northeastern La Pampa Province in Argentina. Science of the Total Environment, 715, Article 136671.

Belitz, K., Fram, M. S., Lindsey, B. D., Stackelberg, P. E., Bexfield, L. M., Johnson, T. D., Jurgens, B. C., Kingsbury, J. A., McMahon, P. B., & Dubrovsky, N. M. (2022). Quality of groundwater used for public supply across the United States: Source and distribution of fluoride, nitrate, and uranium. ACS ES&T Water, 2(12), 2645–2656.

Cao, W., Zhang, Z., Guo, H., & Li, Z. (2023). Spatial distribution and controlling mechanisms of high fluoride groundwater in the coastal plain of Bohai Rim, North China. Journal of Hydrology, 617(Part A), 128952.

Cronin, S. J., Manoharan, V., Hedley, M. J., & Loganathan, P. (2000). Fluoride: A review of its fate, bioavailability, and risks of fluorosis in grazed-pasture systems in New Zealand. New Zealand Journal of Agricultural Research, 43(3), 295–321.

Edmunds, W. M., & Smedley, P. L. (2013). Fluoride in natural waters. In O. Selinus (Ed.), Essentials of Medical Geology (2nd ed., pp. 311–336). Springer.

Jayawardana, D. T., Pitawala, H. M. T. G. A., & Ishiga, H. (2010). Groundwater quality in different climatic zones of Sri Lanka: Focus on the occurrence of fluoride. International Journal of Environmental Science and Development, 1(3), 244–250.

Kim, K., & Jeong, G. Y. (2005). Factors influencing natural occurrence of fluoride-rich groundwaters: A case study in the southeastern part of the Korean Peninsula. Chemosphere, 58(10), 1399–1408.

Langmuir, D. (1997). Aqueous Environmental Geochemistry. Prentice Hall.

McMahon, P. B., Brown, C. J., Johnson, T. D., Belitz, K., & Lindsey, B. D. (2020). Fluoride occurrence in United States groundwater. Science of the Total Environment, 732, 139217.

Nordstrom, D. K., & Jenne, E. A. (1977). Fluorite solubility equilibria in selected geothermal waters. Geochimica et Cosmochimica Acta, 41(12), 1753–1763.

Podgorski, J., Berg, M. Global analysis and prediction of fluoride in groundwater. Nat Commun 13, 4232 (2022). https://doi.org/10.1038/s41467-022-31940-x.

Rao, N. S. (1997). The occurrence and behaviour of fluoride in the groundwater of the Lower Vamsadhara River basin, India. Hydrological Sciences Journal, 42(6), 877–892. https://doi.org/10.1080/02626669709492085

Schlesinger, W. H., Klein, E. M., & Vengosh, A. (2020). Global biogeochemical cycle of fluorine. Global Biogeochemical Cycles, 34(5), e2020GB006722. https://doi.org/10.1029/2020GB006722

Smedley, P. L., & Kinniburgh, D. G. (2002). A review of the source, behaviour and distribution of arsenic and fluoride in natural waters. Applied Geochemistry, 17(5), 517–568.

World Health Organization. (2006). Fluoride in drinking-water: Background document for development of WHO guidelines for drinking-water quality (WHO/SDE/WSH/03.04/96).

World Health Organization. (2017). Guidelines for Drinking-water Quality (4th ed.). World Health Organization.