Seed Science Research

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Editorial

Cite this article: Barrero JM *et al* (2025). Celebrating the 25th Anniversary of the International Society for Seed Science. *Seed Science Research* 1–8. https://doi.org/10.1017/S0960258525000029

Received: 28 November 2024
Accepted: 4 December 2024

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Celebrating the 25th Anniversary of the International Society for Seed Science

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Foreword from the President

It has been 25 years since the International Society for Seed Science (ISSS) was founded, marking a quarter of a century of shared dedication to advancing seed science worldwide. Over these years, the ISSS has served the scientific community of seed scientists, bringing them together into a vibrant and dynamic community driven by the collaborative spirit of its members. With great pride and a sense of history, I write this foreword to celebrate the society's enduring impact and the remarkable journey we have undertaken together.

The founding of the ISSS is a story of visionaries who recognized the need for a global platform to foster collaboration and innovation in seed science. Mike Black, among others, played a pivotal role in establishing the society, and their legacy continues to inspire our work today.

Central to the ISSS's success has been the dedicated leadership of its presidents, secretaries and treasurers (Table 1). Over the generations, these individuals have shouldered the responsibility of guiding society's growth and direction. They have been supported by the invaluable counsel and contributions of additional trustees serving on the Executive Committee. This collective leadership has shaped the ISSS into the thriving and dynamic organization it is today.

The main focal point of the ISSS is the organization of meetings and conferences. These gatherings have been instrumental in fostering connections, sparking ideas, and shaping careers. For many of us, ISSS conferences have been defining in career moments. They provide a rare opportunity to step away from the daily demands of research and administrative duties and take time to reflect on our research and its place in the broader context of seed science. In an increasingly fast-paced and interconnected world, these interludes are more important than ever. Reflecting on my journey, I vividly recall the excitement of attending my first ISSS conference, meeting future mentors and collaborators, and experiencing the dynamic exchange of ideas that these events facilitate. Science thrives on discovery and collaboration, and ISSS meetings provide the perfect environment to nurture both.

The ISSS values its efforts to support and encourage young scientists. The 14th ISSS Biennial Conference at Sorbonne University in Paris stands out as an excellent example. Through financial support, the society enabled 62 PhD students to attend, offering discounted registration fees and 15 travel grants. These efforts ensure the future of seed science remains bright, with new generations inspired to take up the mantle.

As a global scientific society, the ISSS recognizes its responsibility to contribute to sustainability. We need to be committed to exploring alternative ways for members to connect, including virtual and hybrid meeting formats, to complement in-person gatherings. We will continue to rotate the location of our biennial meetings across different continents, ensuring accessibility for members worldwide and reducing the need for long-distance travel for some. By adopting these practices, we aim to balance the benefits of collaboration and community building with the need to protect our planet for future generations.

Training young scientists remains a cornerstone of our mission, but it is increasingly important to extend our reach beyond traditional academic boundaries. Social media and digital platforms provide opportunities to inspire younger generations about the importance of seeds in agriculture, ecosystems and daily life. Amid growing misinformation, the ISSS plays a crucial role in promoting transparency and collaboration. The transition of our journal,

Table 1. Past, current and future presidents, secretaries and treasurers that served the ISSS

Presidents		Secretaries		Treasurers	
1999–2002	Daniel Côme (France)	1999–2004	Kent Bradford (USA)	1999–2002	Hugh Pritchard (UK)
2002–2005	Ralph Obendorf (USA)	2004–2008	Karen L. Koster (USA)	2002–2010	Kenneth Thompson (UK)
2005–2008	J. Derek Bewley (Canada)	2008–2012	John Dickie (UK)	2014–2024	Steven Penfield (UK)
2008–2011	Patricia Berjak (South Africa)	2013–2017	Peter Toorop (UK)	2024–2027	Jake Chandler (UK)
2011–2014	William Finch-Savage (UK)	2018–2026	Louise Colville (UK)		
2014–2017	Françoise Corbineau (France)				
2017–2021	Henk Hilhorst (Netherlands)				
2021–2025	Julia Buitink (France)				
2025-2029	Fiona Hay (Denmark)				

Seed Science Research, to 'Gold Open Access' emphasizes the society's commitment to accessibility, reproducibility and collaboration. The publisher, Cambridge University Press, provides partial or full waivers to authors from more than 100 low- and middle-income countries, and ISSS members benefit from a reduction in the publication fee.

Over the past decade, our relationship with the International Seed Testing Association (ISTA) has grown. This was notably reinforced during the 10th ISSS Conference in Brazil in 2011, where an ISTA session titled 'Seed Science in the 21st Century' highlighted the intersection of science and application. Since then, our two organizations have held a biannual webinar series focusing on both fundamental and applied aspects of seed science, with presentations from members of our respective organizations. These joint efforts have deepened the ties between seed scientists and technologists, ensuring that our research has practical and far-reaching implications.

The ISSS is a truly global society, with members spanning continents and cultures. This diversity is reflected in the work of our regional representatives, who serve as vital links between the society and its members. They play a crucial role in fostering communication, addressing local needs and ensuring that the ISSS remains inclusive and representative of the global seed science community. To celebrate the diversity and richness of seed science across regions, we invited our regional representatives to reflect on significant achievements, collaborative networks and personal stories that illustrate the impact of seed science in their areas. Their contributions, which you will find below, paint a vivid picture of the global nature of our field and the many ways in which seed science touches lives.

While we strive to connect with all members through our regional representatives, we recognize that not all areas are covered equally. To bridge this gap, we maintain regular communication through our newsletters, website and social media platforms. We encourage all members to take their initiative and propose ideas or activities that enhance the societys outreach and impact. We accept applications for financial support for ISSS-sponsored sessions as part of other scientific meetings and for seed science-related training, and we encourage regional representatives to organize regional webinars. The ISSS thrives on the energy and creativity of its members, and every contribution helps strengthen our community.

In closing, I extend my heartfelt thanks to all who have contributed to the ISSS over the past 25 years. From our founders and leaders to our regional representatives and members, your dedication and passion have made the society what it is today. As we embark on the next chapter of our journey, I am confident that the ISSS will continue to thrive as a hub for the global seed science community.

Julia Buitink – President of the ISSS

Western Europe and Scandinavia (regional representative Olivier Leprince)

Since the creation of the ISSS, numerous European researchers have made major contributions to understanding seed behaviour. Seed coverings and endosperm play crucial roles in development and germination, while seeds themselves carry thermal memory influenced by the mother plant and the embryo. Beyond hormonal and transcriptional control, additional regulatory mechanisms have been uncovered, including epigenetic, translational and post-translational processes. Seeds also harbour microbial ecosystems on their surfaces and within tissues, raising intriguing questions on if and how we can leverage the seed microbiome to combat seed-borne pathogens or increase resilience to climate change. Advances in modelling seed germination now allow for the quantitative description of patterns across thousands of species and seed lots using data from conservation seed banks to address macroecological and evolutionary questions.

Gene banking and biodiversity preservation

This region is also home to major initiatives in seed (gene) banking and preservation of wild and cultivated biodiversity: the Millennium Seed Bank of the Royal Botanic Gardens Kew, IPK-Gatersleben and Svalbard Global Seed Vault. Not only genetic resources are preserved but major progress has been made in understanding the impact of storage conditions on seed ageing and setting standards for safe seed banking. Likewise, efforts on improving conservation through seed banking include the Alpine Seed Conservation and Research Network (http://www.alpineseedconservation.eu/), with five partners from the UK, France, Austria and Switzerland, which has delivered an integrated programme of conservation and research for endangered plant species in the European Alps since 2015. This project is now followed by the LIFESEED FORCE project including 15 institutions from Italy, France and Slovenia.

Creation of seed networks within countries

In several countries, local networks have been established to promote interaction between seed scientists and industrial partners. In France, the French Seed Biology Network gathers over 120

https://doi.org/10.1017/S0960258525000029 Published online by Cambridge University Press

researchers who present their latest results. In the Netherlands, the annual Plantum Dutch Seed Symposium is an interesting network event for academia and the seed industry, where a wide spectrum of issues about seeds and seed physiology are discussed. In the Netherlands, the Seeds for the Future initiative was launched in 2021, a collaboration between seven industrial partners and the Wageningen Seed Science Centre to increase awareness and interest of the public and students for seed science, technology and its global impact. In Italy, a Seed Biology network also exists and has already led to large collaborative projects.

Collaborative research and training

European Union funding, through the EU FP6, FP7, Horizon 2020 and Horizon Europe programmes, has helped to establish and sustain transnational and interdisciplinary groups of scientists. Over the past two decades, there have been numerous large collaborative projects, including ECOSEED, ECOBREED, LIVESEED, LIVESEEDING, VITASEED, BENEFIT-MED and QUINOA4MED, that advanced seed science in many areas, including conservation practices, improved organic seed production, enhancing seed vigour and climate resilience and the creation of seed trait databases. It also led to the establishment of ENSCONET, a European native seed conservation network.

Training of PhD students in seed science is key in this region. Several EU-funded European PhD training networks have been operational, including NASSTEC, Episeedlink and HEADDR. A seed functional ecology winter school also supported by the ISSS was organized in 2021, 2022 and 2023 at the University of Pavia, Italy on theory and practices related to main seed functions: dispersal, persistence and recruitment. Many PhD students, postdoctoral fellows and researchers who began their careers in academia and presented their work at ISSS meetings have since transitioned into the industry, where they now play a significant role in the success of the European seed sector. Several European countries, including France and the Netherlands, are global leaders in seed production and export, driven by their excellence in plant breeding and innovations in seed technology.

Future prospects

Looking ahead, ISSS members from this region have identified key research priorities in seed science, including exploring seed biodiversity, leveraging the seed microbiome and enhancing seed resilience to climate change. Advances in technologies like single-cell analysis, artificial intelligence-driven modelling and genome editing are expected to revolutionize seed biology and its applications. Strengthening collaborations among academia, industry and policymakers will be vital for fostering innovation and implementing research. Equally crucial is engaging younger generations through training and outreach to highlight seeds' critical role in global food security and ecosystem stability.

Eastern Europe (regional representative Tomasz A. Pawłowski)

Eastern Europe is rapidly emerging as a key region for seed research and development, playing an increasingly important role in the global agricultural sector. Countries such as Poland, Ukraine, Hungary and Romania are becoming central to seed research due to the growing need for improving crop yields, enhancing plant resistance to climate change and ensuring food security. One of the region's primary challenges is adapting seeds to harsh climatic conditions, including periodic droughts and frosts, which are becoming more frequent. As a result, research institutes and private companies are working to develop new, more resilient plant varieties capable of thriving in more demanding environments.

History of seed science

The history of seed science in Eastern Europe is rich with contributions from several key figures. Among the most notable is Marianna G. Nikolaeva from the USSR, who developed a system for seed dormancy classification that remains influential in modern seed research. From Poland, Marian Lityński and Stanisław Grzesiuk are pioneers in the broader field of seed science. Stanisław Lewak further contributed to the understanding of dormancy phenomena, while Stanisław Tyszkiewicz and Bolesław Suszka were instrumental in research on forest tree seeds. They developed innovative technologies for seed treatment, from harvesting to sowing, a legacy that continues through the Institute of Dendrology of the Polish Academy of Sciences, which focuses on seed biology, including ecology, dormancy, germination and longevity. It is noteworthy that in 2008, Professor Ryszard Górecki organized the 9th ISSS conference on Seed Biology in Olsztyn, Poland, at the campus of the University of Warmia and Mazury.

Key research institutions

In Eastern Europe, numerous institutions play a crucial role in seed research. In Poland, the Plant Breeding and Acclimatization Institute (IHAR) is one of the most important centres, focusing on genetic research related to seeds, particularly in the development of new crop varieties. Similarly, in Ukraine, the Institute of Plant Physiology and Genetics of the National Academy of Sciences invests in innovative plant breeding technologies, which are essential for improving agricultural output. In the Czech Republic, Palacky University Olomouc is a significant research institution conducting studies on legumes. In Hungary, research on the conservation and restoration of grassland ecosystems is carried out at the University of Debrecen and the Institute of Ecology and Botany. In Slovakia and Lithuania, studies on seed germination stimulation using non-thermal plasma are being developed at Comenius University Bratislava and Vytautas Magnus University, respectively. In Romania, the University of Galați is focused on improving the quality of grain seeds, while in Serbia, the Institute for Plant Protection and Environment conducts research on seed quality. In Estonia, the University of Tartu is known for its research on seed banks, while in Russia, the Timiryazev Institute of Plant Physiology and St. Petersburg State University are recognized for their work on seed dormancy and germination. International cooperation, particularly in and with European Union countries, supports the advancement of research and the implementation of modern technologies.

Seed banks and conservation

A major achievement in Eastern Europe has been the establishment of large-scale seed banks for preserving genetic diversity. Poland's National Centre for Plant Genetic Resources stores over 70,000 accessions of various plant species, including cereals, legumes and vegetables. The Kostrzyca Forest Gene Bank focuses on

https://doi.org/10.1017/S0960258525000029 Published online by Cambridge University Press

preserving forest species. In the Czech Republic, the Agricultural Research Institute Kromeriz holds a collection of barley, oats and rye, with nearly 6,000 accessions. Similarly, Hungary's National Centre for Biodiversity and Gene Conservation plays a significant role in plant gene preservation, while other nations in the region maintain their national seed banks, contributing to global biodiversity conservation and climate resilience efforts.

Conclusion

Eastern Europe's contributions to seed science and education are vast and growing. With a rich history of pioneering research and ongoing advancements in biotechnology, organic seed development and genetic studies, the region is playing an essential role in shaping the future of agriculture and forestry, food security and environmental sustainability. The potential for further innovations in the face of climate change makes Eastern Europe a significant player in the international agricultural and natural landscape.

North America (regional representative Héctor E. Pérez)

The North American region has made significant global contributions to seed science over the past 25 years. Individual researchers, research groups and consortia have driven advancements in seed behaviour, storage and germination. Initiatives like the USDA Hatch Program and the establishment of the Seed Biotechnology Center (SBC) at UC Davis (https://sbc.ucdavis.edu/) exemplify efforts to solve agricultural challenges and strengthen ties with the global seed industry.

Key contributions to seed biology

Allison Kermode and Derek Bewley's work on seed development opened the door for questions related to how development influences seed storage physiology. Subsequently, Christina Walters expanded our understanding of the anatomical, biophysical, biochemical and physiological aspects of seed development with respect to storage physiology and seed deterioration. Peggy Ozias-Akins' work on apomixis enabled current methods of clonal seed propagation for hybrid crops.

Our knowledge of seed dormancy and its alleviation, ecology and evolution expanded considerably due to the prodigious efforts of Carol and Jerry Baskin. Their work included major syntheses of seed dormancy across global biomes, in-depth analyses of physical dormancy and the characterization of dormancy cycling. Marc Cohn's work on dormancy and its relation to the domestication of rice was also groundbreaking.

Kent Bradford introduced population-based threshold (PBT) modelling to seed science. This broadened our perspectives on the integration of environmental and physiological signals that control ageing, dormancy and germination. Along the way, Phil Allen and Susan Meyer made important contributions in terms of ecological applications of PBT modelling.

Alvin Yoshinaga developed a long-term seed longevity study of the Hawai'ian flora, which is in its 29th year. The study is unique in that seeds of wild species are being stored at different combinations of moisture content and temperature for longer than previously reported. The significant revelation was that seeds that tolerated extreme desiccation and storage at freezing temperatures did not necessarily store better at freezing temperatures than at 5°C, but this was not apparent until after many months or years.

Advances in seed science education

Derek Bewley and colleagues published several important books that serve as essential references for researchers and students. Allison Kermode, Lawrence Copeland, Miller McDonald, Sabry Elias and other authors published books on topics such as seed conditioning, seed testing and other technological aspects of seed science. McDonald and Copeland's 1989 laboratory manual has been reprinted several times and makes an outstanding resource for anyone teaching seed biology. Likewise, Carol and Jerry Baskin's monumental work on seed dormancy and germination ecology stands as a foundational text while also serving as an essential work across the botanical sciences. More recently, Baskins and co-authors ask readers to consider the consequences of global climate change on a spectrum of processes involved in plant regeneration from seeds.

Members of the North American region have also contributed to seed science education with a variety of in-person and online programmes. For example, the SBC offers in-person courses for graduate students, faculty and industry professionals on seed production; the seed business and seed biology, quality, and pathology. The Iowa State University (ISU) Seed Science Center created an online graduate programme in Seed Technology and Business designed for seed sector professionals. Similarly, Colorado State University offers an online certification programme for people interested in becoming certified seed analysts or technologists.

Personal reflections

My first experience with the ISSS was attending the 7th International Workshop on Seed Biology in Salamanca, Spain as a graduate student. It was amazing meeting many of the scientists whose research informed my research. But it was also intimidating as a first-generation college student with no previous experience attending such events. What stood out was how welcoming everybody was despite my neophyte status. It was interesting to see how colleagues could have spirited debates during the day but then share good times together in the evening. I feel that this sense of community, where the 'titans of seed science' are humble enough to interact with students or other pre-career professionals in meaningful ways, is one of the distinctive competencies of the ISSS.

China (regional representative Si-Chong Chen)

The diversity of China's flora and the role of seed science

With over 30,000 plant species, China boasts one of the world's most diverse floras. This biodiversity is critical for maintaining ecological balance and offers opportunities for advancements in agriculture, conservation and ecosystem restoration. Recognizing the importance of seed science, China has made it a cornerstone of efforts to address global challenges such as climate change, biodiversity loss and food security. Supported by a robust network of research institutions and scientists, the nation has advanced both fundamental and applied aspects of seed science, contributing significantly to global research.

Progress in seed science research

China's seed science research has flourished in recent decades, evidenced by a dramatic increase in high-quality publications

https://doi.org/10.1017/S0960258525000029 Published online by Cambridge University Press

that have bolstered its leadership in the field. Studies on seed dispersal, dormancy, germination and adaptive strategies have improved biodiversity conservation practices. Organizations such as the Botanical Society of China and its Seed Science and Technology Committee have fostered collaboration and hosted major events, including the 4th International Seed Ecology Conference held in Shenyang in 2013 and the 11th Seed Science Conference of the ISSS in Changsha in 2014.

China's advancements in crop seed research, particularly in drought and pest resistance, underscore its leadership in sustainable agriculture. The integration of genomic editing and molecular biology has enabled precise modifications in seed traits, enhancing crop yields and resilience. A landmark achievement in this field is the development of high-yield hybrid rice by Longping Yuan and his team, which revolutionized global food security by significantly boosting rice production and alleviating poverty. This innovation highlights the transformative potential of seed science in addressing hunger and malnutrition.

China excels in preserving plant genetic diversity through initiatives such as the Kunming Institute of Botany's Germplasm Bank of Wild Species, which houses over 95,000 seed samples. These efforts contribute to *ex situ* conservation, safeguarding endangered and endemic species. Other facilities focus on preserving regional and ecological resources, such as Tibetan Plateau flora and essential forestry species. Institutions like the National Crop Genebank of China also play pivotal roles in conserving crop genetic resources and advancing research to address Anthropocene challenges.

Education and public outreach in seed science

Seed ecology plays an essential role in science education and public awareness in China. Botanical institutions such as the National Botanical Garden and Shanghai Chenshan Botanical Garden actively engage the public in seed conservation. Events like the Chinese Academy of Sciences' annual 'Science Popularization Week' integrate seed science activities to educate about biodiversity and conservation.

At Wuhan Botanical Garden, initiatives like the 'Seed Observer' programme offer immersive experiences where students learn about seed dispersal methods and the cultural significance of seeds. Activities, such as making rice balls and sharing stories of pioneers like Longping Yuan, foster a deeper understanding of the critical role seeds play in ecosystems, agriculture and human life.

Future prospects

Looking ahead, the future of seed science in China holds immense promise both nationally and globally. As research advances, new discoveries will enhance our understanding of seed ecology and its applications in fields such as ecosystem restoration and conservation biology. By fostering interdisciplinary research and international collaboration, China can continue to contribute to addressing global challenges such as biodiversity loss and food security. Through these efforts, and by continuing to inspire future generations through education, China will play a pivotal role in shaping sustainable agricultural and conservation practices worldwide.

Australia and New Zealand (regional representative Jose Barrero)

Seeds play a vital role in Australia and New Zealand, where agriculture is a cornerstone of our economy. Australia, for example, is one of the world's major seed exporters, contributing significantly to global food security. Our region is home to approximately 50 ISSS members, although the number of scientists working in seed research across Australia and New Zealand is at least 10 times that.

Seeds have always been important in Australia, not only for modern agriculture but also for Aboriginal Australians, who have long relied on them as a staple food source and for cultural practices. The importance of seed science in our region is highlighted by several key achievements. For instance, the discovery of karrikin, the active smoke compound capable of triggering seed germination, was made at Kings Park and Botanic Garden in Perth. We have also organized several successful National Seed Science Forums, such as the one at Mount Annan near Sydney in 2016 and the Australian Seed Science Conference in Canberra in 2021. These events have demonstrated the vibrant seed science community in Australia and New Zealand and its contributions to global seed science knowledge.

Personal reflections

Attending ISSS conferences has been one of the highlights of my career. I have participated in conferences in Paris (2013), Changsha (2014), Monterey (2017) and virtually at Kew Gardens (2021). I have also served on the organizing committees of several other events. Each conference has provided an opportunity not only to share scientific insights but also to reconnect with colleagues and friends.

The ISSS conference has only been hosted in Australia once before, in Brisbane in 2005. In 2017, I prepared a proposal to host the conference in Perth (Western Australia) in 2020. Although that bid was not successful at that time, I am thrilled that the next ISSS conference in 2025 will finally be held in Perth, providing a unique opportunity to showcase Australia's expertise in seed science.

Looking forward to ISSS 2025 in Perth

The 2025 conference will be held from September 15th to 19th, organized by Dr David Merritt and hosted at Kings Park, home to the renowned Western Australian Botanic Garden. The Western Australian wheat-belt region is the most productive cereal-growing area in Australia, and this conference will undoubtedly attract international delegates interested in seed crops such as wheat, barley, canola and beans. Moreover, the conference will highlight our region's contributions to seed ecology, conservation and innovative technologies, such as smoke technology and weed control.

Hosting the ISSS conference in Perth will not only increase the visibility of Australian seed science but also provide valuable networking opportunities for young scientists and industry partners. It will strengthen existing collaborations and open up new avenues for partnerships and funding.

As we commemorate the 25th Anniversary of the ISSS, I want to highlight the strong sense of community within our society. The ISSS has been a constant source of inspiration and collaboration, and I am excited about the future of seed science in our region. I look forward to welcoming you all to Perth to celebrate the ISSS's 25th Anniversary in person!

Central and South America (regional representative Edvaldo Aparecido Amaral Da Silva)

Central and South America serve as vital centres of biodiversity and are globally significant for breeding and seed multiplication.

https://doi.org/10.1017/S0960258525000029 Published online by Cambridge University Press

Countries such as Argentina and Brazil have heavily invested in developing seed science and agriculture through government-led strategies initiated in the 1970s. These efforts included training programmes that nurtured a generation of scientists: pioneers like Prof. Luiz Fernando Gouvêa Labouriau, who contributed to thermal biology and the development of thermal time models, are now widely used to predict climate change impacts. In the second generation of seed scientists, researchers like Prof. Roberto Benech-Arnold, who focused on ecophysiology, helped establish the region as a leader in robust scientific research. These scientists came from diverse academic backgrounds and laid the foundation for a new generation to explore seed biology creatively in the Neotropical area. Their work has been instrumental in addressing agricultural challenges while respecting native species.

Seed scientists in the region have actively worked to preserve and utilize biodiversity, developing new crop cultivars with improved traits. Research efforts have also expanded to extend the shelf life of seeds, crops and forest species. Many Central and South American countries have implemented seed certification programmes to ensure the quality of seeds sold to farmers. Some of these programmes, such as Brazil's framework established by the Ministry of Agriculture, Livestock, and Food Supply, are considered state of the art.

More recently, molecular biology has been at the forefront of developing innovative seed technologies, such as biofortification to enhance the nutritional content of crops, precision breeding techniques to accelerate the development of new cultivars, and seed priming methods to improve germination and early plant growth. The seed industry in Central and South America has experienced significant growth in recent years due to a constant commitment to new technologies, such as image analysis, driven by the increasing demand for high-quality seeds.

Modern seed science has therefore profoundly impacted Central and South America's agricultural landscape, boosting productivity, resilience and food security. Genetically modified (GM) seeds and hybrid cultivars have increased yields and addressed climate-related challenges. Researchers are actively developing cultivars with enhanced tolerance to drought and heat. The focus on producing high-vigour seeds has been crucial in meeting growing agricultural demands.

Seed science education

Since 1997, ISSS members have conducted seed science courses in Brazil, starting in Lavras, Minas Gerais, led by Dr Henk Hilhorst. Later editions in São Paulo featured Prof. Derek Bewley, Prof. Kent Bradford, Dr Peter Toorop, Prof. Olivier Leprince, Dr Julia Buitink and Brazilian scientists. Initially focused on seed biology, the courses later addressed genetic resource conservation, bioinformatics, seed maturation and longevity. Collaborative research and PhD programmes further supported regional education. Dr Hilhorst's efforts in promoting science and education in this region and in training new seed scientists and inspiring students deserve special recognition.

Future prospects

Some of the world's largest agricultural producers are located in South America. Thus, seed science and research in Central and South America reflect an emphasis on sustainability, innovation and resilience in agriculture. Researchers are focusing on developing seeds with drought tolerance, heat resistance, disease resistance and higher vigour to ensure crop productivity. There is increasing use of biotechnology tools such as genetic engineering to enhance crop traits and seed quality. Efforts to conserve traditional seed varieties are advancing in Central and South America. The adoption of precision agriculture techniques is also influencing seed research and development in the region. Collaboration among research institutions, government agencies, seed companies and farmers is prominent. With a growing demand for organic and sustainably produced food, there is a trend towards developing organic seed cultivars and promoting sustainable seed production practices. The use of image analysis combined with artificial intelligence to ensure assertive interpretations of seed quality is increasing.

India (regional representative Dunna Vijay)

India's rich biodiversity and seed science landscape

India is home to approximately 7–8% of the world's documented species, encompassing four of the 34 globally recognized biodiversity hotspots. Diverse edaphic, climatic and topographic conditions allow for a wide range of ecosystems, habitats and year-round cultivation of various crops. Seed research in India is conducted by numerous organizations, each with specific mandates. Institutions under the Indian Council of Agricultural Research (ICAR), such as the Indian Agricultural Research Institute (IARI) and the Indian Institute of Seed Science, focus on agricultural species. The ICAR-National Bureau of Plant Genetic Resources specializes in germplasm conservation, while institutes like the Forest Research Institute and the ICAR-Indian Grassland and Fodder Research Institute focus on forest and forage crops, respectively. Additionally, national institutes and universities, including NIPGR, NBRI, Nalanda University, Delhi University and several Private Universities, work on both basic and applied seed research.

Collaborative research efforts

Collaborative research under the All India Coordinated Research on Seed (crops) involves 24 organizations, generating extensive data on seed production. This includes seed rate, planting windows, hybrid seed production technologies, flowering synchronization and alternate seed production areas. These collaborations have also led to the development of varietal descriptors for safeguarding novel plant varieties and protocols for seed germination and dormancy alleviation in certain crops. Advances in genetic purity and hybrid testing, seed quality enhancement and seed-borne pest and pathogen regulation have emerged from these efforts. Crop-specific grading sieves and air-drying protocols have improved seed handling and storage.

Seed science education

Seed science education in India comprises well-organized course curricula. It started as a separate discipline in the 1960s, and now, all major agricultural universities offer master's and doctoral programmes in Seed Science and Technology. This provides trained human resources to cater to India's seed production, certification and research needs.

The Indian seed sector

India's seed sector uniquely balances contributions from both public and private sectors. Initially supported by public initiatives,

https://doi.org/10.1017/S0960258525000029 Published online by Cambridge University Press

the private sector has grown significantly and operates independently. In the early nineteenth century, India recognized the significance of seeds for agricultural development and established several improvement programmes. A highly significant strong positive correlation was observed between certified seed distribution and crop yield and food grain production in the last 34 years. Thus, high-quality seeds are considered one of the main pillars of the success of the green revolution in India.

Seed science played a crucial role in policy development, resulting in India occupying the fifth position in the global seed market. Policy support has been instrumental in the steady growth of seed replacement rates in major food crops. India's robust seed testing infrastructure, which began with its first laboratory in 1961, now includes 145 government-notified laboratories and numerous private facilities, ensuring high-quality seeds for farmers.

India has emerged as the frontrunner in developing numerous biofortified varieties, aiming to guarantee nutritional security for its expanding population. Similarly, the climate-smart varieties are being developed on a large scale under the climate change mitigation strategy. Of the total varieties released in 2014–2019, 83% are climate resilient for various characteristics.

Future prospects

With the development of new varieties and the incorporation of new traits, the role of seed science is increasing in importance. Also, the involvement of the latest technological tools and artificial intelligence in seed testing procedures is necessary. The ISSS can contribute significantly through student and faculty exchange programmes and by organizing scientific meetings to strengthen the research ecosystem. Collaborative projects with advanced seed labs in developed countries can help address the gap in strong research leadership in India. Through these efforts, India's seed science sector can continue to grow, addressing challenges in agriculture and supporting global food security.

Africa (regional representative Chris O. Ojiewo)

The current state of the seed sector in Africa

Access to quality seeds of improved varieties is essential for enhancing agricultural productivity, a cornerstone of initiatives like the Comprehensive Africa Agriculture Development Programme (CAADP), the African Union (AU) Agenda 2063 and the United Nations Sustainable Development Goals (SDGs). These seeds enable farmers to achieve higher yields, adapt to climate change and ensure food security. However, the African seed sector faces significant challenges, including inadequate infrastructure and limited capacity among stakeholders, which hinder its ability to meet farmers' demands effectively.

The African Seed and Biotechnology Programme (ASBP) serves as the African Union's strategic framework for seed sector development, established in 2007. It aims to enhance food security, nutrition and poverty alleviation by creating efficient seed systems and integrating biotechnologies. ASBP's implementation relies on the African Seed and Biotechnology Partnership Platform (ASB-PP), which fosters collaboration among AU institutions, regional economic communities, development partners and experts. The platform strengthens technical and functional capacities by promoting partnerships and sharing information on seed development projects. Its governance includes both Thematic and Geographic Working Groups.

The Partnership for Integrated Seed Sector Development in Africa (PISSA) aims to contribute to implementing the ASBP within and across countries, regions and the continent. It emerged through consultations involving ASBP stakeholders, including Wageningen University and Research (WUR) Alliance for a Green Revolution in Africa (AGRA), CGIAR SeedEqual Initiative, Crop Trust, Food and Agriculture Organization (FAO), International Seed Federation (ISF), Seed Systems Group, The Africa Seed Access Index (TASAI), GRAD Consulting Group, Resilience and Sahel Consulting, Sub-Regional Organizations, African Development Bank (AfDB) including through its Technologies for African Agricultural Transformation (TAAT) Ecosystem and The World Bank's Food System Resilience Program for Eastern and Southern Africa.

Seed science and education

Many African scientists have moved the field of seed science forward. Patricia Berjak, a renowned South African scientist, exemplified this impact through her role as President of the ISSS from 2008 to 2011. Her pioneering research on recalcitrant seeds and desiccation sensitivity has profoundly influenced seed biology and conservation. Under her leadership, her team initiated a series of workshops focused on desiccation sensitivity and tolerance in seeds and resurrection plants from 1994 onwards that were sponsored by the ISSS. This ongoing series highlights the vital role of Africa in addressing global challenges related to seed science and plant resilience.

Between 2006 and 2016, the AGRA funded the training of 55 MSc students (21 female) in Seed Science and Technology from 12 countries, focusing on over 15 crops at African universities, including Makerere University Regional Center for Crop Improvement (MaRCCI), West Africa Center for Crop Improvement (WACCI) at the University of Ghana and the Africa Center for Crop Improvement (ACCI) at the University of KwaZulu-Natal. Since 2007, WACCI has enrolled 109 MPhil students in Seed Science and Technology from 13 countries, with 50 graduates now strengthening their national agricultural research systems. WACCI also hosts 117 PhD holders in Plant Breeding across 15 African countries and serves as a VACS (Vision for Adapted Crops and Soils) Capacity Hub, enrolling 87 PhD and 45 MSc students to address Africa's food security challenges. Established in 2002, ACCI offers Pan-African postgraduate programmes in Plant Breeding and Seed Science. MaRCCI, building on Makerere University's PhD and MSc programmes initiated by RUFORUM in 2008, provides MSc training in Plant Breeding and Seed Science. These universities are key providers of postgraduate training in Seed Science and Technology in Africa.

Future prospects

Under the PISSA framework, endorsed by the African Union Commission (AUC) and the African Union Development Agency (AUDA), stakeholders will focus on areas such as policy and regulatory frameworks, genetic resource conservation, variety improvement, seed production technologies and biotechnology adoption. Emphasis will also be placed on DNA-based quality assurance, seed storage and post-harvest handling. Working groups have been established to ensure cross-sectoral collaboration and effective implementation of these initiatives. By addressing these challenges and leveraging collaborative frameworks,

https://doi.org/10.1017/S0960258525000029 Published online by Cambridge University Press

Africa's seed sector has the potential to transform agricultural productivity and contribute to sustainable development across the continent. ASBP is also a stakeholder in the Seeds for Food Coalition, which aims to (i) ensure that farmers have ongoing access to diverse seeds for their varied needs; (ii) support the development of inclusive, sustainable seed sectors that serve diverse farmers and agri-food systems and (iii) engage food, health, environmental and financial sectors to highlight the critical role of equitable seed systems in transforming agri-food systems.

Japan (regional representative Naoto Kawakami)

The Japanese islands extend north to south, subarctic to subtropical zones, and the range of mountains creates a variety of weather conditions. The Asian monsoon climate brings wet and dry seasons. These conditions brought about rich biodiversity, whereas unstable and unseasonable weather conditions sometimes cause trouble in crop and seed production.

Bioresources and seed banks

The Genebank Project of the National Agriculture and Food Research Organization (NARO) plays a pivotal role in preserving and distributing genetic resources, with 240,000 accessions stored and 5,000–10,000 distributed annually for research, development and education. Complementing this is the National BioResource Project (NBRP), established in 2002, which provides genetic, genomic and phenotypic data for eight plant groups, including rice, wheat and barley. These efforts support seed research, development and the distribution of experimental plant lines, ensuring the availability of diverse bioresources.

Seed science meetings, education and publications

Two prominent seed science organizations contribute to advancing the field in Japan. The Japanese Society for Seed Physiology and Biochemistry, founded in 1979, promotes seed science through annual meetings involving over 120 members from universities, research institutes and private companies. Key publications, including *Seed Bioscience* and *Seed Science and Biotechnology*, have consolidated knowledge in the field. Another vital organization, the Japanese Society for Preharvest Sprouting, established in 1996, focuses on seed dormancy and germination research, particularly addressing preharvest sprouting in cereals – a significant issue in Japan's wet and rainy summers. Notable achievements include the development of sprouting-resistant wheat cultivars by Shun-ichi Osanai, whose innovative breeding strategies have become integral to national programmes for enhancing seed dormancy traits.

Educational resources have played a crucial role in disseminating seed science knowledge. The book *Seed Germination – Physiology, Ecology and Molecular Mechanisms* – is widely regarded as a key reference for students and researchers, offering review articles, research updates and experimental protocols. International collaboration has also been a hallmark of Japan's seed science community. Events like the 6th Plant Dormancy Symposium (2018) and the 15th International Symposium on Preharvest Sprouting in Cereals (2023) have provided platforms for scientists worldwide to discuss advances in seed dormancy, germination and crop improvement.

Recent advances and future prospects

Recent research breakthroughs backed by bioresources have further strengthened Japan's contributions to seed science. Over the last decade, key seed dormancy genes such as *Sdr4*, *MFT* and *MKK3* have been identified in crops like rice, wheat and barley, enabling a deeper understanding of phase transitions and temperature-dependent germination. Emerging approaches with chemical biology and artificial intelligence will enrich and accelerate our understanding and application. The promotion of collaboration among academia, public research institutes and industry will be the key to achieving food security and climate change adaptation.

Acknowledgements. We would like to give our heartfelt thanks to the members that contributed to these different sections: Clement Adjorlolo, Mariana Silva Artur, Christophe Bailly, Alma Balestrazzi, Kent Bradford, Angelino Carta, Eric Danqua, Beatrice Egulu, Abdulrazak Ibrahim, Raquel Iglesias, Frank Lanfermeijer, Rufaro Madakadze, Andrea Mondoni, Husein Shimelis, Alvin Yoshinaga, Marie-Hélène Wagner and Dustin Wolkis.

https://doi.org/10.1017/S0960258525000029 Published online by Cambridge University Press