# ANNUAL REPORT 2021

WHEAT INITIATIVE

## ORGANISATION OF WHEAT INITIATIVE

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|---|---|
| **Chair Research Committee** | Frank Ordon |
| **Chair Institutions' Coordination Committee** | Nicole Jensen / John Spink |
| **Chair Scientific Board** | Peter Langridge |
| **Wheat Initiative Programme Manager** | Teresa Saavedra-Bravo |
| **Communications Manager** | Xuan Hinzmann / Nora Henneberg-Sprekeler |
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COORDINATING GLOBAL
WHEAT RESEARCH

# CONTENT

## THANK YOU VERY MUCH FOR YOUR INTEREST IN OUR WORK

2021 was a landmark year for the Wheat Initiative (WI) as we celebrated the 10-year anniversary of this major global collaboration. We marked the event with the support of our community, and our webpage showcases videos, quotes, milestones, and more. We are grateful for the support we have received for the last 10 years and look forward for the years to come.

In early 2021 the WI participated in the Stocktaking exercise under Italian Presidency of the G20. On June 15 - 16 the G20 Agricultural Chief Scientists (MACS-G20) met, and the WI was invited to participate. This gave us an opportunity to outline new wheat breeding technologies and the importance of wheat research to support global food security.

On September 2nd, we joined the G20 workshop on Climate Change along with colleagues from our Associated Programme "International Wheat Yield Partnership" (IWYP) and addressed participants on the challenges that climate changes imposes to food security.

Although 2021 proved to be a difficult year in the face of the ongoing COVID 19 pandemic, the WI community once again demonstrated its resilience, adaptability, and drive to deliver against our common objectives.

Great news in 2021 was that the WI welcomed the Republic of Korea as a new member.

During 2021 we began work on a key milestone, the update of our 2015 Strategic Research Agenda. This has been a collaboration across our community and was completed with the launch of the new Strategic Research Agenda in mid-2022.

The second International Wheat Congress (IWC), postponed to 2022, will now be held as a hybrid model. Despite our hopes that this would be an event where wheat researchers could meet face-to-face again, this cannot happen given the current constraints. However, there is strong commitment from the entire international wheat community to deliver a successful hybrid model.

The Expert Working Groups (EWGs) continue to be the mainstay of the WI and we would like to thank, once more, the Chairs and members for their excellent work and dedication to maintain their interactions through meetings, workshops and training activities using the available virtual tools. You will learn more about the great work of the EWGs in the following sections where each EWG provide a report on their activities and plans.

Importantly, a new program proposal emerged from the Pest and Diseases EWG which aims to support the establishment of a global disease diagnosis and monitoring system to assess disease severity and spread. This effort will now be taken over by the new Pathogens EWG.

WheatVIVO, an open-access web portal, was officially launched to the public in November 2021 (https://wheatvivo.org/). It aims to provide information on wheat researchers, organisations and projects. Feedback from users has been encouraged and improvements are continually being made.

During 2021, some of our EWGs went through a process of change of Chairs and Co-Chairs. We would like to express our thanks to Thomas Payne (CIMMYT) and Ahmed Amri (ICARDA) who were Chairs of the Germplasm EWG since its inception; and to Gilles Charmet (INRAe) and Chris Burt (RAGT) who served as Chair and Co-Chair of our Breeding EWG respectively.

We welcome the new chairs and co-chairs: for our Germplasm EWG, Benjamin Killian (Global Crop Diversity Trust) Shivali Sharma (Global Crop Diversity Trust), Hakan Özkan (University of Çukurova), Peter Civáň (INRAe); and for our Breeding EWG Sanjay Kumar Singh (ICAR) and Suchismita Mondal (Montana State University).

The International Wheat Yield Partnership (IWYP), a WI affiliate program has continued to deliver against its strategic plan, with an emphasis on the validation and translation of scientific insights related to increasing wheat yield.

Since its creation in 2020, the international umbrella organization, the Alliance for Wheat Adaptation to Heat and Drought (AHEAD), has continued to grow thanks to the support of the Julius Kühn Institute and the German Ministry of Food and Agriculture. In 2021, Stefanie Hagemann became AHEAD's new global coordinator. She has brought new ideas and energy to the Alliance, and in 2021, three more members joined AHEAD and two workshops were held.

The WI is managed by three committees: the Institutions´ Coordination Committee (ICC), the Research Committee (RC) and the Scientific Board (SB). As in the previous year, during 2021 the two committees and the board were unable to meet in person. Therefore, virtual meetings were held with the members of the ICC in April and November, and with the members of the RC in October. The SB continues to meet virtually every month, as do the chairs of the three committees.

In 2021, two members of the SB, Hirokazu Handa and Curtis Pozniak, finished their terms on the SB. After a call for nominations, the October RC meeting appointed of three new members, expanding the skill base of the SB: Sylvie Cloutier (Agriculture and Agri-Food Canada), Hisashi Tsujimoto (Tottori University) and Roberto Tuberosa (University of Bologna). We also thank Silvia German (INIA) and Fiona Doohan (University College Dublin) for agreeing to stay for a second term as SB members.

The Secretariat and all the members of the WI thank Hirokazu and Curtis for their hard work on the SB. Both have been involved since the WI was created in 2011 and they have made fantastic contributions to WI activities and its development.

Nicole Jensen, our ICC Chair, completed her term as Chair and did not stand for re-election. In late 2021 John Spink, Head of Crops, Environment and Land Use Programme, Teagasc, was appointed as new Chair.

We would like to thank Nicole for the time she devoted to the WI, her commitment and dedication, and the many initiatives she helped develop. The WI has benefited greatly from her time as Chair and we look forward to our continued collaboration as she continues as a member of the ICC.

During the October RC meeting, members agreed to renew the appointment of Frank Ordon, and Pierre Devaux, as Chair and Co-Chair of our RC respectively. They have both graciously accepted to stay for another term.

The WI's communication has remained active: the newsletter, media brief and website have continued as planned and subscriptions to these free services have increased significantly.

In addition, the WI Secretariat has provided support, guidance and assistance to the EWGs in organizing virtual meetings, workshops and training sessions. The secretariat has edited videos for subsequent uploading to the WI website to make them available to a wider public.

There have been changes to the staffing of the WI Secretariat. Anja Haudricourt left us at the end of the year and our Communications Manager, Xuan Hinzmann, went on maternity leave. We would like to thank Anja for her hard work while with us and congratulate Xuan on her third child. Sandra Bischoff is our new Administrative Assistant, and Nora Henneberg-Sprekeler, our new Communications Manager. We are pleased that the WI Secretariat is fully staffed again.

The WI Secretariat is working hard to ensure the efficient operation of the organisation and to create synergies with all in the wheat community.

Dr Nicole Jensen, former Chair, Institutions Coordination Committee
Dr John Spink, Chair, Institutions Coordination Committee
Prof. Dr Frank Ordon, Chair, Research Committee
Prof. Dr Peter Langridge, International Science Coordinator & Chair, Scientific Board

# 1. INTRODUCTION

# INTRODUCTION

## WHAT TO EXPECT IN THE 2021 ANNUAL REPORT

Thank you for your interest in our 2021 Annual Report. Continuing with the modified version of the report used in response to the Covid-19 pandemic, this report aims to show how the wheat research community adapted to the new times, moving activities to a virtual world.

The 2021 annual report contains information about developments in global wheat research, starting with the WI's profile, advances on our newest associated programme, AHEAD, and the future plans of our EWGs (including the creation of a new associated program). We are also pleased that the process of updating our Strategic Research Agenda was able to start in late 2021.

We thank our members, including representatives from member and observer countries, organisations and private companies, for providing us with an overview of their activities, which are included in this report. The communication section outlines the media channels being used and the actions and initiatives created to celebrate our 10th anniversary. The annual report concludes with a financial overview of 2021.

We are a growing and evolving community, adapting to challenges. Every member of the WI is valuable and helps to shape and achieve success in wheat related research. If you would like to help us on our mission to assure food security through wheat improvement, please do get in touch with us on wheat.initiative@julius-kuehn.de or click below.

Get involved, stay informed and shape wheat research by:

- Becoming a member: https://www.wheatinitiative.org/become_a_member
- Becoming an Expert Working Group Member: www.wheatinitiative.org/expert-working-groups-2
- Signing up for the quarterly newsletter: www.wheatinitiative.org/newsletter
- Signing up for the weekly "Wheat In The Media" media: www.wheatinitiative.org/wheat-in-the-media

The WI is an international organisation endorsed by the G20 Agriculture Ministers in 2011. It draws together multiple countries and organisations to address global challenges facing wheat production.

From its creation in 2011 and until 2018, the WI Secretariat was hosted in France at the Institut National de la Recherche Agronomique (INRAE). In 2018, it moved to its new host institution and country, the Julius Kühn Institute (JKI) in Berlin, Germany, where it has been well supported by the Ministry of Food and Agriculture (Bundesministerium für Ernährung und Landwirtschaft, BMEL).

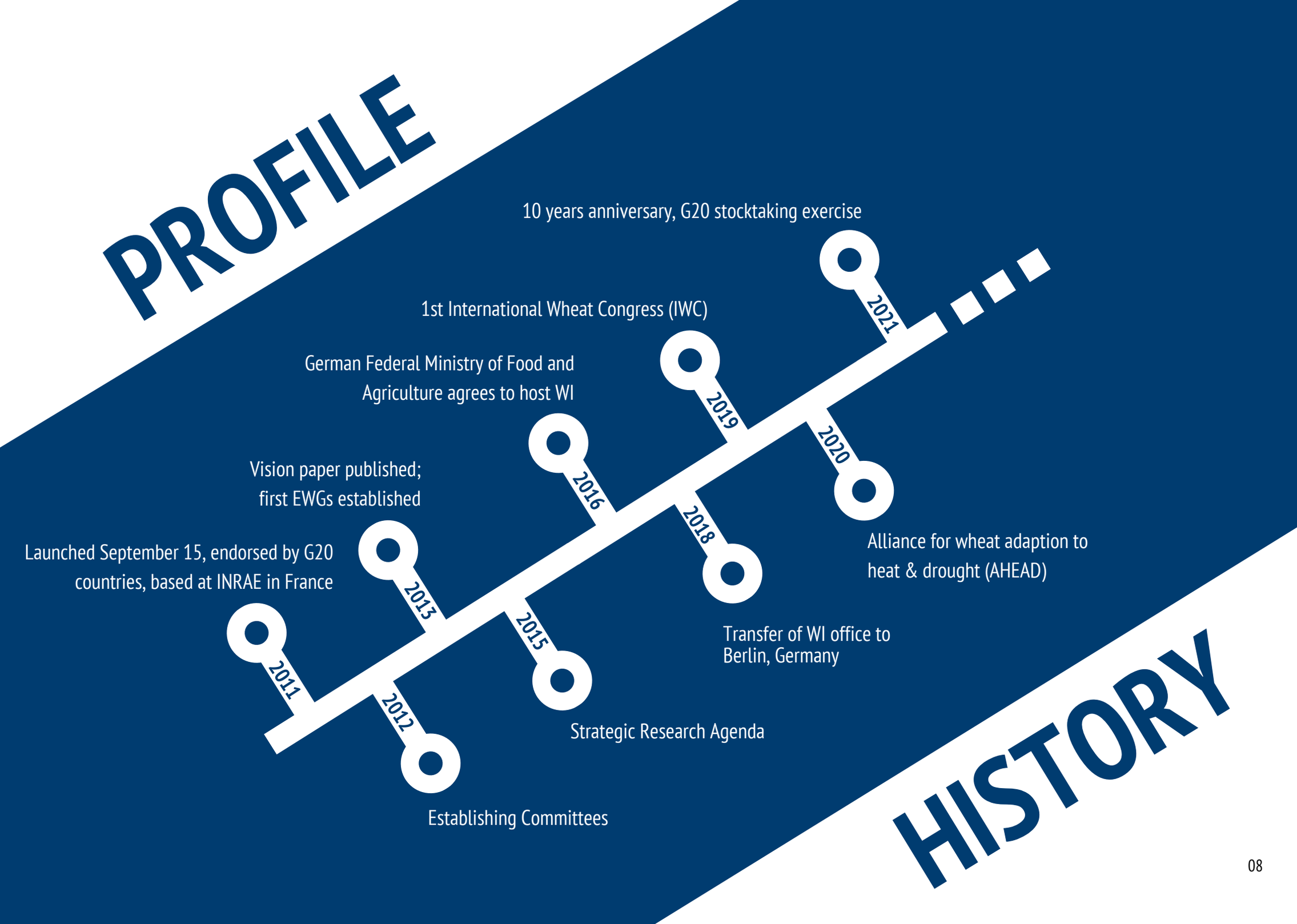
The WI mission is to increase food security, wheat nutritional value and safety while taking into account societal demands for sustainable and resilient agricultural production systems. The aim is to create a vibrant global public-private research community that shares resources, capabilities, data, game changing ideas, and technologies to improve wheat productivity, quality, and sustainable production around the world.

The WI provides a framework to initiate, establish and advance strategic wheat research and priorities. Its network consists of more than 600 wheat scientists from 48 countries. They contribute through the 10 Expert Working Groups that make up the WI task force. Its Institutions' Coordination Committee, Scientific Board and a Research Committee, provide oversight of the activities and priorities. The WI currently has 14 member countries, 6 observer countries, 3 international research centres and 4 private companies.

In 2021 the WI celebrated its 10th anniversary. Through the process of updating of our SRA, we evaluated our progress, reassessed the international research priorities, and identified major technological advances. This analysis has highlighted the large impact the WI on the community, and we look forward to continuing this role in the years to come.

# PROFILE

# HISTORY



# PROFILE

11 Expert Working Groups

600+ EWG members

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from 48 countries

14 member countries (public)

4 industry members (private)

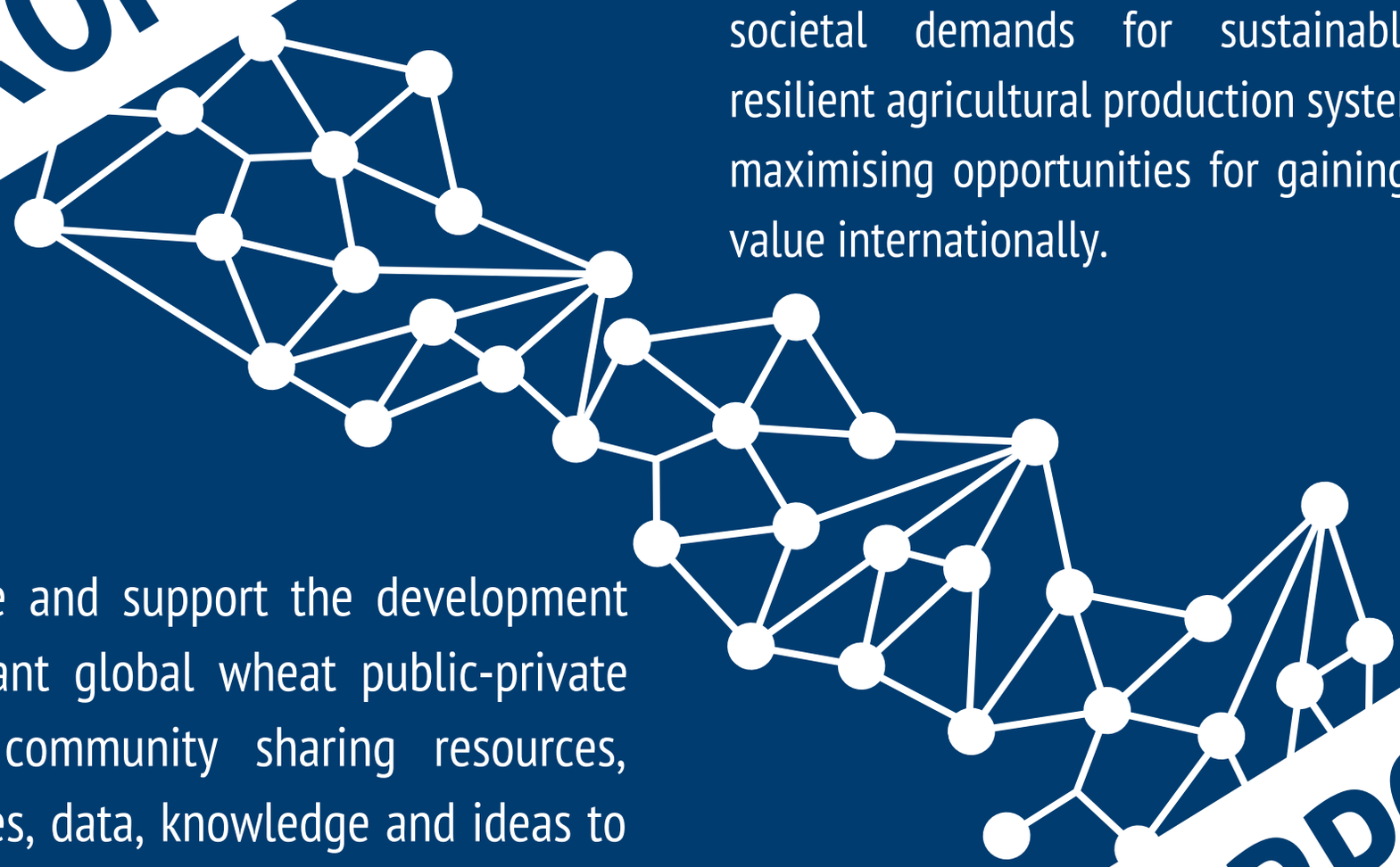
6 observer countries

3 research oganisations

# NUMBERS

5 Associated Programmes

# PROFILE



## MISSION

Increase food security, wheat nutritional value and safety while taking into account societal demands for sustainable and resilient agricultural production systems; and maximising opportunities for gaining added value internationally.

## VISION

Encourage and support the development of a vibrant global wheat public-private research community sharing resources, capabilities, data, knowledge and ideas to improve wheat productivity, quality and sustainable production around the world.

# PURPOSE

## WHEAT RESEARCH BREAKTHROUGHS AND CHALLENGES

### WOLFGANG FRIEDT: Breeding wheat varieties better adapted to unfavourable conditions - Achievements to date and future challenges

The European Union (EU) wants to become climate neutral as soon as possible. Faced with the threats of climate change and environmental degradation, the EU wants to reduce greenhouse gas emissions by at least 55% by 2030 compared to 1990. The basis for the upcoming changes is the "European Green Deal", which generally aims to reduce emissions. Agriculture is also massively affected by this (A European Green Deal | European Commission | europa.eu). However, it must be borne in mind that, in view of the shortage of agricultural raw materials and foodstuffs, an increase in harvest volumes is necessary. This is especially true for bread wheat, the world's most important food crop.

To date, the breeding of wheat varieties - mostly line varieties, so far, few hybrids - has been very successful: for example, evaluations of many years of performance tests for variety registration in Germany show an average increase in winter wheat yield of about 40 kg per ha per year. Furthermore, resistance tests and phytopathological studies have shown that, parallel to the increase in yield, susceptibility to diseases has generally decreased significantly; new varieties are thus usually higher-yielding than older ones and at the same time more disease resistant. Thus, today's elite varieties often have a combined resistance to the most important fungal pathogens, such as Brown rust, Yellow rust, Fusarium head blight, Pseudocercosporella, Powdery mildew, Septoria tritici or Septoria nodorum blotch.

Due to climate change, new crop production concepts with crops and varieties that are also resistant or tolerant to pests (insects) are needed. Varieties will also need to better withstand abiotic stress factors such as heat and drought. These varieties should manage with less chemical crop protection and instead use genetic defence mechanisms more efficiently. In practice, resistance to several pathogens is necessary. However, combined resistance is difficult to achieve through classical line breeding. This is where the new breeding techniques come into play: gene editing enables targeted improvement of resistance to a pathogen without otherwise changing the genotype.

In the case of bread wheat, for example, gene editing using CRISPR/Cas9 has already succeeded in generating modified plants without negative non-target effects; examples of sequence-specific genome modifications using CRISPR/Cas relate to chloroplast function (carbon fixation), pathogen resistance (e.g. powdery mildew), plant architecture (half/dwarf plants), grain yield (higher grain weight), and bread making quality (modification of gluten content) (Kumlehn et al., 2018).

A sufficient supply of water and nutrients is necessary for a good yield. In the future, varieties will be needed in many places that can also manage with less fertilisation, use nutrients and water more efficiently and thus deliver sufficient yields per hectare. A special focus here is on nitrogen (N) fertilisation and N use efficiency (NUE), which in addition to intact photosynthetic leaf area also depends on intact root development and function. Respective research shows a wide anatomical and functional variation of the root system of cereal species; numerous studies point to genes whose characterisation can also enable genomic or marker-assisted selection and more efficient breeding. The prospects for wheat breeding and adequate cultivation are therefore promising.

## LUIGI CATTIVELLI AND ROBERTO TUBEROSA: Reference durum panels to leverage the tetraploid wheat genome and diversity

Representative, broad and diverse collections are an essential resource to dissect genetic diversity, meet pre-breeding and breeding goals, and eventually allow for gene/QTL cloning and editing following the identification of beneficial haplotypes. International collaboration into the genomics of traits for adaptation to the ongoing climate crisis and for enhancing yield potential are facilitated by germplasm panels based on their level of allelic diversity and linkage disequilibrium (LD). Consequently, the international durum wheat research community undertook a joint and comprehensive action, primarily for breeding purposes, to assemble a common germplasm panel, the Global Durum Genomic Resource. This is a collaborative tool for the exploitation of durum wheat genetic diversity.All passport and genotype info are available at GrainGenes (https://wheat.pw.usda.gov/GG3/global_durum_genomic_resources).

The Global Durum Genomic Resource is composed of two collections: 1) the Tetraploid Germplasm collection (TGC) from the Durum Wheat Genome Sequencing Consortium (Maccaferri et al 2019), which includes a large proportion of the tetraploid genetic diversity from wild emmer, domesticated emmer to primitive wheat and durum landraces and 2) the Global Durum Panel (GDP) which captures the readily exploitable genetic diversity of Triticum turgidum ssp. durum modern germplasm and landraces while including also a small selection of emmer and primitive wheats.

The two collections fit with the objective of freely sharing common collaborative materials to facilitate research discoveries, ultimately providing a rapid means to identify and exchange useful alleles/haplotypes worldwide and make them available to breeders. All TGC and GDP accessions were genotyped with the iSelect 90K wheat SNP array as described, respectively, in Maccaferri et al. (2019) and Mazzucotelli et al. (2020), a manuscript included in a special issue mainly targeting durum wheat genomics (Tuberosa et al., 2021).

The deep genetic characterization and the public availability of seeds and marker data make the Global Durum Genomic Resource unique and valuable to identify and map genetic diversity useful to any breeding program. GDP is available at ICARDA, University of Bologna and CREA-Research Centre for Genomics and Bioinformatics.

The resource has been complemented by the Tetraploid Core Collection (TCC) available at University of Bologna and CREA-Research Centre for Genomics and Bioinformatics, and John Innes Centre. The TCC has been defined based on the joint population structure of the TGC + GDP iSelect 90K SNP data and includes 432 accessions capturing over 95% of the GDP and TGC biodiversity (info at https://wheat.pw.usda.gov/GG3/global_durum_genomic_resources). The TCC has a pyramid structure with genotypes at the top (gold, 30 accessions), intermediate (silver, 100 accessions) and lower (bronze, the remaining 300 accessions) levels based on their representation of common and/or population-specific haplotypes.

From a breeding standpoint, haplotypes provide valuable retrospective details, as shown by Zhang et al. (2020) which clearly indicates that modern wheat breeding in China greatly benefitted from the work of Nazareno Strampelli, the main Italian wheat breeder. Haplotyping is particularly valuable once reliable phenotypic values are available for the target traits. Recently, root traits are receiving increasing attention in view of the essential role of root system architecture (RSA) features in the uptake of water and nutrients, both crucial factors to ensure food security, particularly for durum wheat grown in drought-prone areas.

The genetic basis of RSA in wheat is increasingly being investigated (Ober et al., 2021) and novel haplotypes have been identified in a collection of Ethiopian durum landraces (Alemu et al., 2021a) confirmed the key role of root angle to influence durum wheat yield under different water regimes (Alahmad et al., 2019). Both the GDP and the TCC panels are being phenotyped for disease resistance and are available for further breeding and gene discovery/cloning of target traits of interest.

**LEONARDO CRESPO-HERRERA, MATTHEW REYNOLDS, JANET M LEWIS, ALISON R BENTLEY (May 2022): Building resilient wheat to meet future challenges**

Over the past years, global wheat production and trade have seen many changes and challenges from variable climatic and biophysical factors, varying market forces and shifting patterns and trends in consumer demand. In future, it is likely we will need to focus our efforts across both productivity and resilience. This is particularly true in addressing the rising threats from insect pests as well the abiotic threats of heat and drought stress which are increasing.

**The increasing challenge of pest control**

Pest control for wheat production is paramount to increase food security and sustainability of agricultural systems. Reports from some countries indicate that wheat yield losses due to pests have not decreased and are even tending to increase despite large expenditures on pesticides (Dhaliwal et al., 2010; Oliveira et al., 2014). A global assessment of crop yield losses indicates that the wheat grain loss per centigrade degree increase owed to climate change can be up to 25% in relation to current losses (Deutsch et al., 2018). With global warming, we expect changes in pest distribution, and earlier and more intense out-breaks of pest species (and the viruses they can transmit), particularly in regions where temperatures presently are near but below the optimal reproductive pest threshold (Aljaryian and Kumar, 2016; Deutsch et al., 2018; Hullé et al., 2010). Addressing this challenge will require further knowledge to be generated and integrated into breeding and pest management strategies spanning from genetics through to development of new chemistry and management approaches.

The exploitation of existing genetic variation for resistance to pests can be a valuable tool to increase wheat yield protection, to benefit farmers by reducing production costs and contribute to sustainable food production by reducing the use of pesticides. Furthermore, host resistance is very advantageous for farmers in situations where they have limited or no access to other control methods. Efforts are underway at CIMMYT to improve resistance to major pests in elite wheat germplasm and exchange the improved materials with partners. As part of the new WI EWG on Pests, we plan to distribute an annual germplasm set which combines material identified as having resistance to priority pests. With a view to increasing resilience, intensifying work on pest response is urgently required.

**Tackling heat and drought tolerance**

In addition to addressing biotic stress changes, it is widely recognized that the abiotic conditions for wheat production are becoming more challenging in many parts of the world, due to rising temperatures and reducing availability of water. In 2021, the CIMMYT-led Heat and Drought Wheat Improvement Consortium (HeDWIC) completed the first year of a five-year project supported by FFAR, "Harnessing translational research across a global wheat improvement network for climate resilience", described in a 2021 publication in the Journal of Experimental Botany.
A major HeDWIC goal is to better characterize breeding target environments. The Elite Diversity Panel International Experiment (EDPIE) involves 150 spring wheat lines selected for adaptation to heat and/or drought stress. The lines were shared with over 20 international public and private partners whose field environments represent a cross-section of largely warm and/or dry climate profiles. Data from these sites will be used to better understand the genetic bases of broad and local adaptation. A retrospective analysis -employing a big data approach using international wheat trials from 1980 to 2018 was published in Nature Plants (Xiong et al.). The main conclusions were that rank changes among lines targeting higher yielding environments have increased due to warmer conditions, while rank changes were generally reduced in lines targeted to abiotically stressed environments, indicating their wider adaptation.

HeDWIC also welcomed a number of PhD students to conduct research studies at the HeDWIC Hub in Mexico in collaboration with researchers at the University of Hohenheim (with support from the ATSAF Academy), Purdue (with support from CONACYT-Mexico) and the University of Nottingham (with support from CONACYT-Mexico and SADER). HeDWIC was excited to conduct a competitive small-grant call, with five projects now funded (for a total of $270,000), that leverage and complement HeDWIC research activities with in-kind resources from funded researchers.

In 2021 HeDWIC distributed its 11th Stress Adaptive Trait Yield Nursery (SATYN), focused on climate-resilience traits identified by physiological pre-breeding. Collectively (1st – 11th SATYN) the nursery has been distributed to researchers at over 200 locations. Impacts from breeding (under the Accelerating Genetic Gains in wheat and CRP-WHEAT projects linked to FFAR-HeDWIC) included thirty-six spring bread wheat and seven spring durum wheat varieties -with a baseline of heat and drought tolerance- that were registered across 12 countries. Five of these varieties are also biofortified.

As conditions for global wheat production change, we need to ensure wheat germplasm and management adapt to keep pace with a growing spectrum of challenges. Within the CIMMYT Global Wheat Program, we continue to work on enhancing resilience whilst maintaining productivity gains. In particular, we are focused on emerging and expanding insect pests (and the viruses they transmit) as well as adaptation to heat and drought stress.

# 2. MILESTONES

## HIGHLIGHTS: The following pages show the highlights of 2021

### NEW MEMBER: REPUBLIC OF KOREA

After a connection was made between Professor Frank Ordon, President of the Julius Kuehn Institute and the Republic of Korea in 2021, an invitation was made to the Republic of Korea to become a member of the WI. The invitation was gladly accepted due to their great interest in wheat and the benefits they could see from being part of the WI network.

In autumn 2021, the Wheat Initiative Secretariat welcomed the Republic of Korea´s Rural Development Administration as observer member, and shortly after as a member with full rights.

The Chair of the Scientific Board, Peter Langridge welcomed Republic of Korea to the Wheat Initiative:

"Given the strength and importance of wheat research in South Korea, we welcome greater participation from their research community in our activities. There are currently over 600 wheat scientists from 48 countries in our Expert Working Groups and participation from Korean scientists enriches their discussions and expand opportunities."

Dr. Kwon Taek-Ryoun, Director General, Technology Cooperation Bureau, Rural Development Administration of the Republic of Korea mentioned:

"Faced with the stagnation of wheat productivity due to global warming and the continuous increase of wheat consumption I am currently looking into more long-term measures, including joining the Wheat Initiative. I am impressed with roles of the Wheat Initiative to identify global research priorities for wheat to ensure food security a coordinate global wheat research. I hope that our participation will give us the opportunity to share knowledge and technologies to improve world wheat productivity."

The Wheat Initiative is very happy to welcome the Republic of Korea as its newest member.

### G20 AGRICULTURE DEPUTIES MEETING AND MACS-G20 MEETING

The Presidency of the G20 in 2021 was held by Italy. As a G20 initiative, the WI was invited to participate in the stocktaking exercise of the Agriculture Deputies Meeting held on April 19-20, 2021, where a report of activities was presented along with a video: https://www.wheatinitiative.org/other-videos

The WI also attended the G20 Meeting of the Agricultural Chief Scientists (MACS-G20) on June 15 – 16, 2021.

As part of the MACS-G20 Meeting two workshops were organized:

- G20 Workshop on Antimicrobial Resistance, September 1st, 2021. Virtual format.
- G20 Workshop on Agriculture and Climate Change, September 2nd, 2021. Virtual format.

The Wheat Initiative participated in the workshop on Climate Change along with colleagues from our Associated Programme "International Wheat Yield Partnership" (IWYP). The delegation included Richard Flavell (IWYP, Chair of Science and Impact Executive Board), Jeff Gwyn (IWYP Programme Director) and Teresa Saavedra (WI Programme Manager), and Peter Langridge (Chair of the Scientific Board). During the workshop, Peter Langridge took the opportunity to address the attendees.

Further details on our participation on the G20 Meetings is available in our press releases (https://www.wheatinitiative.org/press-releases)

- Wheat Initiative at the MACS-G20 Meeting advocates for internationally consistent regulation.
- Wheat Initiative at the G20 Climate Change Workshop: The urgency of action considering climate change and food security.

The Secretariat would like to thank all WI members for their support during the G20 Agriculture Ministers' Meeting communiqué drafting. The 2021 meeting communiqué from the minister's meeting, acknowledged the role of the WI and its effectiveness over the past ten years.

For more info on the MACS meeting and communiqué download visit:
https://www.politicheagricole.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/17340

## VIRTUAL MEETINGS, SEMINARS AND WORKSHOPS

As in 2020, virtual meetings were the order of the day in 2021. Sudden changes to travel rules and quarantine requirements made face-to-face events complicated. Therefore, our Expert Working Groups (EWGs) maintained their efforts to keep the community together through virtual meetings and workshops.

### Durum EWG

The Chairs of the Durum EWG, Luigi Cattivelli and Roberto Tuberosa, organized once again the Virtual Durum Meetings (VDMs). VDMs are video conferences organised around topics related to durum wheat, where 4-5 short presentations are given per session followed by time for discussion. The 2021 VDMs took place on 21-22 July, and they attracted more than 100 attendees. Most of the presentations are published on the Wheat Initiative website, which you can access at https://www.wheatinitiative.org/virtual-durum-meeting-videos

The session in July featured the following topics:

- Bread and durum wheat: two variants of the same crop with different genome configurations but interchangeable quality and technological properties. - Anna Maria Mastrangelo (CREA-Research Centre for Cereal and Industrial Crop, Italy)
- Quality traits in wheat wild relatives for new breeding programs - Ilaria Marcotuli (University of Bari, Italy)
- Advances in breeding for quality at CIMMYT & introgression of novel traits for alternative uses of durum wheat - Karim Ammar & Mari Itria Ibba (CIMMYT, Mexico)
- Explore the genetic factors of grain protein concentration independent of grain yield in Canadian durum wheat - Yuefeng Ruan (Agriculture and Agri-Food Canada, Swift Current, Canada)
- Improving wheat quality by targeted mutagenesis: case studies in durum and bread wheat - Damiano Martignago (University of Milan, Italy)
- Application of biochemical, small-scale quality and G x E research to improve durum wheat breeding in Australia - Mike Sissons (NSW Department of Primary Industries, Australia)
- Breakthrough genetic technologies for food traceability in high-quality pasta chain production - Paola Carnevali and Valeria Terzi (Barilla and CREA-Research Centre for Genomics and Bioinformatics, Italy).
- Conventional and biotechnological approaches to improve nutritional quality of durum wheat - Francesco Sestili and Stefania Masci (University of Tuscia, Viterbo, Italy)
- Gluten-free durum wheat: progress and challenges - Francisco Barro (Institute for Sustainable Agriculture, Córdoba, Spain)
- Increasing dough strength in soft kernel durum wheat using Glu-D1 and Gpc-B1 - Craig Morris (USDA-ARS Pullman, USA)

### Germplasm EWG

On 22 September 2021, the outgoing Chairs of the Germplasm EWG, Tom Payne and Ahmed Amri, organized the seminar on “International policies governing access to plant genetic resources and benefit-sharing”; with the support of Isabel Lopez Noriega and Michael Halewood from the Alliance of Bioversity and CIAT, and coordinators of the CGIAR Genebank Platform Policy Module.
The seminar targeted the wheat community with interest in learning about international regulations governing access to genetic resources and the sharing of benefits arising from the use of those resources. The seminar video can be accessed through:
https://www.youtube.com/watch?v=aSmIPIPDCk0

**Quality EWG**

On 24-25 November 2021, the Chair and Co-Chair of the Quality EWG, Tatsuya Ikeda and Carlos Guzman, held the 1st Virtual Quality Meeting. Its objective was to provide an update to all the wheat research and breeding community about the advances in wheat quality research and breeding. The meeting covered all wheat quality aspects (end-use quality, nutrition & health, food safety).
Most of the presentations are published on the Wheat Initiative website, which you can access at https://www.wheatinitiative.org/1st-virtual-quality-meeting
The session featured:

- Durum quality research from down under - Mike Sissons, NSW Department of Primary Industries, Australia
- Effect of wheat processing on micronutrient retention and bioavailability - Maria Itria Ibba, CIMMYT, Mexico
- Impact and mechanism of sulphur-deficiency on modern wheat farming nitrogen-related sustainability and gliadin content - Wujun Ma, Murdoch University/Australia-China Joint Centre for Wheat Improvement, Australia/China
- Molecular basis of micronutrient (Fe and Zn) absorption and accumulation in wheat grains: current understanding and future perspectives - Sewa Ram, ICAR-Indian Institute of Wheat and Barley Research, India
- Amylase-trypsin inhibitors as potential triggers of wheat-related diseases - Lisa Call, University of Natural Resources and Life Sciences (BOKU), Austria
- Differences in Compositional and Quality Traits of Spelt and Bread Wheat Genotypes Grown under Conventional and Organic Production - Verica Takac, Institute of Field and Vegetable Crops, Serbia
- BigBaking - Ensuring high baking quality and nitrogen-use efficiency through optimization of storage protein composition and enzymatic activity - Oliver M. Knopf, Christine Kämper, Germany
- Trade-offs between functional and nutritional traits - Nick Fradgley, NIAB, UK

**Breeding EWG**

The outgoing Chairs of the Breeding EWG, Gilles Charmet and Chris Burt organized in February 2021 a three day workshop, with the support of the Excellence in Breeding Platform, The James Hutton Institute and GOBii, and Elizabeth Jones acting as coordinator of the workshop.
The workshop focused on GOBii data management and data analysis in Flapjack (marker-assisted backcrossing, pedigree verification and forward breeding) and Galaxy (Genomic Selection). The same workshop was given twice, to better accommodate attendees located in different time zones. Working materials and software was provided to participants to actively participant during workshops.

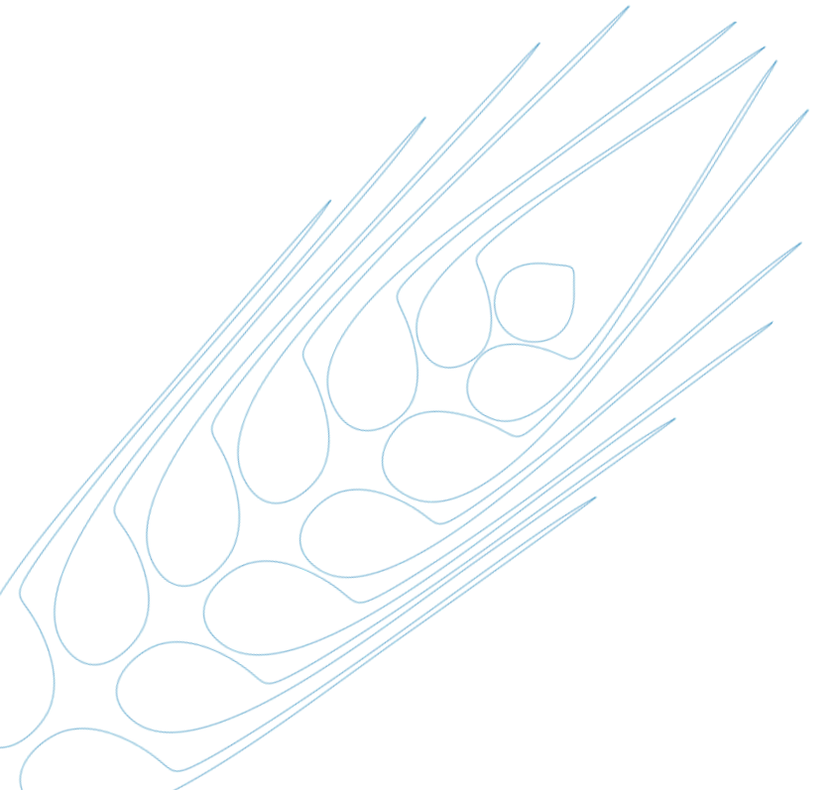
- The full workshop videos are available at https://www.wheatinitiative.org/transforming-wheat-breeding-through-integrated-data-management-with-gobii-and-analysis-in-flapjack

# 3. REPORTS & HIGHLIGHTS

## THE EXPERT WORKING GROUPS (EWGs)

On the following pages our scientific working force - the EWGs, our essential backbone - present a summary of their 2021 year.

They bring together international experts from various fields, which benefits research efforts by sharing ideas, knowledge, information, and data with a focus on a topic of relevance to WI's aims and objectives. The numerous EWGs reflect all important research fields for yield improvement and include experts from the public and private sectors.



# ADAPTATION OF WHEAT TO ABIOTIC STRESS (AWAS EWG)

AWAS

108 members from 28 countries
Co-Chairs: Fernanda Dreccer (Australia),
Krishna Jagadish (USA) and Tadesse Wuletaw Degu (Lebanon)
SB Liaisons: Wolfgang Friedt and Roberto Tuberosa

## AIMS

The AWAS EWG aims to accelerate current genetic gains in wheat under abiotic stress by deploying the most recent advances in phenotyping and physiology, biotechnology, complementing breeding efforts. The EWG provides a platform for members to discuss research priorities on abiotic stress, connect across organisations and act as experts in education/extension activities concerning abiotic stress impact for capability building purposes.

## 2021 MEETINGS

There were no meetings held this year due to the on-going COVID-19 pandemic.

## EWG ACTIONS AND PROGRESS IN 2021

The AWAS EWG conducted a poll with its members to determine what activities they would like to do since face-to-face meetings were not possible. The poll identified the following activities, being the most popular:

1. Explore project development opportunities in regional networks
2. Cross-disciplinary papers on abiotic stress
3. Competition-post docs and presentation focused on abiotic stresses
4. Competition for training videos
5. Public and private industry webinar

As a result, there was a video competition held, together with the Phenotyping EWG. The Twitter promotion of the video helped increase awareness of the WI to Early/Mid-Career researchers (EMCRs).

There have been discussions regarding at least four special issues on abiotic stress in four major journals (Field Crops Research, Plant MDPI, TAG and Frontiers in Plant Science). Work on this has been limited due to the COVID-19 pandemic but it is hoped that further progress can soon be made.

## MAJOR SCIENTIFIC DEVELOPMENTS IN 2021

There was participation by at least two Co-Chairs in AHEAD meetings and Strategy Revision.

Listed below are some publications by EWG members published in 2021:

- Alemu A, Suliman S, Hagras A, et al (2021b) 'Multi-model genome-wide association and genomic prediction analysis of 16 agronomic, physiological and quality related traits in ICARDA spring wheat' Euphytica, 217: 205. doi.org/10.1007/s10681-021-02933-6
- Tekeu H, Ngonkeu ELM, Belanger S, et al (2021) 'GWAS identifies an ortholog of the rice D11 gene as a candidate gene for grain size in an international collection of hexaploid wheat'. Scientific Rep. 11: 19483. doi.org/10.1038/s41598-021-98626-0
- El Gataa Z, El Hanafi S, El Messoadi K, et al (2021) 'Genome wide association and prediction studies of agronomic and quality traits in spring bread wheat (Triticum aestivum L.) under rain-fed environment with terminal moisture stress'. J Cereal Sci. 101. doi.org/10.1016/j.jcs.2021.103278

## PLANS FOR 2022

The EWG will participate in the International Wheat Congress (IWC) in September (either hybrid or online) and plans to hold the annual meeting at the IWC, where they will discuss specific research topics.

It is planned to hold a training course in Morocco (seat of the new Global Drought Phenotyping platform from the CGIAR system) for 3-4 Early Career Researchers (ECR) to learn new techniques.

The AWAS EWG also plans to hold various webinars and seminars in the second half of the year to provide research updates of the current members, encouraging participation of EMCR.

# BREEDING

34 Members from 7 countries
Chair: Sanjay Kumar Singh (India)
Vice-Chair: Suchismita Mondal (Mexico)
SB Liaisons: Roberto Tuberosa, Chris Burt

## BREEDING METHODS AND STRATEGIES (BREEDING EWG)

### AIMS

The Breeding EWG aims to coordinate ongoing wheat breeding methods research, identify support for public wheat breeding programmes and develop a trans-national training programme in state-of-the-art breeding methods. The EWG's research areas are: genomic selection, hybrid wheat, mutation breeding (including genome editing) and utilization of cultivated and wild genetic resources (to cross with GR-EWG).

### 2021 MEETINGS

There were no meetings held this year due to the on-going COVID-19 pandemic.

### EWG ACTIONS AND PROGRESS IN 2021

Due to the COVID-19 pandemic, there was no progress made towards objectives.

### MAJOR SCIENTIFIC DEVELOPMENTS IN 2021

The EWG highlighted two research articles related to Breeding Methods and Strategies that were published in 2021.

- Varshney RK, Bohra A, Yu J, et al (2021) 'Designing future crops: genomics-assisted breeding comes of age.' Trends Plant Sci. 26: 631-649. doi.org/10.1016/j.tplants.2021.03.010

- Singh S, Jighly A, Sehgai D, et al (2021) 'Direct Introgression of Untapped Diversity into Elite Wheat Lines'. Nature Food, 2: 819-827. doi.org/10.1038/s43016-021-00380-z

### PLANS FOR 2022

The Breeding EWG plans to participate in the IWC in September 2022.

There will be an online webinar on Genome Editing in May-June 2022 and an online conference on advance breeding strategies for higher wheat productivity in collaboration with CIMMYT/IARI in New Delhi.

## CONTROL OF WHEAT PESTS AND PATHOGENS (PandD EWG)

PandD

71 members from 24 countries
Chair: Richard Oliver (Australia)
Vice-Chairs: Robert Park (Australia) and Steve Goodwin (USA)
SB Liaisons: Silvia German and Fiona Doohan

### AIMS

The PandD EWG aims to improve the control of diseases and pests of wheat. They are involved in global diagnosis of pest and pathogen presence and significance, the establishment of centres of excellence for each of the major pests and pathogens, and the distribution of resistant germplasm and marker information enabling better breeding of resistant cultivars.

### 2021 MEETINGS

During 2021, several meetings and discussions were held between the EWG chair, co-chairs, and the Scientific Board about the strategy for developing a new program on the diagnosis and monitoring of major disease and pathogens.
Due to the travel restrictions, no workshops or meeting were held by the members of the EWG during 2021.

### EWG ACTIONS AND PROGRESS IN 2021

The initial research strategy was developed by the chairs and EWG members during 2019 and 2020, and identified 11 high priority pathogens. Three key objectives were highlighted in the plan:
Objective 1: Isolate collections:

- Improved access to isolates
- Development of global collections (absence of a global collection – particularly for SB, TS and SNB), including assessment of the feasibility of hosting and long-term maintenance of global collections
- Data sharing; for example, sequence data on isolates

Objective 2: Disease diagnosis and monitoring:

- Development of an internationally accepted diagnostic system - disease diagnosis and pathotype identification
- Development of a consistent sampling strategy – timing and tissue
- Development of a global disease monitoring system
- Mixed infection analysis to identify component pathogens
- A system for wheat pathologists to provide specialist advice

Objective 3: Disease control

- Utilisation of the wheat Pan-Genome project (partial sequencing of several thousand genotypes) to expedite the identification of genes underpinning disease resistance and susceptibility
- Use of RenSeq and related techniques for resistance gene identification
- Provision of access to germplasm carrying defined resistances
- Identification of biological control agents for wheat diseases
- Development of a wheat microbiome initiative to investigate the role of the microbiome in suppressing disease development
- Development of integrated disease management programmes

This was recognised as a large and complex research undertaking and after intense discussion a proposal was submitted and approved by the Institutions Coordination Committee (ICC) at their virtual meeting in late 2021. The proposed course of action followed the concept developed by the Funding EWG and implemented in the heat and drought programme, AHEAD. The result was approval of a new umbrella programme Wheat Initiative Crop Health Alliance (WATCH-A). At the end of 2021, members countries and organisations were invited to indicate their interest in participating.
The ICC also decided that the Pest and Disease EWG members should be asked if it may be more effective to split the group into two, one to cover pathogens and one for pests.Consequently, a survey of members was launched in early 2022.

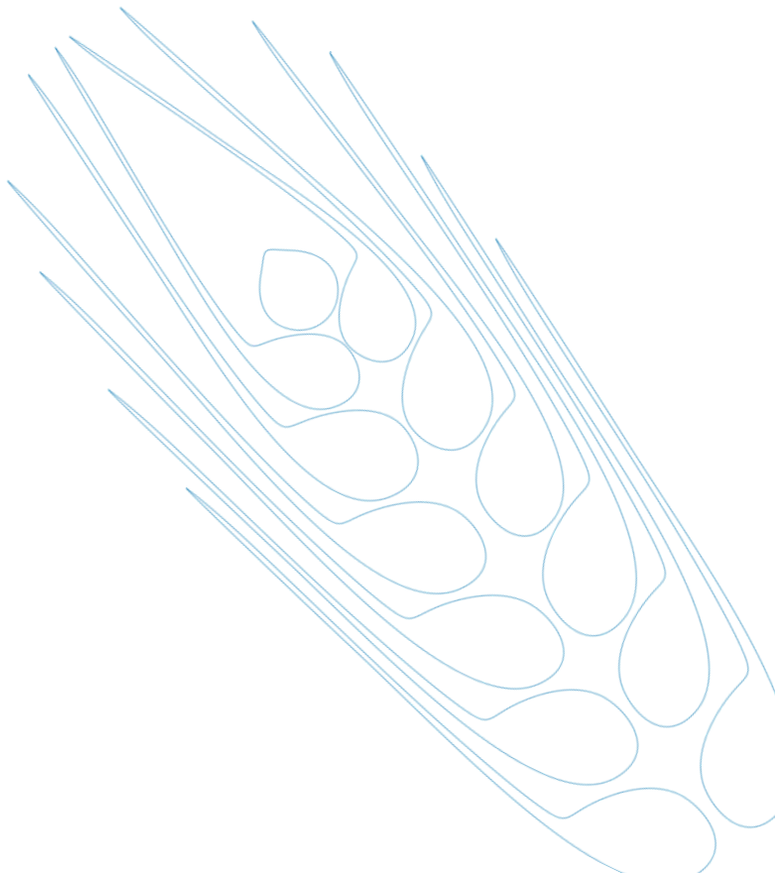
**PLANS FOR 2022**

The survey of EWG members was launched, as planned, in early 2022 and there was overwhelming support for splitting into two groups; Control of Wheat Pathogens EWG and Control of Wheat Pests EWG. It was also decided that the Pest EWG would include diseases spread by pest, largely viruses. Therefore, an important task for 2022 is to establish the two new EWGs, appoint chairs and co-chairs and establish a strong membership base.

Now that the WATCH-A has been approved, the umbrella programme needs to be established. A call for membership of the Steering Committee was made in late 2021.Once the Steering Committee is in place, the first major planning can be initiated.

Initial tasks for WATCH-A in 2022 are:

- Convene the Steering Committee
- Update information on existing projects relevant to the WATCH-A objectives
- Assemble information on pathogen isolate collections and conditions of access to isolates
- Organize a working group to explore options for a globally acceptable disease diagnosis system
- Develop an action plan to advance the objectives of WATCH-A



# DURUM

>100 members from >25 countries
Chairs: Luigi Cattivelli (Italy) and Roberto Tuberosa (Italy)
Vice-Chairs: Jason Able (Australia) and Karim Ammar (Mexico)
SB Liaisons: Peter Langridge and Sylvie Cloutier

## DURUM WHEAT GENOMICS AND BREEDING (DURUM EWG)

### AIMS

The Durum EWG aims to promote synergy between durum wheat research groups; identify research priorities to enhance opportunities for genetic progress in durum wheat breeding globally; promote the utilisation of the durum wheat genetic resources through collaborative initiatives and promote the development of molecular tools and platforms open to the global durum wheat community.

The EWG also aims to enhance the capacity of breeders to access and use high-throughput marker-assisted selection; enhance awareness and familiarity with genomics approaches applied to durum breeding through the organization of workshops and training courses; facilitate the formation of consortia aimed at raising funds for research projects nationally and/or internationally and contribute to assemble the durum wheat pangenome.

### 2021 MEETINGS

21-22 July, webinar, Virtual Durum Meeting (VDM), open to all wheat scientists and followed by about 100 participants.

### EWG ACTIONS AND PROGRESS IN 2021

The 3rd VDM was held on 21-22 July with 10 presentations made:

- Bread and durum wheat: two variants of the same crop with different genome configurations but interchangeable quality and technological properties.
- Quality traits in wheat wild relatives for new breeding programs.
- Advances in breeding for quality at CIMMYT & introgression of novel traits for alternative uses of durum wheat.
- Explore the genetic factors of grain protein concentration independent of grain yield in Canadian durum wheat.
- Improving wheat quality by targeted mutagenesis: case studies in durum and bread wheat.
- Improving wheat quality by targeted mutagenesis: case studies in durum and bread wheat.
- Application of biochemical, small-scale quality and G x E research to improve durum wheat breeding in Australia.
- Breakthrough genetic technologies for food traceability in high-quality pasta chain production.
- Conventional and biotechnological approaches to improve nutritional quality of durum wheat.
- Gluten-free durum wheat: progress and challenges.
- Increasing dough strength in soft kernel durum wheat using Glu-D1 and Gpc-B1.

For the presentations, please visit: https://www.wheatinitiative.org/virtual-durum-meeting-videos

The EWG has been instrumental in promoting an international network of expertise and resources capable of focussing on large sequencing actions for durum wheat improvement. The platinum quality sequence of the durum wheat reference cultivar Svevo has been completed through an approach based on PacBio HiFi and Optical map. The sequence has been generated with the support of CORTEVA and it is currently under annotations. A crowdfunding was organized within the EWG to support an extensive RNAseq analysis of Svevo transcriptome as an essential step for gene annotation. The RNAseq work is currently ongoing. An Isoseq analysis based on ONT has been organized and will be completed in 2022. Several partners of the EWG received specific budgets for sequencing of the wheat pangenome, and international coordination is in progress to finalize the resources toward a single worldwide initiative for a high-quality sequence of the tetraploid wheat pangenome.

The Global Durum Panel (GDP: Mazzucotelli et al. 2020) and the Tetraploid wheat Global Collection (TGC: Maccaferri et al. 2019) represent two and complementary global platforms for durum wheat diversity and their implementation represents one of the Hub Pilot of DivSeek. While the TGC is an effort of few labs, GDP is an internationally open initiative carried out in the frame of the EWG.
The GDP is maintained at the ICARDA genebank and has been distributed worldwide. Several research groups have phenotyped this panel, all using their own funding, for major phenological traits and disease resistances and a coordinated analysis of the data is currently in progress.

Five members of the EWG are acting as Co-editors of a book entitled "The durum wheat genome" to be published by Springer. The book (two volumes), to be published in 2022 will include a series of chapters focusing on durum wheat sequencing and genomics and their applications to wheat breeding and will be mainly authored by members of the EWG.
The EWG has launched an Open-Access Publication Grant Program to cover the cost of open access publications of durum wheat-dedicated manuscripts with a corresponding author or first author from developing countries. The program was designed to stimulate the quality of the research on durum wheat in developing countries.

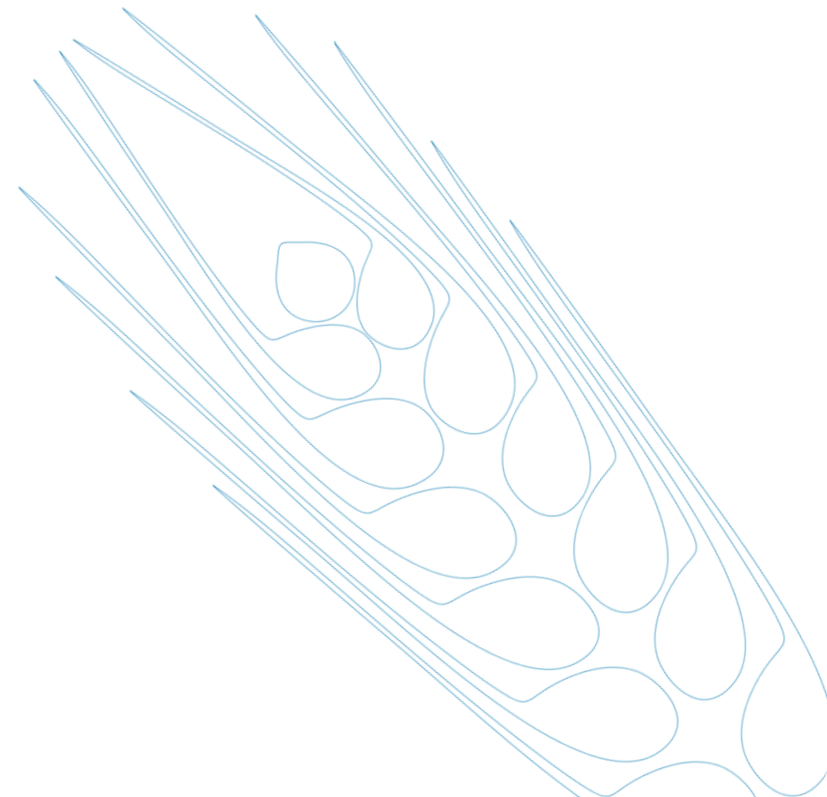
**PLANS FOR 2022**

It is planned to have a face-to-face EWG meeting alongside the 4th from Seed to Pasta Congress to be held in October. There will be an edition of the VDM held in April-May to promote the discussion on the latest scientific advancements on durum wheat genomics and breeding.

The EWG plans to complete annotation of the platinum quality sequence of the durum wheat reference cultivar Svevo and implement the strategic plan for the sequencing of the tetraploid wheat pangenome.

There will be actions carried out to monitor the ongoing GDP phenotyping activities and promote coordination/analyses of the data. This will result in the GDP being a reference panel for durum wheat genomics and breeding.

Work will continue on the Springer book 'The durum wheat genome'.



# GLOBAL WHEAT GERMPLASM CONSERVATION AND USE COMMUNITY

GERMPLASM

44 members from 25 countries
Chair: Benjamin Kilian (Germany)
Vice-Chairs: Shivali Sharma (India), Peter Civáň (France), Hakan Özkan (Turkey)
SB Liaisons: Hans Braun, Chris Burt and Hisashi Tsujimoto

## AIMS

The Germplasm EWG contributed to updating the global wheat conservation strategy by including various use dimensions, and providing global assessments, technical advice, and recommendations for the conservation and use of genetic resources of wheat and related species to individual genebanks, the Crop Trust, and other globally important holders of the crop collection. The Germplasm EWG reaches out to the global community through its representation, targeted communications, and information sharing efforts.

## 2021 MEETINGS

There were no face-to-face meetings held this year due to the on-going COVID-19 pandemic. There were 6 on-line meetings mainly between the leadership team and the Wheat Initiative Secretariat, to facilitate the transition of new leadership.

## EWG ACTIONS AND PROGRESS IN 2021

The Germplasm EWG page on the WI website has been updated to include all the latest information relevant for members, including publications, projects and meetings. A video promoting the Germplasm EWG was produced and included on the website. A roadmap was developed to revise the existing Global Wheat Germplasm Conservation Strategy.

## PLANS FOR 2022

The EWG plans to undertake writing of the first draft chapters of the revised Global Wheat Conservation and Use Strategy, which will involve conducting several key activities such as hiring a lead consultant/support staff and conducting surveys. There will be the annual EWG meeting in the third quarter of the year and a Germplasm workshop is also planned.

## MAJOR SCIENTIFIC DEVELOPMENTS IN 2021

Important publications in Germplasm during 2021:

- Sharma et al, 2021 'Introducing beneficial alleles from plant genetic resources into the wheat germplasm'

Narrow genetic base of cultivated wheat necessitates the introduction of new genetic diversity into wheat breeding programs. Plant genetic resources stored in genebanks and the wild relatives of crops are potential sources of new genetic diversity. This article describes the most important taxonomic and phylogenetic relationships of these PGR to guide their use in wheat breeding and also presents the status of the use of some of these resources in wheat breeding programs. Several introgression schemes are proposed that allow the transfer of qualitative and quantitative alleles from PGR into elite germplasm. With this in mind, the use of a stage-gate approach is proposed to align pre-breeding with main breeding programs to meet the needs of breeders, farmers and end-users. Overall, this review provides a clear starting point to guide the introgression of useful alleles over the next decade. (doi.org/10.3390/biology10100982)

- Keilwagen et al, 2022 'Detecting major introgressions in wheat and their putative origins using coverage analysis'

Introgressions from crop wild relatives (CWRs) have been used to introduce beneficial traits into cultivated plants. Recently, single nucleotide polymorphism (SNP)-based methods have been proposed to detect introgressions in crosses for which both parents are known. However, for unknown material, no method was available to detect introgressions and predict the putative donor species. This article presents a method to detect introgressions and the putative donor species. The utility of this method is demonstrated using 10 publicly available wheat genome sequences and identify nine major introgressions. Further, it is shown that this method can distinguish different introgressions at the same locus. Authors trace introgressions to early wheat cultivars and show that natural introgressions were utilised in early breeding history and still influence elite lines today. Finally, the evidence shows that these introgressions harbour resistance genes. (doi.org/10.1038/s41598-022-05865-w)

# QUALITY

85 members from 23 countries
Chair: Tatsuya Ikeda (Japan)
Vice-Chair: Carlos Guzman (Spain)
SB Liaisons: Hisashi Tsujimoto and John Snape

## IMPROVING WHEAT QUALITY FOR PROCESSING AND HEALTH

### AIMS

The Quality EWG aims to maintain and improve wheat quality under varying environmental conditions. The group focuses on wheat quality in the broad sense, including seed proteins, allergens, carbohydrates, nutrition quality including micronutrients, grain processing, food safety, genetic resources and gene nomenclature. The group shares genetic resources and unifies gene nomenclature related to grain quality.

The Quality EWG plays a vital role to advance the research area of grain quality and apply scientific knowledge to develop improved varieties of wheat with desirable grain quality attributes. The EWG builds on existing basic and applied knowledge and expertise, while utilising outputs of other international initiatives, wheat research organizations and EWGs. The EWG also includes some of the leading experts available worldwide in different aspects of wheat quality, and also links to other international groups that focus on a wide range of grain end-use requirements, adaptability and sustainable wheat production.

### 2021 MEETINGS

24-25 November, online meeting, 218 participants (includes non-members).

### EWG ACTIONS AND PROGRESS IN 2021

The EWG organized its first online wheat quality meeting which was very successful, it involved four senior and four junior researchers giving talks about diverse wheat quality topics. A video to promote the EWG was produced and is available to view on the WI webpage.

There was a method repository produced for 3 protocols used routinely in an INRAE lab, 1) Wheat grain protein extraction, 2) Quantification of N by Duma's and 3) Method and in glutenin and gliadin fractions by HPLC. The master set for dietary fibre was shared to the IPK genebank. Work was done on renewing the rules wheat gene nomenclature and the proposed rules will be published in the near future.

A publication on the evaluation of Fusarium graminearum ss tolerance to triazole fungicides was published *Cantoro et al., 2021), 'Bacillus velezensis RC 218 as a biocontrol agent against Fusarium graminearum: effect on penetration, growth and TRI 5 expression in wheat spikes.' BioControl. 66: 259-270. doi.org/10.1007/s10526-020-10062-7

### PLANS FOR 2022

The Quality EWG plans to hold its annual EWG meeting as a satellite one at the IWC. The EWG will develop a strategy for the training of new grain quality experts and other wheat scientists, and organise different webinars targeting wheat quality researchers and students. Work will be done on a lab protocol repository, and it will decide on the alleles/genotypes for the Master set for grain starch proteins and start collection and analysis of the accessions.
Other plans include producing a method repository for SDS-PAGE, A-PAGE, and molecular markers and identifying quality-related ideotypes (gluten, waxy, Pin, polyphenol oxidase (PPO) alleles) for each end use, which will help breeders for high quality wheat varieties.

The EWG will select and develop a Master set for low allergen and low toxic genotypes, research biocontrol on wheat to reduce the entry of mycotoxins (DON) in the food chain and FHB in wheat. They also plan to evaluate at molecular level, the tolerance to triazole fungicides of Fusarium graminearum ss isolated from different regions (Europe, USA, Argentina, Brazil) and refine the Master Set for dietary fibre and multiplication of seeds.

The EWG will continue to increase knowledge about mycotoxin and heavy metals contamination of wheat products along processing; reinvestigate methods to evaluate dough quality and study puroindoline involvement in the product quality under climate/soil extreme conditions.

# NUTRIENT USE EFFICIENCY

NUE

45 members from 19 countries
Chair: Malcolm Hawkesford (UK)
Vice Chairs: Jacques Le Gouis (France) and Ivan Ortiz-Monasterio (Mexico)
SB Liaisons: Alison Bentley and John Snape

## AIMS

The NUE EWG aims to assess the current state of the art with regard to knowledge on nutrient use efficiency in wheat; evaluate the potential of genetic versus agronomic solutions to improve nutrient use efficiency, assess the importance of interaction between nutrients; assess how priorities for traits and nutrient use efficiency may vary from region to region; promote information and expertise exchange, focusing on promoting mobility of next generation researchers; facilitate discussions with other EWGs to use all available tools to better characterise nutrient use efficiency and coordinate current research on nutrient use efficiency and propose joint initiatives where possible.

## 2021 MEETINGS

There were no meetings held this year due to the on-going COVID-19 pandemic.

## EWG ACTIONS AND PROGRESS IN 2021

There have been discussions on the collaboration on wheat roots and PUE and also on Brazilian wheat and PUE, follow up on these is still required.

## MAJOR SCIENTIFIC DEVELOPMENTS IN 2021

Listed below are particularly interesting publications published recently on NUE in wheat:

Ivić et al (2021) 'Variation for Nitrogen Use Efficiency Traits in Wheat Under Contrasting Nitrogen Treatments in South-Eastern Europe'. Front. Plant Sci. doi.org/10.3389/fpls.2021.682333

Tiong et al (2021) 'Improving Nitrogen Use Efficiency Through Overexpression of Alanine Aminotransferase in Rice, Wheat, and Barley'. Front. Plant Sci. doi.org/10.3389/fpls.2021.628521

Rawal et al (2022) 'Nutrient use efficiency (NUE) of wheat (Triticum aestivum L.) as affected by NPK fertilization'. PLos ONE. doi.org/10.1371/journal.pone.0262771

## PLANS FOR 2022

Leadership changes were initiated in early 2022 with the Chair, Malcolm Hawkesford and one of the Vice Chairs stepping down. New appointments were subsequently made with Jean Pierre Cohan as Chair and Jairo Palta as Co-Chair.

## WHEAT AGRONOMY (Agronomy EWG)

# AGRONOMY

42 members from 14 countries
Chair: Brian Beres (Canada)
Vice-Chair: John Kirkegaard (Australia)
SB Liaisons: Hans Braun and Wolfgang Friedt

### AIMS

The main aim of the Agronomy EWG is to consolidate the global expertise for agronomy with a focus on wheat production systems. The overarching approach is to develop and adopt a 'systems agronomy framework' relevant to any wheat production system. Such an approach first establishes the scale of current yield gaps identifying physiologically defensible benchmarks, and then takes a holistic approach to understand and overcome exploitable yield gaps.

Finally, new opportunities to drive increased productivity will be sought by capturing future Genotype X Environment X Management (GxExM) synergies identified in different systems.The Agronomy EWG will then be able to influence priorities for wheat agronomy research in member countries that would facilitate collaborations, minimise duplication and maximise the likely global impact on wheat production systems.

### 2021 MEETINGS

7-10 November 2021, face-to-face meeting, ASA (American Society of Agronomy)-CSSA (Crop Science Society of America)-SSSA (Soil Science Society of America) Annual Meeting, 12 members, Salt Lake City, USA
26-27 October 2021, online meeting, WI Research Committee meeting, 2 members
Various Strategy meetings, with Scientific Board advisors and WI secretariat, 5 members.

### EWG ACTIONS AND PROGRESS IN 2021

The project "Wheat yield gaps: magnitude and opportunities to sustainably improve yield" started in April 2019 and will be completed in December 2022. It is a partnership between Canada and the USA established in order to bridge the knowledge gap that currently exists in both countries with respect to wheat yield gaps.

A second partnership by both parties was established with the Global Yield Gap Atlas, led by Dr. Patricio Grassini, to utilize an existing framework and methodology for the determination of wheat yield gaps in North America. Yield gap results have been uploaded to the atlas and is freely available at www.yieldgap.org. There are further quality assurance checks being performed on the data and modelling.
A strategic plan for the Agronomy EWG was developed, resulting in the vision document – 'Beyond Yield – A Global Agronomy Effort to Address Yield Stability and Enhance Wheat Cropping System Resilience in a Changing Climate'. The next step is to develop a tangible roadmap that would lead to a collaborative framework and a coordinated call for research among stakeholder countries.

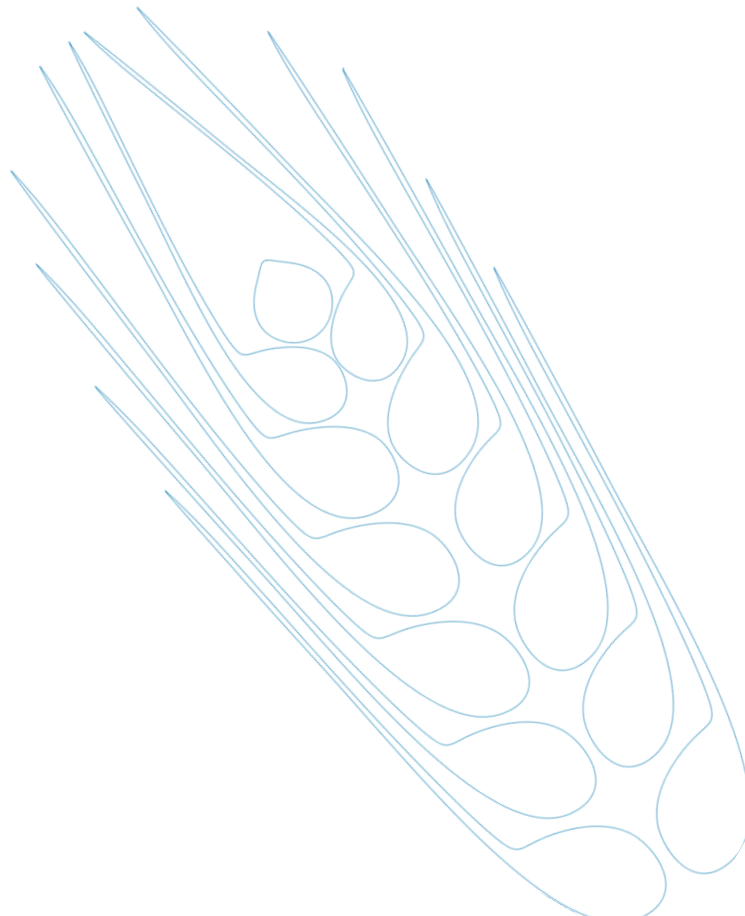
### MAJOR SCIENTIFIC DEVELOPMENTS IN 2021

As described above (under EWG Actions and Progress in 2021, 1st paragraph), the efforts of USA and Canada scientists has resulted in the completion of the mapping exercise related to the calculation of wheat yield gaps in the critical wheat growing areas of both countries. The next phase will be completion of farmer surveys in 2022, which will help elucidate causes leading to either a widening of yield gaps or yield gap closure. Work is currently being conducted on yield gaps related to nutrient management as part of a Masters Science project at the University of Saskatchewan. Also, a recent publication in Weed Technology by a group of USA and Canadian scientists describe work around an objective for the Weed Science Society to understand the implication of weed threats to wheat yield and corresponding economic losses, Flessner et al (2021), 'Potential wheat yield loss due to weeds in the United States and Canada. On average, these losses can be as high as ~25% for winter wheat production in the USA, and even higher for spring wheat (~33%).

A recent publication in Nature Climate Change, Zhao et al (2022), 'Novel wheat varieties deep sowing to beat the heat of changing climates.' describes an Australian study utilizing the recent genetic innovation of longer coleoptile wheat genetics coupled with alternative management practices related to deep sowing in response to changes in water resources. This is exemplary work highlighting the synergy in engaging genetics and management together to optimize wheat adaptation. The crop modelling provides excellent guidance to understanding the value and opportunities with new genetics and systems in variable climates.

**PLANS FOR 2022**

It is planned to attend the ASA-CSSA-SSSA Annual Agronomists annual meeting in Baltimore, USA in November. The EWG will liaise with the WI Secretariat in the revision of the Strategic Research Agenda (SRA). Also, it is planned to have discussions on the role of the Agronomy EWG aims within the framework of the SRA and an agreement on a roadmap that reinvigorates the Agronomy EWG and engages with both membership and the ASA Wheat Agronomists Community.



# WHEAT INFORMATION SYSTEM (WHEATIS EWG)

WHEATIS

22 members from 7 countries
Chair: Taner Sen (USA)
Vice-Chairs: Hadi Quesneville (France), Mario Caccamo (UK) and Dave Edwards (Australia)
SB Liaisons: Alison Bentley and Sylvie Cloutier

## AIMS

The WheatIS EWG works together to define data standards and data exchange protocols and develop a framework to support an integrated Wheat Information System (WheatIS). The WheatIS EWG's aim is to provide the international wheat research community with easy access to wheat genetic, phenotype and environmental information, as well as genomic data and bioinformatics tools.

A central node, called WheatIS core provides a single-entry point for the WheatIS users. The WheatIS core was built upon the resources provided and shared by the nodes. The core provides access to data and information through a web portal. This portal gives access to a data file repository storing files with their associated metadata through a Google-like search engine, which allow users to find data available in the WheatIS core and its nodes using keywords. Several dedicated integrative databases for genomic, genetic and phenotype information, as well as comparative genomics and functional genomics will be made available on the portal. Analysis tools will be available for download from the web portal. Some WheatIS nodes will provide computing resources for data analysis.

## 2021 MEETINGS

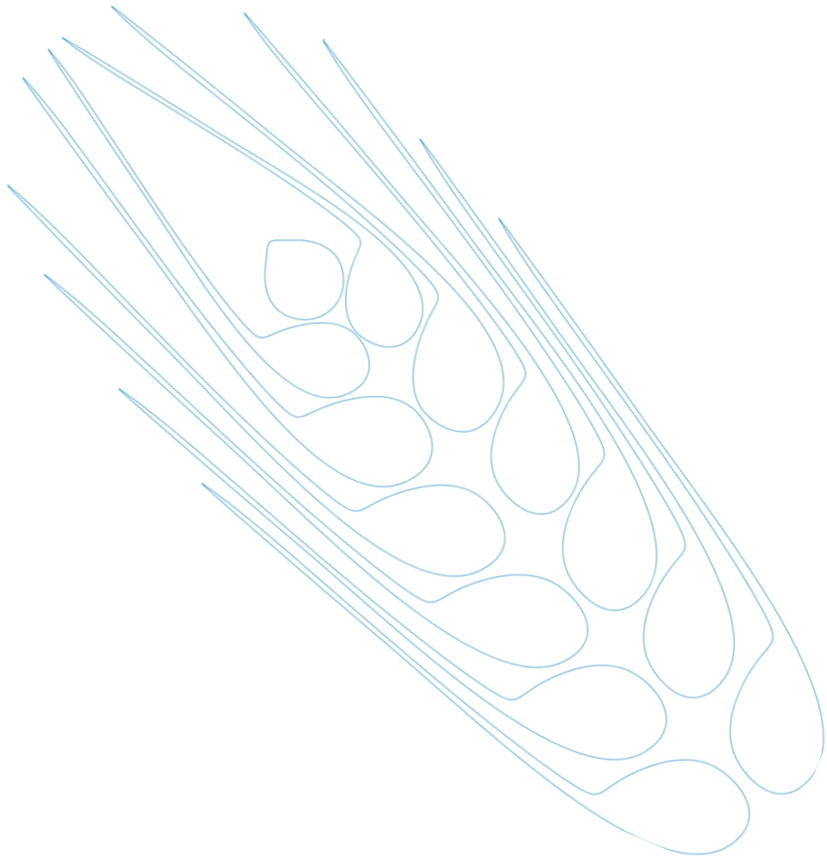
There were no meetings held this year due to the on-going COVID-19 pandemic.

## EWG ACTIONS AND PROGRESS IN 2021

During 2021, a WheatIS logo was designed, distributed to the community and added to the WheatIS website. The WheatIS interface, WheatIS Data Discovery (https://urgi.versailles.inrae.fr/wheatis/) was improved to include an update of EnsemblPlants data to release 51, in April 2021. There is on-going development of a new version of the tool allowing it to use BrAPI sources (https://brapi.org/).

## PLANS FOR 2022

A journal article will be published for the visualisation of Wheat PanGenomes, entitled 'Wheat Panache - a pangenome graph database representing presence/absence variation across 16 bread wheat genomes'.



# PHENOTYPING

55 members from 20 countries
Chair: Bettina Berger (Australia)
Vice-Chairs: José-Luis Araus (Spain) and Ulrich Schurr (Germany)
SB Liaisons: Silvia German and Fiona Doohan

## WHEAT PHENOTYPING TO SUPPORT WHEAT IMPROVEMENT (PHENOTYPING EWG)

### AIMS

The Phenotyping EWG aims to strengthen and support wheat phenomics research, promote international collaborations and the exchange of expertise in wheat phenotyping, enhance the integration of wheat phenotyping into breeding and genomics programs and engage experts from non-plant disciplines in wheat phenotyping.

### 2021 MEETINGS

EWG members took part in various webinars and online symposia in February, April and December 2021. This included webinars by the NAPPN (North American Plant Phenotyping network) and the NCPP (National Centre for Plant Phenotyping) and the RF Baker symposium. The EWG Chair gave presentations about phenotyping applications; there were 50-250 attendees per event. There were 10 online webinars on phenotyping, organized by the International Plant Phenotyping Network (IPPN) which are available to view on YouTube.

### EWG ACTIONS AND PROGRESS IN 2021

There were various online seminars and webinars reaching hundreds of diverse participants and providing training to EMCRs. There was also a video competition held jointly with the AWAS EWG and promoted through Twitter which increased the awareness of the WI by EMCRs. The advantage of online training is that a wide diverse audience is reached, and participation is possible from developing countries where normally travel costs and visa restrictions would limit access.

### MAJOR SCIENTIFIC DEVELOPMENTS IN 2021

Members of the EWG continue to be amongst the highest published researchers in wheat phenotyping. There were numerous publications by EWG members in 2021 including:

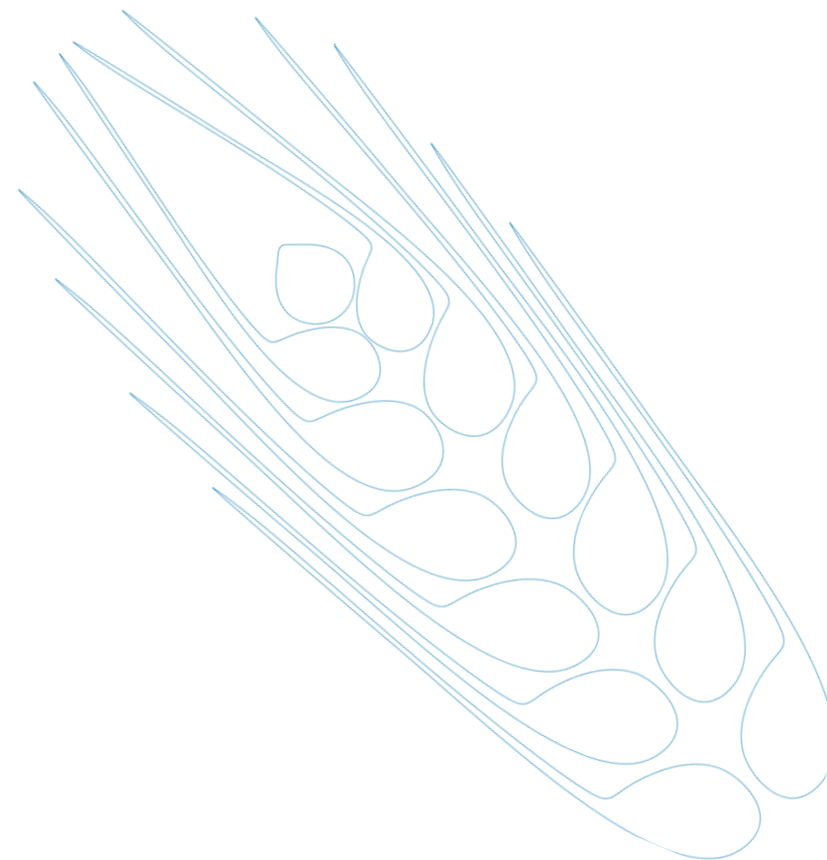
- Langridge and Reynolds (2021) 'Breeding for drought and heat tolerance in wheat'. Theor. Appl. Genet.134: 1753-1769. doi.org/10.1007/s00122-021-03795-1
- Ober et al (2021) 'Wheat root systems as a breeding target for climate resilience.' Theor. Appl. Genet. 134: 1645-1662. doi.org/10.1007/s00122-021-03819-w
- Volpato et al (2021) 'High throughput field phenotyping for plant height using UAV-based RGB imagery in wheat breeding lines: feasibility and validation. Front. Plant Sci. doi.org/10.3389/fpls.2021.591587
- Asif et al (2020) 'Identification of salt tolerance QTL in a wheat RIL mapping population using destructive and non-destructive phenotyping'. Funct. Plant Biol. 48: 131-140. doi.org/10.1071/FP20167
- Joynson et al (2021) 'Uncovering candidate genes involved in photosynthetic capacity using unexplored genetic variation in Spring Wheat.' Plant Biotech. J. 19: 1537-1552. doi.org/10.1111/pbi.13568
- Hu (2021) 'Coupling of machine learning methods to improve estimation of ground coverage from unmanned aerial vehicle (UAV) imagery for high-throughput phenotyping of crops.' Funct. Plant Biol. 48: 766-779. doi.org/10.1071/FP20309

- Araus et al (2021) 'Crop phenotyping in a context of Global Change: what to measure and how to do it.' J. Int. Plant Biol. 64: 592-618. doi.org/10.1111/jipb.13191
- Vatter et al (2021) 'Preharvest phenotypic prediction of grain quality and yield of durum wheat using multispectral imaging.' Plant J. 109: 1507-1518. doi.org/10.1111/tpj.15648
- de Lima et al (2021) 'Comparative performance of high-yielding European wheat cultivars under contrasting Mediterranean conditions.' Front. Plant Sci. 12: 687622. doi.org/10.3389/fpls.2021.687622
- et al (2021) 'Dataset of above and below ground traits assessed in Durum wheat cultivars grown under Mediterranean environments differing in water and temperature conditions.' Data in Brief. 40: 107754. doi.org/10.1016/j.dib.2021.107754
- Rezzouk et al (2022) 'Durum wheat ideotypes in Mediterranean environments differing in water and temperature conditions.' Agricultural Water Management 259: 107257. doi.org/10.1016/j.agwat.2021.107257


**PLANS FOR 2022**

The EWG plans to attend two face-to-face meetings: the 7th International Plant Phenotyping Symposium in Wageningen, Netherlands in September 2022 and the InterDrought 7 Congress in Dakar, Senegal in November/December 2022. There will be the option at both conferences for people to join on-line for the EWG meeting. There will be the continuation of online seminars and webinars.

With the easing of travel restrictions, it is planned that there will be 3-4 placements of Early Career researchers in EWG member labs enabling them to upskill by learning new techniques.



# FEWG

9 Members from 7 countries
Chair: Tim Willis (UK)

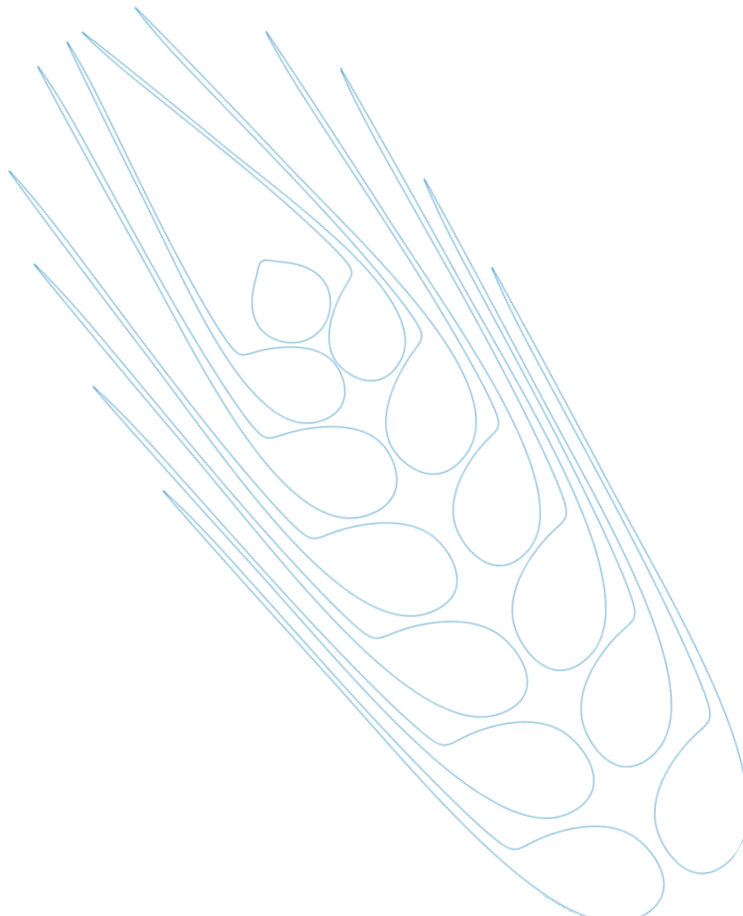
## FUNDING EXPERT WORKING GROUP (FEWG)

### AIMS

The FEWG aims to identify and disseminate information on funding mechanisms and tools available to support multi and bilateral international collaboration in wheat research, for the benefit of WI's EWGs. The EWG aims to enable dialogue and coordination at a funder-to-funder level with an aim to explore priorities and opportunities for alignment of funding under broad wheat research themes.

### EWG COMMENTS FOR 2021

Funders of research are now looking to re-establish their connections and partnerships as COVID restrictions begin to ease in some countries. We are still looking to understand how global food systems can strengthen their resilience to shocks such as pandemics and conflict. Funders are now assessing what needs to be done to sustain projects over several growing seasons. Advances in research and innovation will support ambitious targets to reduce greenhouse gas emissions, protect and enhance the environment and rebuild biodiversity whilst having positive health benefits.



# MEMBERS HIGHLIGHTS 2021

## AUSTRALIA (GRDC)

### 1. WHEAT PRODUCTION (AREA, AMOUNT, AND AVERAGE YIELD) AND MAJOR PRODUCTIONS ISSUES (DROUGHTS, FLOODS, HEATWAVES, ETC.)

Australia is expected to have another record wheat crop in 2021-22 with an estimated production to 34.4 Mt (million tonnes) from 13 million hectares sown. Sufficient rainfall and mild temperature over spring have kept yields in line with the 2020-21 season at 2.6 t/ha (tonnes per hectare).

### 2. SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

This year GRDC has co-invested with its research partners, University of Sydney, University of Queensland, CIMMYT and ICARDA in a further 5-year phase of the successful CIMMYT Australia ICARDA Germplasm Evaluation (CAIGE) program. The CAIGE program is designed to capture global diversity and international genetic gains and evaluate them for yield and disease resistance under Australian conditions. The co-investment of $8.25 million will further evolve the program, utilizing genomic and more detailed phenotypic information from the CGIAR partners to inform selections of novel and relevant genetic diversity for testing in Australia. Knowledge will then be supplied back to the international partners as to the performance of the germplasm in Australia.

### 3. RESEARCH HIGHLIGHTS

Researchers from the Australian Centre for Crop and Disease Management (CCDM), a national centre co-supported by GRDC and Curtin University, have discovered the genetic element that controls the production of Tox1, the toxic effector molecule that results in the economically damaging Septoria nodorum blotch (SNB).

The research, undertaken in collaboration with researchers from CSIRO, the Max Planck Institute of Germany, and the University of Neuchâtel of Switzerland, was published in PLOS Pathogens (Evan et al, 2022). This discovery streamlines the breeding strategies to produce SNB resistant wheat varieties suitable to Australian conditions.

Researchers from Agriculture Victoria and University of Sydney, led by Prof. Richard Trethowan and Dr Hans Daetwyler, continue to provide breeders with new knowledge and germplasm to improve the heat tolerance of wheat. In a recent article published in Theoretical and Applied Genetics (Joukhadar et al, 2021) the group detailed several stable QTLs for agronomic and quality traits that were identified from a metaGWAS analysis of 26 trials sown at optimal or late times of sowing.

### 4. WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMS

In 2021 GRDC initiated a new investment to accelerate integration of physiology-based wheat traits within a commercial breeding program with the aim to significantly enhance water-limited yield potential. The $5.9 million, 5-year co-investment with Australian wheat breeding company AGT will facilitate the evaluation and validation of outputs of the substantial international efforts in fundamental research on plant physiological and biochemical processes in wheat.

The Australian Research Council (ARC) Training Centre for Accelerated Future Crop Development was awarded in 2021 and is due to commence research and training in 2022. The $10 million funded centre, led by Prof. Barry Pogson at Australian National University (ANU), will bring together Australian researchers and industry partners to develop socially responsible genetic and field technologies for future crops.

# CANADA (AAFC)

## 1. WHEAT PRODUCTION (AREA, AMOUNT, AND AVERAGE YIELD) AND MAJOR PRODUCTIONS ISSUES (DROUGHTS, FLOODS, HEATWAVES, ETC.)

In 2021, western Canadian farmers contended with dry soils, wide-spread drought and higher-than-average temperatures. Wheat production fell 38.5% to 21.7 Mt due to lower production in the Prairies. Yields decreased 33.3% to 2.34 t/ha and harvested area decreased 7.7% to 22.8 Mha from 2020. Along with the drought, wheat stem sawfly made an aggressive comeback in some regions.

## 2. SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

AAFC has become a member of the Alliance for Wheat Adaptation to Heat and Drought (AHEAD). AAFC scientists participated in the 2021 AHEAD workshop to provide an overview of on-going projects on heat and drought in wheat at AAFC.
A team of AAFC wheat rust pathologists, geneticists, and plant breeders earned the Borlaug Global Rust Initiative (BGRI) 2021 Gene Stewardship Award for their long-standing innovations and strategies to combat wheat rust in Canada and around the world. AAFC research has focused for nearly 100 years on developing cultivars with durable rust resistance and sharing germplasm with wheat breeding institutions worldwide in the global effort to develop wheat security from epidemic losses to the rust pathogens.
An AAFC research scientist won third place for a video submitted to the Wheat Initiative competition in the category of High Tech Abiotic Stress/Phenotyping App; featuring a new single kernel moisture reader.

## 3. RESEARCH HIGHLIGHTS

As resistant cultivars continue to provide the best protection to disease and insect shifts due to climate change, the search for new genes from wild relatives is vital to stay ahead of epidemics. Many genes come from Aegilops species but only Ae. tauschii has been sequenced to date. The University of Saskatchewan and AAFC are collaborating to sequence the remaining 24 Aegilops species in order to provide a 4DWheat atlas for new resistance genes. A 4DWheat atlas will be an important step towards managing disease and insect threats occurring and expected with climate change.
AAFC has achieved a major breakthrough with Fusarium Head Blight (FHB) resistance in durum. A new durum variety developed at AAFC's Swift Current Research and Development Centre is the first Canadian durum with intermediate FHB resistance.
A University of Saskatchewan-led international team published the genomes for 15 wheat varieties representing breeding programs around the world in the journal Nature. The results will enable scientists and breeders to more quickly identify influential genes for improved yield, pest resistance and other important crop traits.

## 4. WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMS

Prairie wheat commissions have established core wheat agreements with two additional Canadian Universities. $3.5 M was committed to the University of Manitoba and $2 M to the University of Alberta. University of Manitoba's Fusarium Head Blight nursery is a key screening facility in Canada while the University of Alberta's research will focus on traits such as early maturity.
The University of Saskatchewan has announced the establishment of a new Insect Research Facility (USIRF). USIRF will be the first in a western Canadian university that is specifically designed to conduct research on arthropod plant pests and beneficial insects. This facility will allow researchers to identify resistance traits to pests of concern and develop sustainable pest management strategies for field crops.

## CHINA (CAAS)

### 1. WHEAT PRODUCTION (AREA, AMOUNT, AND AVERAGE YIELD) AND MAJOR PRODUCTIONS ISSUES (DROUGHTS, FLOODS, HEATWAVES, ETC.)

In 2021, China produced 134.34 Mt wheat, harvested area was 22.9 Mha, the yield was 5.863 t/ha. It was a very good wheat production season without any major issues due to diseases.

### 2. SIGNIFICANT NEW NATIONAL / INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

A joint research proposal has been developed between China and European countries such as France, Germany and the UK on crop genetics and genomics, based on establishing joint labs with the Ministry of Science and Technology, China. The final evaluation for financial support will be carried out by the middle of 2022.

### 3. RESEARCH HIGHLIGHTS

In China, wheat genomics and applied genomics research has achieved good progress in 2021. Dr Ye's group in Institute of Crop Sciences-CAAS, has successfully overcome genotype dependency in wheat genetic transformation through co-transformation of the target gene with TaWOX5. The WOX5 is a key gene promoting callus regeneration and differentiation (Wang et al, 2022). Two teams (CAU and CAAS) has independently isolated Green revolution gene Rht8, which is not as strong as Rht1 or Rht2 for height reduction, but is a very important partner gene for either Rht1 or Rht2 in breeding for semi-dwarf cultivar breeding in the central wheat production regions (Huang et al 2022; and Chai et al 2022 ).

For disease resistance, Dr Gao's group obtained powdery mildew resistance in wheat without growth penalties through a 304-kilobase pair targeted deletion in the MLO-B1 locus of wheat. The edited lines retain crop growth and yields while conferring robust powdery mildew resistance.

This deletion results in an altered local chromatin landscape, leading to the ectopic activation of Tonoplast monosaccharide transporter 3 (TaTMT3B), and this activation alleviates growth and yield penalties associated with MLO disruption. This work showed the great potential for improvement of disease resistance through editing the genes associated with susceptibility in crops (Deng and Cao, 2022)

For drought tolerance, Dr Mao and his colleagues, NW Agriculture and Forestry Technology University, identified TaNAC071-A tightly associated with drought tolerance by GWAS. Knockdown of TaNAC071-A in wheat attenuated plant drought tolerance, whereas its overexpression significantly enhanced drought tolerance through improved water-use efficiency and increased expression of stress-responsive genes. A 108-bp insertion in the promoter of TaNAC071-A alters its expression level and contributes to variation through bindingTaMYBL1 (Mao et al, 2022).

### 4. WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMS

There was substantial new funding awarded to wheat research for fine phenotyping and improving end use quality by the MOST, China.

# FRANCE (INRAE)

## 1. WHEAT PRODUCTION (AREA, AMOUNT, AND AVERAGE YIELD) AND MAJOR PRODUCTIONS ISSUES (DROUGHTS, FLOODS, HEATWAVES, ETC.)

In 2021, 36.79 Mt wheat + spelt (Eurostat) were harvested (average 2017-2020: 36.53 Mt) on 5.23 Mha (average 2017-2020: 5.08 Mha). The national grain yield is also quite normal (7.32 t/ha) compared to the last four seasons (7.17 t/ha). Grain quality is generally good with also average grain protein concentrations (11.9%).

## 2. SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

In November, the French Ministry for Agriculture, Research and Industry announced three Priority Programs for Research and Equipment (PEPR) for a total of 155 M€. The PEPR "genetics and varietal selection" is led by INRAE, while the PEPR "agroecology and digital" and "Food systems, microbiome and health" are co-led by INRAE. The PEPR "Agroecology and digital" particularly concerns data, agri-equipment but also genetic resources for the agro-ecological transition and adaptation to climate change. Projects are currently being built within this framework and several are dealing with wheat genetics and breeding.

## 3. RESEARCH HIGHLIGHTS

- Serra et al (2021) reported positional cloning of Pairing homoeologous 2 (Ph2) and functional validation of the wheat DNA mismatch repair protein MSH7-3D as a key inhibitor of homoeologous recombination (doi.org/10.1038/s41467-021-21127-1).
- Girousse et al (2021) established temperature-response curves of grain dry mass, water mass, volume, and endosperm cell number for steady post-anthesis temperatures between 15 °C and 36 °C and related different sensitivities to heat of these various processes (doi.org/10.1093/jxb/erab282).
- Leveau et al (2021) analyzed the genetic diversity in 12 groups of wheat-related species and subspecies for traits linked to plant vegetative structures and their development, and to leaf expansion and transpiration, together with their responses to 'non-stressing' ranges of temperature and evaporative demand (doi.org/10.1093/jxb/erab431).
- The Global Wheat Head Detection (GWHD) dataset was created in 2020. It has been reexamined, relabeled, and complemented by adding 1722 images from 5 additional countries, allowing now for more than 275,000 wheat heads (David et al 2021; doi.org/10.34133/2021/9846158).
- Saintenac et al (2021) used comparative genomics, mutagenesis and complementation to identify Stb16q, which confers broad-spectrum resistance against Zymoseptoria tritici. The Stb16q gene encodes a plasma membrane cysteine-rich receptor-like kinase that was recently introduced into cultivated wheat and which considerably slows penetration and intercellular growth of the pathogen (doi.org/10.1038/s41467-020-20685-0).

## 4. WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMS

The EVAGRAIN (2021-2024, coordination L. Saulnier, INRAE) and FFAST (2022-2025, coordinator R. Lopez-Lozano, INRAE) projects were funded by the French National Research Agency.

EVAGRAIN ambition is to design a Decision Support System that will provide a general assessment of the value of bread wheat for different end-uses. A second objective is to set up innovative analytical tests, if possible in real time, which will enable a more complete and rapid diagnosis of wheat quality by integrating non-protein components such as lipids, pentosans and water.

FFAST aims at improving our understanding of wheat genotypes functioning and responses to abiotic stress by identifying functional traits from the assimilation into functional-structural plant models and crop growth models of multiple structural traits observed using different instruments, spatial scales, and environments.

## GERMANY (BMEL)

### 1. WHEAT PRODUCTION (AREA, AMOUNT, AND AVERAGE YIELD) AND MAJOR PRODUCTIONS ISSUES (DROUGHTS, FLOODS, HEATWAVES, ETC.)

Wheat is the most widely cultivated crop in Germany. Based on preliminary representative results, wheat was grown on an acreage of 2.95 Mha in 2021, which corresponds to a share of 48.7 percent of total cereal cultivation. The average yield for wheat is estimated at 7.25 t/ha, which decreased by seven percent compared to last year. The decline in total wheat yield was caused by hot and dry weather conditions in summer resulting in yield depression and also local-scale above-average precipitation, often with severe weather character leading to lodging. In 2021, 19 new wheat varieties (16 winter type, 3 spring type), were registered in Germany. They combine high yield with a high level of resistance and different qualities (E, A, B, C).
References: BMEL Erntebericht 2021 - Mengen und Preise, BSA Beschreibende Sortenliste 2021 - Getreide, Mais, Öl- und Faserpflanzen, Leguminosen, Rüben, Zwischenfrüchte

### 2. SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

TERTIUS, a project resulting from the call promoting innovative ideas for breeding efficient wheat varieties in the face of climate change, started. The overall objective of TERTIUS is to develop wheat prototypes with optimized root system, improved water-use efficiency and good baking quality. TERTIUS is one of the flagship projects in the area of plant breeding in the 2035 arable farming strategy discussion paper of the BMEL and is integrated into the global network Alliance for Wheat Adaption to Heat and Drought (AHEAD).

The private PILTON research project was launched involving nearly 60 German plant breeding companies with the aim of developing wheat with improved fungal tolerance through new breeding methods. Currently, the tolerance of the genome-edited plants is being tested.
Within WDV-MAS, a project resulting from the call promoting innovative ideas for breeding higher-performing wheat varieties from 2013, quantitative trait loci for partial wheat dwarf virus (WDV) resistance were identified. The results were published in 'Frontiers in Plant Science' in 2022.

### 3. WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMS

All eleven collaborative projects resulting from the call promoting innovative ideas for the breeding of efficient wheat varieties in the face of climate change within the Innovation Program are running successfully. After three years, an interim evaluation is conducted from the first quarter of 2022 onwards. After a positive evaluation of the specified success criteria, the projects can be continued for a maximum of two more years.
There were 93 project outlines submitted for call, promoting innovative ideas for the breeding of climate-adapted varieties and crops within the Innovation Program by the deadline in July 2021, nine of which deal with wheat as a crop. The final funding decision is still pending.

## ITALY (CREA)

### 1. WHEAT PRODUCTION (AREA, AMOUNT, AND AVERAGE YIELD) AND MAJOR PRODUCTIONS ISSUES (DROUGHTS, FLOODS, HEATWAVES, ETC.)

Regarding the area, the last census redacted by the Mipaaf official source (ISMEA) considers, in the last 3 years (2018-2019-2020), a surface of around 1.2 Mha dedicated to Durum Wheat and 0.5 Mha dedicated to Common Wheat (no updated data are available for 2021). In the same period of time (3 years), the Italian production was: for common wheat, around 1.6 Mt (grain) and 3.8 Mt (flour); for durum wheat, around 4.0 Mt (grain) and 4.0 Mt (bran). Referring to the geographical distribution, the major regions and production of soft wheat is localized in the northern regions while the durum wheat is more spread in southern regions, islands included.

Regarding the major production issues in 2021, there has been an improvement in the national production of wheat (+1.5% for durum wheat with 3.9 Mt and +4% for soft wheat at 2.8 Mt), despite a decrease in cultivated areas and less investments in the sector. In addition to the alarm dictated by the increase in prices of durum wheat (national and imported), caused mainly by the higher prices of the main agricultural raw materials, accompanied by increasingly volatility of prices (expected drop in harvest in Canada and the United States). Durum wheat in Italy reached its highest price in December 2021, and the supply gap created after the collapse of harvests in Canada (-60%), the world's main exporter, and the drop in other important producing countries, is increasing market instability affected by the persistent drought and the contraction of global stocks. Now we need to consider the recent Ukraine war. In the global supply of durum wheat, the role of countries directly involved in the conflict or falling geographically or politically within the Russian orbit is practically non-existent, with production concentrated mainly in Europe, Canada, USA, Turkey and Algeria. The case of common wheat is different, where the Russian and Ukrainian share of world production reaches 14% (16% if Kazakhstan is also considered), and the situation of instability is having a decisive impact on the main international trading venues and futures markets.

### 2. SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

During 2021, preparations were made for the next international congress on durum wheat, 4th From Seed to Pasta congress (https://www.fromseedtopasta.com ) that will be held in Bologna on 26-28 October 2022. The congress, organized by the University of Bologna, CREA, CNR, CIMMYT, ICARDA, University of Saskatchewan and the Wheat Initiative, will provide a timely update on durum wheat multidisciplinary research towards a more sustainable and resilient durum wheat chain capable of enhancing food security and provide a healthier diet. The congress will hopefully represent the first face-to-face meeting after the pandemic and will provide a unique opportunity to discuss and reconnect the durum wheat scientists. State-of-the-art presentations will showcase how to safeguard soil health while reducing the environmental footprint of durum wheat production based upon higher nutrient-use efficiency coupled with better understanding of GxExM interactions.

At the European level, even if not specific for cereals but focused on agri-food sectors, Mipaaf is working to build new Horizon EU partnerships (eg. Agridata, Agroecology). Mipaaf is also involved in the European initiatives such as JPIs and Eranets and related activities connected to research and innovation in the agri-food sector.

At the national level, Mipaaf has carried on instrumental tools: 1) National Experimental Commission for durum wheat to formulate, in a regulated and transparent manner, the indicative prices and the relative market trend to ensure the transparency of the process of markets, responding in a timely manner to the needs of market operators to have points of reference to base their negotiations; 2) Sector and District Contracts, developed in the different segments of the agro-food supply chain (primary production, processing, marketing and distribution phases), including the wheat sector, to boost investments in agri-food and realize integrated investment programs of interprofessional nature and with national relevance. The two tools are still working.

## 3. RESEARCH HIGHLIGHTS

Italy played a major role in the assembly of a global platform for leveraging the genetic diversity of tetraploid wheat. The University of Bologna and CREA, in collaboration with other members of the EWG on durum wheat genomics and breeding, have assembled two major diversity panels: (i) the Tetraploid wheat Global Collection (TGC), particularly versed for evolutionary studies and gene/QTL discovery and cloning that includes wild relatives and tetraploid subspecies (1,852 accessions in total) and (ii) the Global Durum Panel (GDP), a breeding-dedicated tool suitable for GWAS, mainly focused on landraces and modern varieties (1,056 accessions in total). Both collections have been genotyped and are available as reference panels for durum genetics.

## 4. WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMS

The PRIMA programme (Partnership for Research and Innovation in the Mediterranean Area - https://prima-med.org/), is supported by Horizon 2020 and is the main funding opportunity for Mediterranean countries with European and participant member resources.

Three PRIMA projects dedicated to durum wheat and coordinated by Italian scientist are currently ongoing:

- CEREALMED: “Enhancing diversity in Mediterranean cereal farming systems” coordinated by Agata Gadaleta (University of Bari) and dedicated to the analysis of tetraploid wheat genetic diversity.
- EXPLOWHEAT: “Exploring durum wheat genotypes to minimize drought stress impact on grain yield and nutritional quality” coordinated by Stefania Astolfi (University of Tuscia). A project aiming to identify cultivars, and/or genetic combinations, of durum wheat able to cope with drought and nutrient deficiency.
- IMPRESA: “IMProving RESilience to Abiotic stresses in durum wheat: enhancing knowledge by genetic, physiological and "omics" approaches and increasing Mediterranean germplasm biodiversity by crop wild relatives-based introgressiomics” coordinated by Carla Ceoloni (University of Tuscia). A project focused on the utilization of introgression lines engineered with small alien chromosome segments enhancing yield-related traits.

Looking to 2022, a new relevant national research project aiming to sequence the durum wheat pangenome was recently launched under the coordination of Roberto Tuberosa (University of Bologna): Grain Pangenomics for Durum Wheat Sustainable Production (PanWheatGrain).
Regarding the new future research programs, Mipaaf is involved in the process for the building of new partnerships of the new Horizon Europe and within the Pillar 2 - Cluster 6 - Food, bioeconomy, natural resources, agriculture, and environment.

## JAPAN (AFFRC-JIRCAS)

### 1. WHEAT PRODUCTION (AREA, AMOUNT, AND AVERAGE YIELD) AND MAJOR PRODUCTIONS ISSUES (DROUGHTS, FLOODS, HEATWAVES, ETC.)

In Japan, annual wheat consumption is 5.6 Mt, of which 0.8 Mt are produced within Japan (14.2%). The main production areas are Hokkaido and Kyushu region. Both winter and spring wheat varieties are cultivated in Hokkaido by the fall and spring sowings, respectively, and winter and facultative wheat varieties in other areas by the fall sowing. The national average yield is 4.2 t/ha, which has been increasing in recent years due to new varieties. Wheat in Japan is used for bread and Chinese noodles (16.5% share) and for Japanese noodles and confectionery (83.5%). However, even though wheat varieties suitable for each use are developed, the amount of production is not enough for the consumption. Domestic wheat has a high brand value from the viewpoint of the movement toward food safety and security. Even though bread and noodles produced from domestic wheat are sold as popular brand products, the larger problem is the fluctuation in production amount and quality due to climate change.

### 2. SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

Wheat breeding in Japan is chiefly carried out by the National Agriculture and Food Research Organization (NARO) and the agricultural experimental stations of each prefecture. Therefore, cooperation with international organizations in other countries is not extensive. Wheat research in Japan has a long history. The discovery of wheat chromosome number, hexaploidy, evolution by interspecific hybridization, and cytoplasmic inheritance using cytoplasmic substitution are only a few examples showing extensive discovery in this history. The National BioResource Project-Wheat has collected 11,606 wheat strains, 1,575 experimental strains, and 3,985 strains of Aegilops and provided them to researchers on request. This project's accessions are very reliable because they are carefully maintained by bagging to avoid contamination.

Examples of the international joint research include heat resistant wheat breeding using germplasm of synthetic wheat in Sudan between Tottori University and Sudan Agricultural Research Corporation and breeding for biological nitrification inhibition (BNI) between JIRCAS, CIMMYT and Bolaugh Institute for South Asia.

### 3. RESEARCH HIGHLIGHTS

- Subbarao et al (2021) Enlisting wild grass genes to combat nitrification in wheat farming: A nature based solution. PNAS 118:e2106595118. doi.org/10.1073/pnas.2106595118
- Iizumi et al. (2021) Rising temperatures and increasing demand challenge wheat supply in Sudan. Nature Food 2: 19-27. doi.org/10.1038/s43016-020-00214-4
- Murakami et al. (2021) Prediction of municipality-level winter wheat yield based on meteorological data using machine learning in Hokkaido. ProsOne doi.org/10.1371/journal.pone.0258677
- Sato et al. (2021) Chromosome-scale genome assembly of transformation-amenable common wheat cultivar 'Fielder'. DNA Res. 28. dsab008. doi.org/10.1093/dnares/dsab008
- Maryenti (2021) Development and regeneration of wheat-rice hybrid zygotes produced by in vitro fertilization system. New Phytologist 232:2369-2383. doi.org/10.1111/nph.17747
- Ogawa and Matsumura (2021) Revealing 3D structure of gluten in wheat dough by optical clearing imaging. Nature Comms 12:1708. doi.org/10.1038/s41467-021-22019-0

### 4. WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMS

Wheat research funding in Japan comes from the government, NARO, affiliated organizations (JST, JSPS, JICA), prefectural governments, companies (flour milling and bakery etc.) and universities or other institutions.

## KOREA, REPUBLIC OF (RDA-ITCC)

### 1. WHEAT PRODUCTION (AREA, AMOUNT, AND AVERAGE YIELD) AND MAJOR PRODUCTIONS ISSUES (DROUGHTS, FLOODS, HEATWAVES, ETC.)

- Production of wheat in 2019/2020
  -Cultivation area is 5,224 ha, total production is 16,985 tonne and productivity is 3.25 t/ha.
  -In 2020, wheat yield was decreased by 15% due to the low temperature damage in April, the early heading stage.
- Wheat policy
  -The annual consumption of wheat is around 2.1 Mt and the self-sufficiency rate is less than 1%.

The wheat public stockpiling and a policy of scaling up production to expand wheat production has been implemented since 2021. The quality control system will be performed starting in 2023.

### 2. SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

Joined the Wheat Initiative.

### 3. RESEARCH HIGHLIGHTS

- Key R&D area
  -Research on wheat cultivation technology to expand double-cropping systems (wheat-rice, wheat-bean)
  -Research on technology of sowing, fertilization, and water management of wheat
  -For quality management, seed purity control using molecular marker, Non-destructive kernel quality evaluation technologies, method of distinction kernel vitreousness, and production traceability management system
  -Development of high-quality varieties for noodles and bread wheat

Development of health functional wheat varieties such as high antioxidant and low allergy wheat.

## MOROCCO (INRA)

### 1. WHEAT PRODUCTION (AREA, AMOUNT, AND AVERAGE YIELD) AND MAJOR PRODUCTIONS ISSUES (DROUGHTS, FLOODS, HEATWAVES, ETC.)

**Cereal production in 2020-2021: a "very good" harvest of 10.32 Mt**

The final production of the three major cereals for the 2020-2021 season is estimated at nearly 10.32 Mt compared to 3.21 Mt in 2019-2020, an increase of 221% compared to the previous season. This production comes from an area planted with main cereals of 4.35 Mha, practically similar to that of the previous season (+0.3%) (Statement of the Ministry of Agriculture, Maritime Fishing, Rural Development and Water and Forests, September 2021).

With this "very good" cereal harvest, the initial estimates of growth of the entire agricultural sector with all its sectors, should be confirmed with a projected agricultural value added of 130 billion MAD for the year 2021, a growth of more than 18%, which demonstrates a stronger resilience of the agricultural sector. The average yield was established at 2.37 t/ha, up 320% compared to the previous season. By species, the cereal production is as following: Soft wheat: 5.06 Mt; Durum wheat: 2.48 Mt; Barley: 2.78 Mt.

The 2020-2021 crop year was characterized by a good temporal distribution of rainfall during the key stages of cereal development; which are tillering, booting and grain filling. In some areas, the yields obtained have exceeded the initial forecasts, especially in the northern part of the country.

The 2020-2021 cropping season is historically the second best after the 2014-2015 season, despite the received rainfall comparable to a normal season. This reflects the technical progress made in the cultivation of cereals, in particular the dissemination of genetic progress, the result of the use of certified seeds, the use of mechanization in different cultivation operations and the introduction of new production and soil conservation technologies such as No till.

As such, in favorable areas farmers have been able to achieve yields of 5.0 and 6.0 t/ha, which reflects the efforts made to optimize the potential of this sector.

## 2. SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

During this year, INRA Morocco has strengthened its engagements through new national and international partnerships. At the international level, we have established a new MoU with the company Syngenta using Seed Health technologies to promote safe seed treatments, environment protection and enhance productivity. At the national level, we are working with the national milling industry to promote national durum wheat varieties with good quality (high protein content and high yellow pigment) to produce a Moroccan couscous using INRA varieties. Two durum wheat varieties (Hammadi and Itri) have been retained because of their good quality.

## 3. RESEARCH HIGHLIGHTS

During 2021, we have submitted 6 new wheat varieties for release (3 durum wheat and 3 bread wheat). These new varieties are high yielding, resistant to the main diseases and have good quality. They are superior to normal checks across several environments (arid, semi-arid, favorable and irrigated). Besides, INRA has released 3 new Oat varieties (which is an important cereal crop in Morocco used mainly for feed). The first variety is Nezha (Q100-16); it's a naked oat variety, with an average yield of 3.5 t/ha, early, resistant to crown rust with a good grain quality (high protein and beta-glucan content). It is recommended for the favorable rainfed areas.


Photo: Plant and Seeds of the Oat variety Nezha

The two other oat varieties (Hamdali et Niema) have the following special features: improved hexaploid varieties with high nutritional value of the grain, suitable for human consumption and recommended for the favorable rainfed areas.

Photo1: Hamdali


Photo2: Hamdali

Photo 2: Niema


Photo 2: Niema

### 4. WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMS

Regarding wheat research funding, we have mainly two research programs dealing with wheat:

1. Morocco Collaborative Grants Program Phase IV (MCGP IV) between INRA Morocco and ICARDA (Period: 2020-2024)
    - Component 1. Enhancing genetic gains of cereals and legumes to adapt to climate variability and user requirements (200.000 dollars/year).
    - Component 2. Unlocking the yield gap of wheat-based cropping systems in different rainfed agro-ecological zones of Morocco (300.000 dollars/year).
2. National midterm wheat research program (PRMT2021-2024): the expected funding for the 4-year term is around 40 million MAD.

**The main components of this research program are:**

1. Wheat Genetic improvement and biotechnology (smart breeding and new technologies)
2. Wheat crop management (Production, Protection)
3. Agro-industrial valorization, technological and nutritional improvement of wheat and its derivatives
4. Value chain, governance mechanisms and coordination of the actors of the wheat sector.

**INRA partners in the area of wheat research are:**

International wheat research centres (ICARDA and CIMMYT), public institutions (ADA, DDFP, DSS, DEFR, DRA and ONCA), national wheat organizations (FIAC, FNIS, AMMS, SONACOS, COMADER), national universities (IAV Hassan II, ENA and others).

## TURKEY (TAGEM)

### 1. WHEAT PRODUCTION (AREA, AMOUNT, AND AVERAGE YIELD) AND MAJOR PRODUCTIONS ISSUES (DROUGHTS, FLOODS, HEATWAVES, ETC.)

Bread wheat and durum wheat production in 2021 was 17.65 Mt and total production area: 6.74 Mha. The average yield of bread and durum wheat was 2.67 t/ha. Total production decreased by 3 Mt due to drought stress conditions. Bread wheat and durum wheat production were affected mainly by drought stress conditions in the Central Anatolia and Southeastern Anatolia region in Turkey. Major production issues are decreasing of yield and fluctuation of quality due to various environmental conditions such as lower rainfall and fluctuation of temperature. There was no drought problem in coastal areas, but rust and root diseases, and Septoria leaf disease limited production as an important biotic stress factor in these regions.

### 2. SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

International Winter Wheat Improvement Program (IWWIP) continues with the partnership of international research institutions CIMMYT and ICARDA with international participation.

EU-partnered sub-project on rust diseases is carried out by the grain rust diseases research centre in İzmir, Turkey. Some international cooperation will continue between the national research institutes, universities and TUBİTAK on bread and durum wheat breeding for yield potential, biotechnology, agronomic applications, higher tolerance on biotic and abiotic stresses.

### 3. RESEARCH HIGHLIGHTS

Wheat continues to be the most valuable field crop for Turkey agriculture. Some research projects related with wheat breading and agronomic studies supported by TAGEM and TUBİTAK were completed in 2021, with expected results. As a result of wheat breeding studies during 2021, forty-five (45) new bread wheat varieties and twelve (12) durum wheat varieties, originating from official agricultural research institutes and most of them by private sector seed companies, were registered in Turkey.

The research priority is to develop varieties with high adaptability due to climate change, good yield and quality values, tolerance/resistance to biotic and abiotic stresses. Seed production at the certified level of the registered varieties is among the research priorities.

### 4. WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMS

The main funding institutions in Turkey are TAGEM and TÜBİTAK. Some special projects are supported by Development Agency.

In new research to be initiated due to climate change, it is aimed to reduce the effects of climate change in agricultural production in the country. To provide economic, social and environmental benefits to Turkey through concluding high-beneficiary agricultural research that meets the country needs.

In 2021, there were many ongoing projects concerning wheat research that was funded by the TAGEM.

By the public research institute, nine TAGEM collaborative projects began in 2022 which focus on bread and durum wheat breeding, bread-making quality, agronomy and physiology. Three new project studies will be started by the Public Research Institutes on micronutrients, double haploid and yellow rust in bread wheat.

## UNITED KINGDOM (BBSRC)

### 1. WHEAT PRODUCTION (AREA, AMOUNT, AND AVERAGE YIELD) AND MAJOR PRODUCTIONS ISSUES (DROUGHTS, FLOODS, HEATWAVES, ETC.)

UK 2021 wheat production was 14 Mt, a 45% increase from 2020 and above 2016-2021's five-year average (13.7 Mt). The wheat area in England (where most UK wheat is grown) in 2021 was 1.62 Mha – a 28% increase from 2020. This is a return to expected levels, following the large reduction in 2020 due to wet weather during winter planting.

### 2. SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

BBSRC 2020-2021 expenditure on international collaborative wheat research through international schemes totaled £34k (bbsrc.ukri.org/research/international/funding/schemes/).

BBSRC is a member of the AHEAD Steering Committee. UK's contribution is led by Prof Graham Moore, Designing Future Wheat's (DFW) programme leader designingfuturewheat.org.uk/about/). DFW is a £24 million UKRI-BBSRC strategic investment established in 2017, spanning eight research institutes and universities, aiming to develop new wheat germplasm containing the next generation of key traits.

BBSRC continues to lead and support coordination of the International Wheat Yield Partnership (IWYP), collaborating with the private sector and major funding agencies in research-intensive and developing countries. IWYP outputs are translated by CIMMYT and two newly established Winter Wheat Hubs in USA (Kansas State University) and Europe (NIAB, UK), breeding into elite lines and making seeds available. BBSRC annual responsive mode continues to fund wheat research.

### 3. RESEARCH HIGHLIGHTS

BBSRC-funded researchers, led by Simon McQueen-Mason (University of York) and Emma Wallington (NIAB), have created a new wheat variety that increases grain production by up to 12% by increasing the levels of a wheat protein called expansin, a major determinant of growth in plants, in developing grain. Collaborators at the Universidad Austral de Chile conducted field experiments that demonstrated the effectiveness of the plants under agricultural conditions (New modified wheat could help tackle global food shortage - News and events, University of York: https://bit.ly/3RExLpJ )

A UK consortium, headed by Erik Murchie, Julie King and Ian King (University of Nottingham), in collaboration with CIMMYT, Mexico, have produced two wheat lines with wild-relative DNA insertions associated with increased photosynthetic capacity in laboratory conditions. Researchers performed genetic screening of wild wheat relatives to identify genetic variants associated with improved photosynthetic efficiency and biomass production for exploitation in breeding wheat varieties with higher grain yields. Field experiments, performed at CIMMYT, showed increased biomass and grain yield, demonstrating the potential gains for wheat yields from insights into wild relatives (IWYP48-ScienceBrief Number 1, April 2020: https://bit.ly/3O9QYN7).

### 4. WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMS

UKRI-BBSRC 2020-2021 expenditure on wheat totaled £21M supporting 92 projects in areas including wheat genetics and epigenetics, immunity against infectious diseases, and digital platforms for farming and research uses.

## URUGUAY (INIA)

### 1. WHEAT PRODUCTION (AREA, AMOUNT, AND AVERAGE YIELD) AND MAJOR PRODUCTIONS ISSUES (DROUGHTS, FLOODS, HEATWAVES, ETC.)

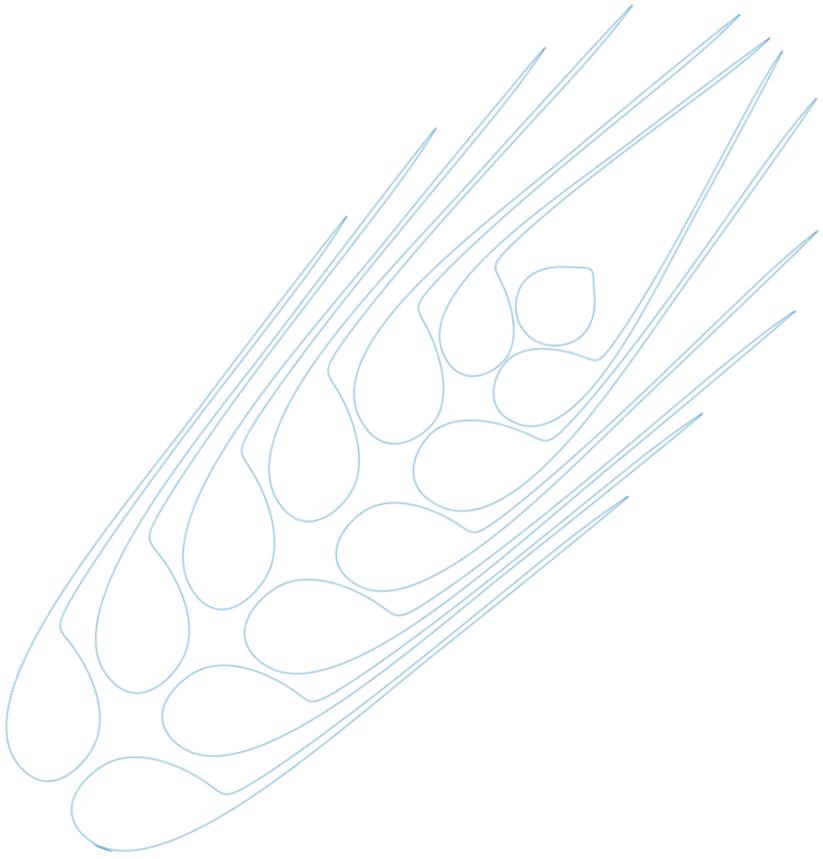
Wheat planted area in Uruguay increased 9% in 2021, as compared to the previous year, including 0.245 Mha. Total production in 2021 was estimated at 0,974 Mt, 4% higher than in 2020 representing a 121% increase compared to the 2017 season, only five years ago. The estimated yield average of 4.0 t/ha is about 5% lower than the previous season. This national yield average is, however, the second highest recorded, behind the record yield of 4.2 t/ha in 2020. Climatic conditions were characterized by normal temperatures and precipitations in general, yet with variable distribution during the growing season. In the northern growing area, higher than normal precipitations occurred at planting and early elongation phase. At flowering and until harvest, lower than average rainfall resulted in a rather long period of water deficit, affecting grain filling. On average, acceptable levels of protein content (12.3%) and test weight (79.2 kg/hL) were achieved. Stripe rust continued to be the most important constraint to wheat production in farmers' fields.

### 2. SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

The Precision field-based Wheat Phenotyping Platform (PWPP) for Wheat Diseases at INIA-La Estanzuela, Uruguay, as part of the Global Field-based Precision Phenotyping Network for WHEAT, which integrates the CGIAR Research Program on Wheat, continued to deliver high quality data for regional and international, public and private research institutions and breeding companies. In 2021, 1157 lines were phenotyped for Septoria tritici blotch (STB), 1364 for leaf rust, and 1248 lines for Fusarium head blight, from 12 institutions of six countries.

### 3. RESEARCH HIGHLIGHTS

In 2021, six new varieties were registered for planting in the last season. Five were introductions from the region, whereas only one was a cultivar developed by the National Wheat Breeding Program from INIA, based at La Estanzuela. This variety has superior milling and breadmaking quality and is categorized as “Urutrigo” (the term used under the Uruguayan classification indicating cultivars with superior breadmaking properties).



## UNITED STATES OF AMERICA REPORT (USDA)

### 1. WHEAT PRODUCTION (AREA, AMOUNT, AND AVERAGE YIELD) AND MAJOR PRODUCTIONS ISSUES (DROUGHTS, FLOODS, HEATWAVES, ETC.)

Winter wheat production for 2021 totaled 1.28 billion bushels (35 Mt), up 9% from the revised 2020 total of 1.17 billion bushels (32 Mt). The United States yield, at 50.2 bushels per acre (3.4 t/ha), was down 0.7 bushel (0.02 t) from 2020. Area harvested for grain was estimated at 25.5 million acres (10.3 Mha), up 11% from the previous year. Record low acres were estimated in Utah in 2021. Record high yields were estimated in Alabama, Illinois, Indiana, New Jersey, New York, Ohio, Pennsylvania, and Texas for 2021. Compared with 2020, harvested acreage was up 10% in the major Hard Red Winter (HRW) growing States, the primary winter wheat-producing area. HRW production totaled 749 million bushels (20.4 Mt), up 14% from 2020. In the Soft Red Winter (SRW) growing area, planted and harvested acreage increased from 2020. SRW production totaled 361 million bushels (9.8 Mt), up 35% from 2020.

Production of spring wheat for 2021 was estimated at 331 million bushels (9 Mt), down 44% from the revised 2020 total of 588 million bushels (16 Mt). Harvested area totaled 10.2 million acres (4.1 Mha), down 16 % from 2020. The United States yield was estimated at 32.6 bushels per acre (2.2 t/ha), down 16.0 bushel (0.44 t) from the record high of 48.6 bushels per acre (3.3 t/ha) in 2020. Of the total production, 297 million bushels (8.1 Mt) were Hard Red Spring wheat, down 44% from the 2020 total. The decrease in production is a result of dry conditions in the major spring wheat growing State.

Durum production for 2021 was estimated at 37.3 million bushels (1 Mt), down 46% from the 2020 total of 69.1 million bushels (1.9 Mt). Area harvested for grain totaled 1.53 million acres (0.62 Mha), down 8% from the previous year. The United States yield was estimated at 24.3 bushels per acre (1.6 t/ha), down 17.2 bushels (0.47 t) from the 2020 yield.

Production in North Dakota, the largest durum wheat-producing state, was down 44% from 2020. The decrease in production is a result of dry conditions in the major durum wheat growing states.

Source: Small Grains 2021 Summary (September 2021). USDA, National Agricultural Statistics Service. ISSN: 1949-162X

## 2. SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

The National Predictive Modeling Tool Initiative (NPMTI) is a new federally funded program that is focused on developing research-based tools that will help forecast incidences of diseases and mycotoxins affecting U.S. crops, including wheat. The Wheat Research Area focuses on rust pathogens and Septoria nodorum blotch.

Source: https://agpmt.org/current-projects/

## 3. RESEARCH HIGHLIGHTS

The Wheat Coordinated Agricultural Project 2017-2021 participants published a total of 237 peer-reviewed papers, released 98 commercial wheat varieties, and 24 germplasms lines. There were 30 PhD students and 13 MS students supported by the WheatCAP grant.

Source: Final Report 2017-2021 Wheat Coordinated Agricultural Project. J. Dubcovsky.https://www.triticeaecap.org/publications-and-germplasm/

## 4. WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMS

For historical and agronomic reasons, wheat is disproportionately dependent on public investments for continued crop improvement in the US. An estimated 65 percent acres of wheat grown each year in the U.S. are planted with wheat varieties that originated out of the public system. USDA devotes an estimated $50 million to wheat research within its own labs and at universities around the country.
The US Wheat & Barley Scab Initiative continues to be the single largest public investment in wheat research and was again fully funded at the authorized amount of $15 million this past fiscal year. Details about the progress in the fight against this pathogen can be found at https://scabusa.org/home-page.

The Wheat Genetics Resource Center's Industry/University Research Consortium (WGRC I/UCRC), The WGRC I/UCRC is a consortium that focuses on precompetitive, innovative research and is housed at Kansas State University (https://wgrc-iucrc.k-state.edu/). The WGRC IUCRC research focuses on mining and harnessing novel alleles from wheat's ancestors to help breeders. The WGRC IUCRC secured an additional $1 million dollars in annual federal funding for operations.
The 2017-2021 Wheat Coordinated Agricultural Project (WheatCAP) has ended.Planning of the 2022-2026 Wheat Coordinated Agricultural Project started in December 15, 2021.

Source: Public Funding is Critical. National Association of Wheat Growers. https://wheatworld.org/wheat-101/research/public-funding/

## WHEAT - CRP (CIMMYT and ICARDA)

### 1. WHEAT PRODUCTION (AREA, AMOUNT, AND AVERAGE YIELD) AND MAJOR PRODUCTIONS ISSUES (DROUGHTS, FLOODS, HEATWAVES, ETC.)

Staple cereals will continue to play a critical role in global efforts towards food security, contributing nearly half of both daily calories and protein intake in low- and middle-income countries (Grote et al., 2021). In wheat and maize value chains in Africa and Asia, the stability and utilization dimension of food security merits increased research attention.

Better estimates of the number and distribution of crop-specific farms will lay the foundation for agricultural policy and R&D efforts in the Global South. A fifth of all farms globally grew wheat in 2020, a number expected to decrease by 4% in 2030 (Erenstein 2021). Wheat is cultivated on 216 M ha (2020); 29% of which is in lower- and lower-middle income countries (L/LMICs). Compared to high-income countries (HICs), LICs have more than four times the number of farms, ten times the rural population, half the agricultural area and a tenth of the average farm size.

Climate change will decrease global wheat production by −1.9% by mid-century; the most negative impacts are projected to affect developing countries in tropical regions. Models suggest large, negative yield impacts for African (-15% by 2050) and Southern Asian countries (-16% by 2050), where food security is already a problem (Pequeno et al., 2021).

Introducing new, climate change-tolerant crop genetic traits as an adaptation response to climate change would improve yield in many regions.

NARS scientists estimated the return on wheat research in Nepal over the last 19 years: 91% internal rate of return (IRR) (Timsina 2021).

In Bangladesh, DNA fingerprinting analysis showed that in farmers' fields, 68% of grain samples were varieties released after 2000, but also wheat blast-susceptible. Varieties released in the past 5 years, including wheat blast-resistant BARIGom33, were detected in 4% or less of field samples, translating into roughly 7.3% of Bangladesh's 340,000 ha wheat area (Gade et al., 2021).

Despite institutional challenges, wheat research in Morocco has paid off. Considering all costs and benefits of wheat research investment in Morocco (using 2002 – 2014 data), scientists estimated a conservative benefit-cost ratio (BCR) of 19.64 with 623,000 tons (14.8%) of additional wheat supply valued at US$355 million p.a. (Yigezu 2021).

### 2. SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

Private and public sector consensus on priority, pre-competitive wheat productivity research domains. A group of public sector and major seed companies' scientists identified key translational research areas (e.g. translating pure plant science knowledge to breeding) with a high probability of boosting productivity: research into hormones, recombination, respiration, roots and source–sink make it more feasible to explore crop genetic resources and improve breeding strategies and the models behind them (Xiong et al 2021). Scientists focused on researchable issues that benefit from combining breakthrough technologies with proven ones. Companies and institutes affiliated with this review aim to develop a partnership to address these challenges in pre-competitive space (see: Subbarao et al 2021).

Breeding research-based impacts. Within 6 years, HarvestPlus-led scaling efforts have reached 1.4 million Pakistani households with high zinc wheat on the basis of CGIAR-derived varieties (www.harvestplus.org).

## 3. RESEARCH HIGHLIGHTS

In independent research, scientists found that the diffusion of modern crop varieties during the Green Revolution reduced infant mortality by 2.4-5.3% – implying significant health benefits from increases in agricultural productivity and improved varieties (von der Goltz et al., 2021).

With regard to future research priorities, WHEAT and partner scientists from five countries looked at wheat root systems, which capture the water and nutrients needed to support crop growth. Improved root systems tailored to specific environments could improve climate resiliency. Authors listed 3 critical steps to underpin future direct selection of root traits for improved crop performance (Ober et al., 2021).

Due to poor soils and nutrient management, many developing countries will only successfully climate-adapt if more nitrogen fertilizer were deployed. WHEAT co-funded 'A "more ammonium solution" to mitigate nitrogen pollution and boost crop yields,' which points to Biological Nitrification Inhibition to foster soils with a more even mix of nitrogen sources, including the less-chemically-reactive compound, ammonium (Subbarao et al., 2021a; CIMMYT 2021a).

High-Biological Nitrification Inhibition (BNI)-wheat: Proof of concept and potential impacts on life-cycle greenhouse gas emissions including N2O – with FP1. WHEAT and partner scientists successfully bred high BNI-elite lines that also showed greater overall biomass and grain yield, with no negative effects on grain protein levels or breadmaking quality (Subbarao et al., 2021b). In parallel, scientists developed a new model based on life-cycle assessment (LCA) to evaluate the total greenhouse gas (GHG) emissions generated at each stage of wheat production for BNI-enabled wheat (Leon et al., 2021). A 9.5% reduction in nitrogen fertilizer-derived greenhouse gasses is attainable, if BNI-enabled wheat with 40% nitrification-inhibition were grown on slightly acidic to neutral soils (ca. 30%, or 72 Mha, of the world's wheat area of 240 Mha) (Subbarao et al., 2021a; CIMMYT 2021a).

Scientists investigated dietary adaptation mechanisms to climate change-driven impacts on nutrient levels in staple grains, which may contribute to mineral deficiencies amongst at-risk populations. Researchers found that replacing refined grains with whole grains could help compensate for climate change-related reductions in iron and zinc concentrations in wheat, rice and maize. Additionally, it could improve fiber intake, protein deficiencies, and reduce mortality from chronic disease (see: CIMMYT, 2021).

For more information on research findings, please visit the WHEAT legacy website (wheat.org) and the CGIAR Results Dashboard (www.cgiar.org/food-security-impact/results-dashboard/) (you can filter for WHEAT).

## 4. WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMS

At the end of 2021, the CGIAR Research Program on Wheat closed down. CGIAR wheat-related research will continue in the new OneCGIAR Initiatives managed by the CGIAR Genetic Innovation Science Group (www.cgiar.org/research/action-areas/#genetic).

## ARVALIS-Institut du vegetal

### 1. WHEAT PRODUCTION

In 2021, French bread wheat production was around 35.5 Mt for a mean yield of 7.13 t/ha. It represents a production increase of + 21.5% compared to 2020 and of + 6.2% compared to the mean production of the last 5 years. This good performance is partially linked to an increase of the surfaces dedicated to bread wheat. The agricultural campaign was a succession of contrasting phases, favorable at the beginning of the crop cycle (autumn-winter), then more problematic (spring drought and late frost in some cases), fortunately compensated by better conditions at ear emergence and flowering. Grain quality criteria were generally correct, with high grain protein concentration (national mean at 11.9%), despite some significant rain events during summer. Concerning durum wheat, the production reached nearly 1.6 million tons for a mean yield of 5.46 t/ha. It represents a production increase of 20.3% compared to 2020 but a drop of -6.5% compared to the mean production of the last 5 years. Like bread wheat, the surface of durum wheat increased in 2021 compared to 2020. The agricultural campaign significantly varied from one production area to another. Grain protein concentration was generally high.

### 2. SIGNIFICANT NEW NATIONAL/INTERNATIONAL COMMITMENTS OR PARTNERSHIPS

ARVALIS validated its new triennial R&D 2022-2025 program funded by the French interprofessional organization for cereals, maize, and sorghum (including farmers and feed and food value chain members). Wheat R&D is in the heart of the four operational objectives of this program: 1) to guarantee a healthy and sustainable food supply for all markets, 2) to develop agricultural practices less reliant on external inputs, contributing to environment protection and economically efficient, 3) to adapt the agricultural systems to climate change and make them contribute to its mitigation and, 4) to evaluate and promote multi-efficient agricultural systems in all French production areas. With this program, producers and value-chain members allocated 72% of their funds to the R&D conducted by ARVALIS.

### 3. RESEARCH HIGHLIGHTS

To support most field studies addressing the wheat tolerance to abiotic stresses, we develop several sensors-based phenotyping tools, in the framework of the PHENOME-EMPHASIS project (ANR-PIA funded, lead INRAE) and of the UMT CAPTE$^2$[ST1] consortium. Alongside high throughput phenotyping platforms like ARVALIS's PHENOFIELD® (Beauchêne et al., 2019), we are developing a lighter phenotyping device called Literal-Phenoman, dedicated to providing a greater number of research stations with simple and easy to use camera-based sensors (LITERAL project, CASDAR funded, lead ARVALIS). We also aim to broaden the use of field root phenotyping tools like Minirhizotron (Postic et al. 2019), by using it in various EU H2020 project like SOLACE (lead INRAE) and INVITE (lead INRAE).

### 4. WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMS

Among the 5 new projects funded by the FSOV call 2020 (French Fund to support plant breeding) and led by ARVALIS in 2021, we could put the light on 2 of them which begin to deliver their first field results. The DUROSTRESS project aims to design adaptation strategies to drought and heat stress for durum wheat. Thanks to the efforts of 3 countries (Portugal with INIAV, Italy with CREA, France with Florimond-Desprez, RAGT, INRAE, GIE durum wheat and ARVALIS), a multilocal trials network has been conducted to evaluate the tolerance of a range of genotypes to abiotic stresses and identify the related traits (included root traits). The PGEN-BW project, designed in the NUE EWG of the Wheat Initiative, aims to decipher the genetic components of the Phosphorus Use Efficiency in bread wheat. A first successful year of field experiments has been conducted in France (more than 200 genotypes evaluated in 2 sites across 2 modalities of P supplying) and will provide relevant data for the first attempts of genetic analysis. It will be completed by other experiments conducted in field and controlled conditions by the partners (INRAE, ROTHAMSTED Research, ADAS, IPSP-CNR, NIAB, CIMMYT, SYNGENTA, EMBRAPA, ARVALIS).

## FLORIMOND DESPREZ VEUVE & FILS

Florimond Desprez is an independent breeding and seed company headquartered in France and has had a long commitment to wheat breeding. Wheat varieties bred by Florimond Desprez are successfully cropped in many European countries as well as in South America and North Africa. Florimond Desprez has a long tradition of teaming up with colleagues from both public and private research and has joined in 2021 the French private-public research consortium PlantAlliance. The current collaborations include works aiming at breeding innovative wheat varieties with sustainable resistances to pests and diseases and also meeting the various market expectations in terms of quality. Florimond Desprez devotes more than 15% of its yearly turnover to R&D.

## KWS

KWS wheat had another good year with new, strong varieties entering the market, and established varieties performing well. 2021 was a difficult year climatically for our wheat growers and breeders in many EU markets. Despite this, our broadly adapted winter wheat bread making variety, KWS Extase, performed in line with other years. In the Eastern US soft winter wheat market our portfolio is increasing in strength, and we look forward to seeing our newest varieties in commercial multiplications.

Sustainability is a key objective for KWS. Performance under lower input agricultural practices is gaining importance for many growers, and KWS is acknowledging this fact. Disease resistance has always played a crucial role in wheat breeding but weed competition and performance under lower nitrogen input are becoming standard practices in our programmes. Likewise, the climatic fluctuations and changes to rainfall patterns demands varieties with high production stability, and this too is being addressed at KWS.

KWS has an active role in the German project 'Pilton', aiming at producing improved, durable, and multi-disease resistant wheat using genome editing. Along with the partners, we hope this will help in the ongoing debate on new breeding methodologies. The change in UK legislation opening for more R&D field trials with genome edited material is an exciting development. Although KWS UK has no intention of conducting such trials, we see this as a step in the right directions and look forward to work with academic institutions on this. Essential however is the development of robust and transparent protocols on handling genome edited material in field trials.

Hybrid wheat remains a key objective for KWS, working on many topics in small and large collaborations. The recently established 'Hybrid Wheat Initiative' in the UK is fully supported by KWS, and we hope that it will engage the public sector in answering fundamental questions related to hybrid wheat. We are convinced that hybrid wheat technology is the best long-term solution for attracting increased investments into breeding and research, resulting in improved varieties for our growers. A crucial step for this is the research on floral biology, and KWS is engaged in the German HYFLOR project as well as supportive of the wild species introgression work on-going at the University of Nottingham. These two projects will provide short- mid- and long-term solutions to the challenge of making wheat a better outcrossing species.

## RAGT

Founded in 1919 and established in all major European agricultural regions, RAGT researches, breeds, produces and sells seeds including wheat, corn, barley, oilseed crops, oats, pulses, forage grass and soil health crops. Innovation is vital to us, and we spend over 15% of our turnover in research, supporting 17 subsidiaries, 17 research stations, 300 scientists and technicians, and 4 multi-species laboratories. RAGT is a leader, with a strong market share for wheat in European markets including France, Germany and the UK. As part of our efforts in wheat research we are involved with international partnerships such as the Wheat Initiative, the International Wheat Yield Partnership (IWYP) and the International Wheat Genome Sequencing Consortium (IWGSC). We believe in collaborative research and are involved in many PhD and post-doctoral research projects with Universities and research institutes, all of which share the aim of providing insight into wheat genetics. A major development at RAGT in 2021 was the launch of a research collaboration with Bayer on hybrid wheat. The aim of this collaboration is to use the complementary expertise within the two organisations to develop hybrid wheat varieties to meet the evolving needs of farmers in Europe.

# 4. ASSOCIATED PROGRAMMES

## ASSOCIATED PROGRAMMES

In order to provide a framework on wheat research, the WI has established linkages with several programmes and initiatives, who have become associated programmes, promoting open collaboration and communication, and supporting key initiatives.

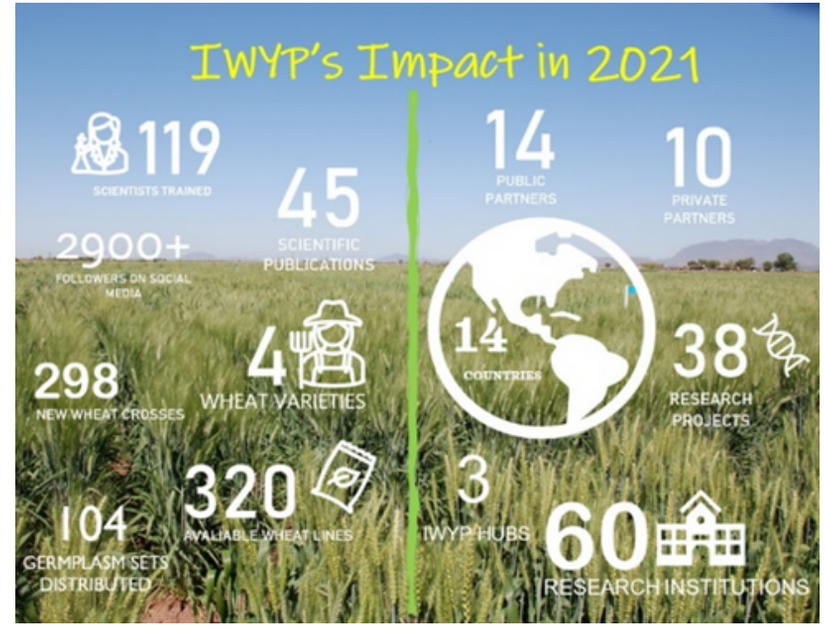
### 10+ WHEAT GENOMES PROJECT

The 10+ Wheat Genomes Project is a global partnership that leverages collaborative expertise and funding with the aim to characterize the wheat 'pan genome'. In addition to assembled genomes it will also generate annotated gene models based on electronic prediction and experiment transcriptome data. This research partnership will also build the most comprehensive functional analysis of the 'pan genome', by comparing gene expression (transcription) networks throughout plant development. The partnership will generate at many high quality wheat genome assemblies and develop strategies and resources to compare multiple wheat genome sequences from around the globe.
The sequence of ten wheat genotypes was completed and published in 2020 (Walkowiak et al., 2020).

### IWYP

- Over 2021, the International Wheat Yield Partnership (IWYP) continued to make significant progress towards its goal of boosting the genetic yield potential of wheat beyond the current rates of genetic gain. Of the achievements made over the year a few selected highlights are presented below:
- IWYP Research Projects transferred many new outputs to the IWYP Hub at CIMMYT for validation and pre-breeding, including new phenotyping assays and germplasm with enhanced yield traits including biomass production, spikelet architecture, grain protein content, productive tiller number and spikelet number per spike.
- Analysis of the best IWYP lines from several consecutive Wheat Yield Consortium Yield Trials (WYCYTs) in replicated side-by-side field trials showed that many of the best new IWYP lines containing combined IWYP targets out-yielded the parental lines and elite check varieties, including grain yield (28% of new lines), final biomass (45% of new lines) and harvest index (24% of new lines). Other target traits, e.g., thousand grain weight, grains per spike and spike length positively impact yield improvement.
- An analysis of data from over 26 international environments revealed the best new IWYP lines from the 7th WYCYT conducted in 2019/20 had more than 9% higher grain yield over the CIMMYT long term standard check Sokoll. Data on 8th and 9th WYCYTs are still being collated but it is expected will show similar results. For more detail see the 2020/21 IWYP Annual Report (https://iwyp.org/annual-report/). These results indicated that IWYP is progressing toward the levels of increased yields targeted by incorporating novel yield potential traits.
- The IWYP North American Winter Wheat Hub at Kansas State University selected several donor traits from 7 IWYP Research Projects for introgression in 11 targeted genetic backgrounds using marker assisted backcrossing.

- The National Institute of Agricultural Botany (NIAB) in the UK contracted by the European Winter Wheat Hub began the introgression of several key traits important for hybrid wheat seed production in selected UK and European wheat lines by marker-assisted backcrossing. Toward the end of last year, several new yield potential traits including fruiting efficiency and increased photosynthesis were added to the program with new introgressions into elite lines being initiated.
- An IWYP Program Conference was organized as a three-half day virtual event. It was structured as a mix of selected scientific presentations and breakout sessions. It was well attended with participation of over 90 IWYP Members. Topics included a review of the IWYP Scientific Strategy, presentation of the IWYP Wiring Diagrams, review of the IWYP outputs promoted through the IWYP Stage Gate system, a review of the outputs and tools available from the USDA National Institute of Food and Agriculture (NIFA) Wheat CAP Project, the role of crop modelling, and an update on the progress from the 3 IWYP wheat translational Hubs.
- Over 30 peer-reviewed scientific articles from IWYP researchers were published in 2021 with several in high impact journals. A list of peer-reviewed articles published since the inception of IWYP is available from https://iwyp.org/publications/).
- Our monthly IWYP Science Briefs have continued to be published and provide summaries of exciting discoveries from the IWYP Research Projects, progress being made by the IWYP Hubs and other scientific topics relative to the IWYP initiative. This past year's topics included, among others, plant phenology, spike modification, canopy architecture, high throughput phenotyping (HTP), hybrid wheat, gene editing, photosynthesis, root phenotyping, and modeling. All Science Briefs can be downloaded from https://iwyp.org/iwyp-science-briefs/
- A summary of all the progress and activities IWYP has made over the past year can be found in our IWYP Annual Report available for download at https://iwyp.org/annual-report/.



## IWGSC

Founded in 2005, the International Wheat Genome Sequencing Consortium (IWGSC) is dedicated to delivering a high quality, gold standard reference genome sequence and sequence-based resources for the accelerated development of improved varieties through an enhanced understanding of the molecular basis of key agronomic traits and the deployment of molecular breeding technologies. The IWGSC is a 501(c)(3) nonprofit organization registered in the United States.

- Board of Directors in 2021
  - Kellye Eversole (IWGSC Executive Director and chair of the Board of Directors)
  - Rudi Appels (University of Melbourne & AgriBio, Australia)
  - Ute Baumann (University of Adelaide, Australia)
  - Hikmet Budak (Montana BioAg Inc, USA)
  - Chris Burt (RAGT Seeds, United Kingdom)
  - Pierre Devaux (Florimond Desprez, France)
  - John Jacobs (BASF, Belgium)
  - Yann Manès (Syngenta, France)
  - Pierre Sourdille, INRAE, France

Coordinating Committee: 58 members from academia and industry who develop the strategic objectives of the consortium and requirements for IWGSC projects.

Number of members: 3,350 in 71 countries, representing 914 institutions / companies

### 2021 activities and progress

- IWGSC RefSeq Assembly and Annotation v2.1
  - An updated version of the Chinese spring reference sequence (IWGSC RefSeq v2.1) was made available to the community in April 2021. This new version integrates new datasets, resolves ambiguities, closes gaps, and increases the contiguity of the reference genome.
  - To complement the new assembly, a new version of the annotation (IWGSC RefSeq Annotation v2.1) was also released, integrating manually curated genes submitted by the wheat community.
  - An article outlining these new resources and the improvements to the wheat reference sequence has been published in The Plant Journal and is available on open access. https://doi.org/10.1111/tpj.15289
  - Both IWGSC RefSeq v2.1 and IWGSC RefSeq annotation v2.1 are publicly available at the IWGSC data repository at URGI-INRAE Versailles, France, at https://wheat-urgi.versailles.inra.fr
- Genomics Tools
  - As part of the IWGSC ongoing collaboration with Daicel Arbor Biosciences, a target capture panel for promoters and other regulatory elements in wheat was developed. The panel is designed to capture ~168 Mbp of genomic space as measured on RefSeq v1.0. The kit became available in January 2022.
- Wheat Diversity project
  - In this project, the IWGSC plans to develop platinum quality sequences of a core set of eight landraces, representing the full breadth of genetic diversity in bread wheat. Lower quality genome sequences of other landraces and elite lines will be added as available.
  - In 2021, the IWGSC leadership worked on putting together a team and securing funding for the project.
- Webinar series
  - The IWGSC organized 12 webinars, with a record attendance from all over the world. The webinars showcase research results, tools, and resources. They are free to attend, and the recordings are posted on the IWGSC YouTube channel to allow access for people who cannot attend the live event.

For more information on the IWGSC, visit https://www.wheatgenome.org/

## AHEAD

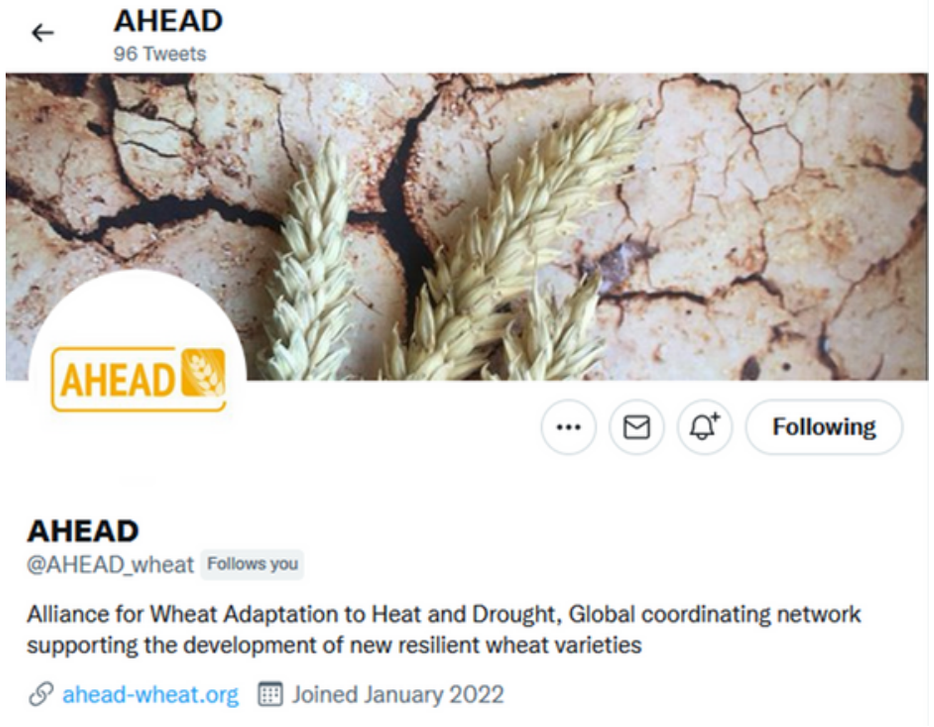
Next to other factors, Heat and Drought play a crucial role when it comes to food security and stable yields. The development of resilient lines is one way to avert future yield losses and stabilise food chains. But many questions about useful methods, techniques and strategies to address this issue globally remain unanswered. The Alliance for Wheat Adaptation to Heat and Drought (AHEAD) offers a forum for discussion about this topic, to identify synergies and work out strategies to secure future wheat supply under the conditions of a changing climate. AHEAD was founded in August 2020 and now enters its third developmental stage.

The first phase, or initiation phase, identified the need for such an Alliance and established the basic framework. In order to coordinate this development, a global coordinator was appointed who took over the first key steps which included setting up the first communications, the organisation of meetings as well as the organisation of the Steering Committee. The Steering Committee is composed of members from governmental agencies, funding and research bodies and provide leadership, give insight into national funding strategies and connect project leaders with different stakeholders. Together with the first two AHEAD members (HeDWIC (Matthew Reynolds; CIMMYT) and TERTIUS (Bernd Hackauf; Julius Kühn Institute) the basic framework for the Alliance was completed and the next phase could be started.

The second phase was dedicated to reaching two specific goals, which were to enhance the visibility of wheat heat and drought research and the alliance and to attract new members. Managed by the new Global Coordinator Stefanie Hagemann, the mission and vision of the Alliance were distributed to different audiences. Invited by the WI Secretariat, Stefanie Hagemann gave a short introduction and update of the Alliance at the Wheat Initiative Research Committee (RC) Meeting in October 2021 as well as at the Institution's Coordination Committee (ICC) Meeting in November 2021.

Additionally, a major achievement has been the launch of the new AHEAD webpage in February 2022 (www.ahead-wheat.org). Previously, information about AHEAD was provided on a subpage of the Wheat Initiate website. Due to the development of the network and the wish to publish an increased amount of information about the Alliance, the members and their work, the new website was designed according to these needs. There is an updated AHEAD brochure available on the website which outlines what AHEAD is all about and how to become involved.

To promote awareness of the Alliance and the website, an AHEAD Twitter Account (@AHEAD_wheat) was started at the day of the website launch. The Twitter account serves as a platform to deliver information about this research area, by highlighting scientific papers, and including news about events, job and funding opportunities from all around the world. From the promotional activities and efforts, the AHEAD network increased to six members at the beginning of 2022.




The framework of AHEAD was successfully established and the network grows constantly by attracting new members. Now the third phase has started with the 3rd AHEAD workshop held in March 2022. Important areas for action were defined and research needs, gaps and drawbacks were discussed. The AHEAD network will work on solutions by collecting and sharing information and knowledge, building up new collaborations and supporting young researchers to work on these precious topics. This progress will be sustained by an Action plan, which includes the major challenges of wheat heat and drought research and the strategies to accomplish them. The editing of the Action plan should be finalised by the end of this year. However, in parallel to this process the AHEAD members have already started working on the first outcomes.

If you would like to receive more information about AHEAD, please contact Stefanie Hagemann (ahead@julius-kuehn.de), visit the AHEAD website (www.ahead-wheat.org) or follow @AHEAD_wheat

# 5. WI SECRETARIAT INSIGHTS

## WHEAT INITIATIVE COMMUNICATION

The Wheat Initiative's 2021 communication strategy has been focused on offering support and help with new opportunities for the wheat research community. Videos from our EWGs were created and virtual meetings were organised and planned. The newsletter, media brief, website have been running as planned.
We provided support as well for establishing the first frame to develop the AHEAD website.

### NEWSLETTER

In 2021 the Wheat Initiative's newsletter, has continued to be sent out quarterly. The click per unique opens in 2021 stayed well above average (according to MailChimp, a newsletter tool, the average newsletter opening rate lies at 23.31%). The Wheat Initiative's newsletter opening rate in 2021 was in January 40%, April 30.2%, July 30.9% and October 44.2%.

The newsletter gained more than a 100 new subscribers in 2021, making a total of 834 subscribers by 31 December 2021.

### MEDIA DIGEST – WHEAT IN THE MEDIA

The weekly media digest continued being sent out on Fridays by the Genome Canada Programme 4D: Diversity, Discovery, Design and Delivery.

The Media Digest presents a collection of the latest news articles and publications in Wheat. The Wheat Initiative uses a specialized provider to scan diverse sources for information.

### TWITTER

The Wheat Initiative's Twitter account is used every weekday to publish research or industry related topics such as wheat news, relevant job opportunities, research projects, funds, and to share publications of interest and of our members. The platform is also used to promote the Wheat Initiatives own events, newsletter, videos, projects and virtual workshops. The Wheat Initiative has had great success in 2021 by reaching the 3000 followers mark.
New followers in 2021: +678
Total number of followers up to December 31, 2021: 3189

**WEBSITE**

Dynamic changes have been made to the website to keep pace with events, grants and video meetings and workshops. https://www.wheatinitiative.org/

**Wheat Field Gallery**

The idea of a Wheat Field Gallery was born in 2020. The gallery shows different wheat fields around the world and their development throughout a year. Every three months, pictures are taken and uploaded to the Wheat Initiative's Website, creating a diverse image gallery of wheat fields making use of the international network of the Wheat Initiative. The project shows the diversity and progress of wheat fields being sown, growing and harvested.

Pictures of wheat fields arrive from Argentina, Germany, Japan, India, Paraguay, UK and Uruguay.

**Virtual Durum Meetings**

Continuing with the efforts from 2020, the Durum Expert Working Group organised in 2021 the 3rd edition of the Virtual Durum Meetings (VDMs) where experts presented their work related to durum wheat. The sessions was held in July 2021 and were recorded and edited to single clips. With the permission of speakers those videos were added to the existing Virtual Durum Meeting Video Library, offering to the public interesting and valuable content for this wheat research area.

www.wheatinitiative.org/virtual-durum-meeting-videos

**EWGs workshops videos**

Following the lead of the VDMs, our EWGs organized workshops and events using virtual platforms. Videos from sessions were recorded and a new section was created to make them available to public.

https://www.wheatinitiative.org/workshop-and-presentations

## 10th ANNIVERSARY CELEBRATION

The 10th Anniversary of the Wheat Initiative is a celebration that began on September 15, 2021, and is planned to continue through to September 15, 2022. To maintain the celebration, communication items such as the following have been developed:

- 10 year badge on the website
- A dedicated section for the 10th anniversary on the website including:
  - Thank you message
  - Quotes from Chairs, SB members
  - Anniversary facts video clips (Milestones)
  - EWGs videos: In collaboration with five EWGs, videos were produced to promote their work. These videos can be found on the home page of the WI website: https://www.wheatinitiative.org/

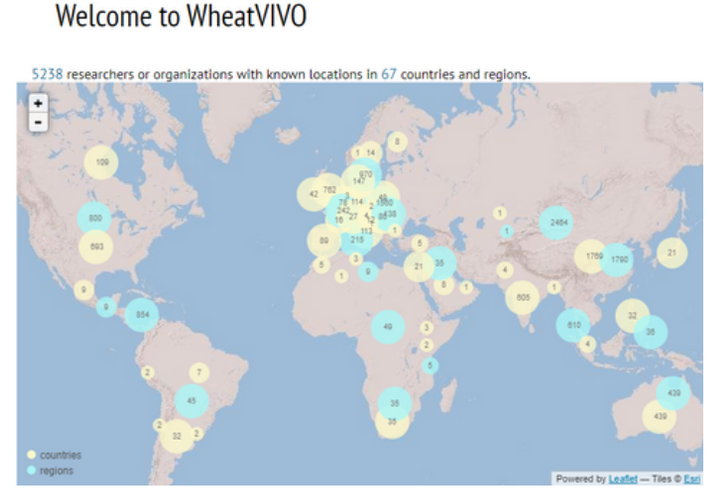
New ways to celebrate are currently underway.



## WheatVIVO

www.wheatvivo.org

WheatVIVO is an open access database that was officially launched in November 2021. It enables users to search for researcher's profiles, organisations, publications and projects.
WheatVIVO obtains its data from the harvesting of databases: Microsoft Academic, RCUK, ORCID, CORDIS, Florida, OpenAire and Concepts. Since the launch, there have been over 700 users and over 200 people have signed up to have their personal profile included. Improvements are continually being made and new features added, the latest being a 'What's New' section.
Feedback is welcomed from users via a satisfaction survey on the website or by emailing: wheatvivo@julius-kuehn.de



## FINANCIAL STATEMENT 2021

The budget of the Wheat Initiative relies on the annual membership fees of its members, and exceptional contributions. This revenue is used to cover the activities related to the coordination of the Wheat Initiative.

The Wheat Initiative is administratively embedded in the JKI as Managing Institution. Due to this, all funds are managed by the JKI finances section according to the JKI rules, and therefore, under the German Ministry of Food and Agriculture guidelines. Since 2019, the budget has been managed on a cash basis.

This section is a condensed version of the 2021 Annual Financial Report which includes a summary of the financial activities from 1 January to 31 December 2021.

Financial Key Points

- The Wheat Initiative Secretariat posted a budgetary surplus of 61,869 Euros for 2021, compared to an estimated deficit of -242,808 Euros, due to substantial underspending of the budget in many areas. The underspend was the result of COVID limiting travel opportunities during 2021.
- When the 2020 Carry forward of 776,143 Euros is included, the Wheat Initiative had a positive balance on 31 December 2021 of 838,012 Euros.

**Table 1:**
Wheat Initiative Income and Expenditure Summary 2021 (Cash Basis-Euros) | 1 January 2021-31 December 2021

| Revenue | Budget 2021 | Closing 2021 |
|---|---|---|
| **Membership fees (includes outstanding fees)** (1) | 219,000 | 199,013 |
| **Exceptional contributions** (2) | 178,545 | 170,697 |
| **Total Revenue 2021** | **397,545** | **369,710** |
| | | |
| **Expenditure** | | |
| **Secretariat** | | |
| Personnel (3) | 258,653 | 234,427 |
| Travel Reimbursements (WI Staff) | 10,000 | 366 |
| Communication | 30,000 | 13,438 |
| Consumables | 1,700 | 1,062 |
| Equipment | 1,500 | 1,099 |
| WheatVIVO support (4) | 8,000 | 6,309 |
| AHEAD – Consumables | 10,000 | - |
| WI support (5) | 50,000 | 47,600 |
| Staff Training | 5,000 | 1,308 |
| Contingency | 20,000 | - |
| **Expert Working Groups Expenses** | | |
| Expenses for 2021 Activities | 145,500 | 2,231 |
| **Meetings & Workshops** | 80,000 | - |
| **Education & Training** | 20,000 | - |
| **Total Expenditure 2021** | **640,353** | **307,841** |
| **Balance 2021** | -242,808 | **61,869** |

1. Budget includes 189,000 for 2021 membership fees, plus outstanding fees of 30,000 Euros.
2. Exceptional contributions include BMEL support to Wheat Initiative salaries of 150,000€ and JKI Support for the AHEAD Coordinator (.3).
3. Personnel expenditure includes:
   - 1.0 Programme Manager (January - December 2021)
   - 1.0 Foreign Language Secretary (January - December 2021)
   - 0.5 Communications Manager (January - December 2021)
   - 0.5 Chair of Scientific Board, International Science Coordinator (January - December 2021)
   - 1.0 AHEAD Coordinator (January 2021) and .3 (July- December 2021)
4. WheatVIVO Support includes technical support and cloud services for the WheatVIVO database.
5. WI Support is for 0.6 Finance, IT and Research Coordination Officer (January – December 2021).

# 6. APPENDICES

# ABBREVIATIONS

| | |
|---|---|
| **AAFC** | Agriculture and Agri-Food Canada |
| **AFBI** | Agri-food & Biosciences Institute |
| **AGG** | Advances in Genetic Gains (for Maize and Wheat) |
| **AHEAD** | Alliance for Adaptation of Wheat to Heat and Drought |
| **ANR** | The French National Research Agency |
| **APR** | Adult Plant Resistance |
| **AVR** | Agriculture Victoria Research |
| **AWAS** | Adaption of Wheat to Abiotic Stress |
| **BBSRC** | Biotechnology and Biological Sciences Research Council. |
| **BMEL** | Bundesministerium für Ernährung und Landwirtschaft |
| **CIMMYT** | Centro Internacional de Mejoramiento de Maíz y Trigo |
| **conacyt** | Consejo Nacional de Ciencia y Tecnología |
| **CSIRO** | Commonwealth Scientific and Industrial Research Organisation |
| **CWANA** | Central and West Asia and North Africa |
| **DFW** | Designing Future Wheat |
| **EWG** | Expert Working Group |
| **FEWG** | Funding Expert Working Group |
| **FFAR** | Foundation for Food and Agriculture Research |
| **FHB** | Fusarium head blight |
| **FSOV** | French Funds to support Plant Breeding |
| **GDP** | The Global Durum Wheat Panel |
| **GM** | Genetic modification |
| **GRDC** | Grains Research and Development Corporation |
| **GWHD** | Global Wheat Head Detection |
| **GxExM** | Genotype X Environment X Management |
| **HeDWIC** | Heat and Drought Wheat Improvement Consortium |
| **HMW-GSs** | high molecular weight glutenin subunits |
| **ICARDA** | International Centre for Agricultural Research in the Dry Areas |
| **ICC** | Institutions' Coordination Committee |

# ABBREVIATIONS

| | |
|---|---|
| **ICRISAT** | International Crops Research Institute for the Semi-Arid Tropics |
| **INRAE** | Institut National de la Recherche Agronomique |
| **INVITA** | INnovations in plant VarIety Testing in Australia |
| **IPPN** | International Plant Phenotyping Network |
| **IPPS** | International Plant Phenotyping Symposium |
| **ITPRFA** | International Treaty on Plant Genetic Resources for Food and Agriculture |
| **IWC** | International Wheat Congress |
| **IWGSC** | International Wheat Genome Sequencing Consortium |
| **IWWIP** | International Winter Wheat Improvement Programme |
| **IWYP** | International Wheat Yield Partnership |
| **JIC** | John Innes Centre |
| **JKI** | Julius Kühn Institute |
| **LMA** | Late maturity alpha-amylase |
| **LR** | Leaf rust |
| **MARPLE** | Mobile and Real-time PLant disEase |
| **MCGP** | Morocco Collaborative Grants Programme |
| **MoBiDIv** | Mobilising and selecting intra- and inter-specific crop diversity for systemic change towards pesticide-free agriculture |
| **NAPPN** | North American Plant Phenotyping Network |
| **NARO** | National Agriculture and Food Research Organisation |
| **NIASM** | National Institute of Abiotic Stress Management |
| **NSFC** | Natural Science Foundation of China |
| **NUE** | Nutrient use efficiency |
| **OECD** | Organisation for Economic Co-operation and Development |
| **OG** | Operational Groups |
| **PandD** | Control of wheat pest and pathogens |
| **PM** | powdery mildew |
| **PUE** | phosphorus use efficiency |
| **RAGT** | Rouergue, Auvergne, Gévaudan, Tarnais |
| **RC** | Research Committee |
| **ReVaViLoVGra** | Recovery and valorisation of old local Venetian varieties of soft wheat |
| **SAB** | Strategic advisory board |
| **SB** | Scientific Board |
| **SB** | Spot blotch |
| **SMTA** | Standard Material Transfer Agreement |
| **SNB** | Septoria nodorum blotch |
| **SNP** | Single nucleotide polymorphisms |
| **SONACOS** | National Seed Marketing Company |
| **SR** | Stem rust |
| **STB** | Septoria tritici blotch |
| **TERTIUS** | Genome-based strategies to use the tertiary gene-pool for breeding of climate-smart wheat |
| **TGC** | Tetraploid wheat Global Collection |
| **TGW** | Thousand grain weight |
| **TS** | Tan spot |
| **UBC** | University of British Columbia |
| **VDM** | Virtual Durum Meeting |
| **WB** | Wheat blast |
| **WheatIS** | Wheat Information System |
| **WI** | Wheat Initiative |
| **WUE** | Water Use Efficiency |
| **YDV** | Cereal aphids/yellow dwarf viruses |
| **YR** | Stripe/yellow rust |

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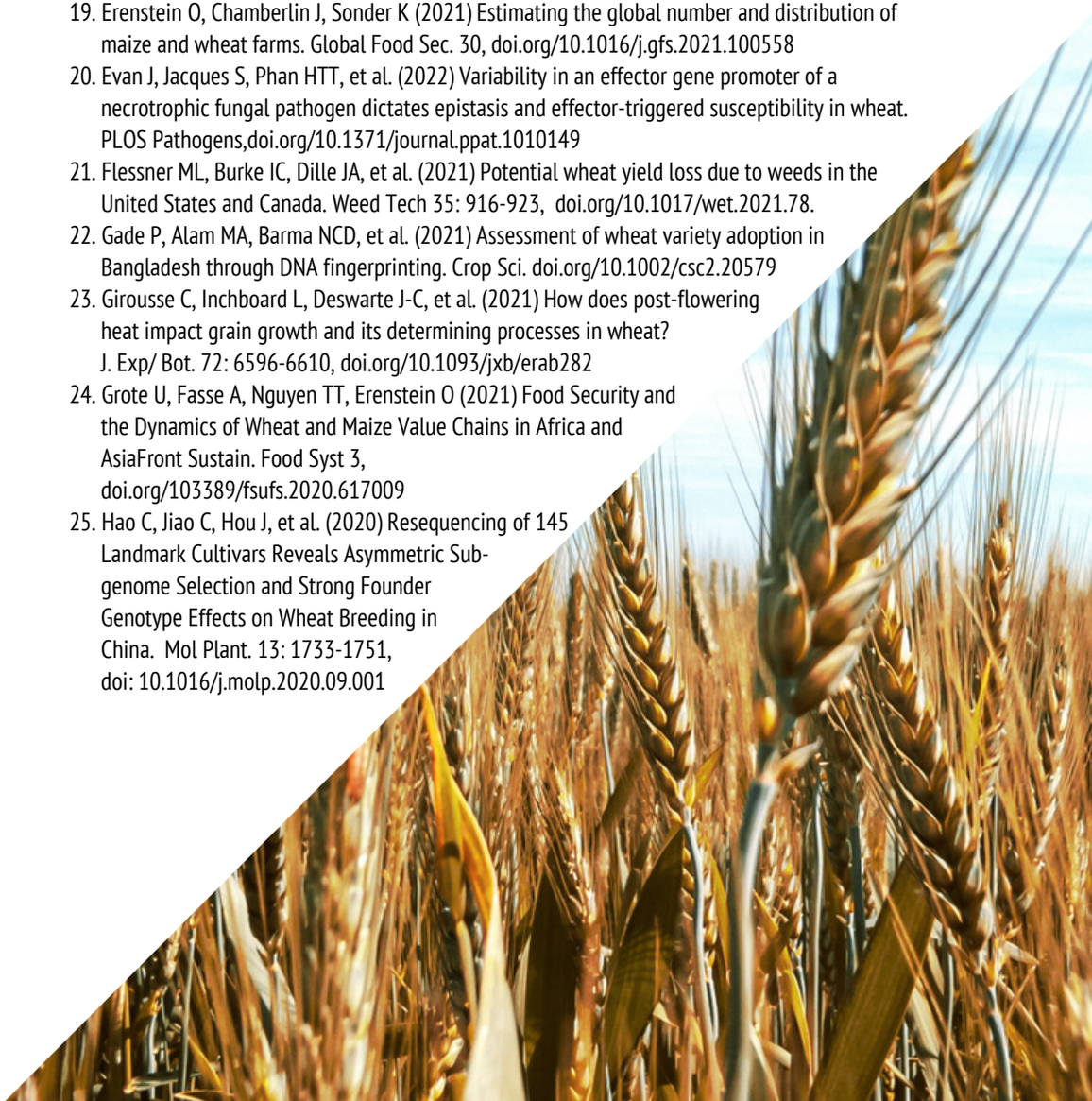


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## A NOTE OF THANKS

Starting the year under the same circumstances as the previous one was not easy. Keeping the WI community together required extra efforts and a spark of imagination to create new ways to keep us connected.

We would like to thank particularly our Expert Working Group Chairs, Co-Chairs and all Expert Working Group members for their dedication to wheat research and for working hard in 2021, facing the challenges that started in 2020.

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We also wish to thank Lisa Incoll, for her support and contributions to this annual report.

We would like to welcome the Republic of Korea once again to the Wheat Initiative, and thank them for their trust in the work we do and for becoming our newest member.

Finally yet importantly, we would like to thank you, our readers, for your interest in the Wheat Initiative and in reading our Annual Report 2021.

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