

ANNUAL REPORT 2020



COORDINATING GLOBAL WHEAT RESEARCH



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THANK YOU VERY MUCH FOR YOUR INTEREST IN OUR WORK

2020 has been unusual and challenging, not only because it gave us an opportunity to show resilience and an ability to adapt to change, but also as a result of all the opportunities that arose due to the COVID-19 pandemic.

This change of circumstances has allowed the Wheat Initiative (WI) to refocus and consider new options and approaches to support our vision to “Create an active global wheat research network supporting and sharing data, ideas and resources to assure global food security through improved wheat production by understanding wheat quality and resistance”.

The travel restrictions meant that the second International Wheat Congress (IWC) planned to be hosted in Beijing in 2021 was postponed to 2022. We look forward with anticipation to the IWC 2022, as it will possibly be one of the first chances for wheat researchers to come together again.

A major highlight in 2020 was welcoming Morocco as the first African member of the WI.

A key milestone in 2020 was the completion and publication of the wheat pan-genome. This international collaboration (The 10X Wheat Genome Project) generated reference quality sequences for 15 wheat genotypes to reveal the complexity and diversity of wheat genome organisation and firmly place wheat researchers in the genomics era. The project was a partnership between funders and researchers from Canada, Germany, USA, Australia, Japan, Switzerland, Israel, Mexico, Saudi Arabia and industry.

The Expert Working Groups (EWGs) continue to be the mainstay of the Wheat Initiative and we would like to thank the Chairs and members for their excellent work and dedication to maintain their interactions through meetings, workshops and training activities using available virtual tools.

Our Agronomy EWG has continued the development of a global wheat yield gap atlas with significant progress on the North American component. The Pest and Disease EWG has also commenced building internationally accepted procedures for the diagnosis of major wheat diseases. This work has also involved discussion with curators on pathogen collections to improve access and diagnostic support. A survey of wheat pathologists has been completed and indicates very strong support from the research community. This new activity will support the establishment of a global disease monitoring system and provide a framework for assessing disease severity and spread.

The Quality EWG has been identifying reference germplasm for assessing different components of quality and preparing a set of defined protocols to ensure global consistency in determining the quality characteristics of wheat varieties. The Nutrient Use Efficiency EWG was successful in developing two new projects on phosphorus use efficiency (PUE): one screening for genetic diversity and the second on roots and PUE. The new project has been funded and involves nine research organisations from UK, France, Italy, Brazil and Mexico.

The Durum EWG has been developing durum wheat reference collections that were successfully multiplied during the 2019 growing season and again in 2020 to allow global distribution. These collections are now entering routine use around the world. The Durum EWG also decided in 2020 to initiate a new consortium to develop the Durum pan genome. The Wheat Information System (WheatIS) EWG has also continued to expand its scope by providing the research community with improved access to a database distributed around the world. A paper on the WheatIS EWG has been submitted to F1000Research, entitled “*Building a successful international research community through data sharing: The case of the Wheat Information System (WheatIS)*”

In 2020, we were also able to move forward with the WheatVIVO database. WheatVIVO is an open-access web portal that aims to provide information regarding wheat researchers, organisations and international projects. The database should be ready to be launched in the second half of 2021.

The reduced travel did provide an opportunity to reorganise the structure and priorities for some of our Expert Working Groups. This was the case for the EWGs on Breeding Methods and Strategies and Global Wheat Germplasm Conservation and Use Community.

We would like to take this opportunity to thank the Chairs and Co-chairs of all our EWGs, for their fantastic effort in leading their respective groups and helping to draw the research community together.

During 2020, four EWGs - Adaption of Wheat to Abiotic Stress (AWAS), Breeding, Germplasm and Funding (FEWG) went through a process of renewal or change of Chairs and/or Co-Chairs as some retired or took on other responsibilities within the WI or elsewhere. We would like to express our thanks to Simon Griffiths (John Innes Centre) who has been the Chair AWAS EWG since inception, and to Evangelia Kougioumoutzi (Biotechnology and Biological Sciences Research Council - BBSRC), who passed the lead of the FEWG to Tim Willis (BBSRC). We thank Fernanda Dreccer (Commonwealth Scientific and Industrial Research Organisation - CSIRO) for accepting once again her nomination as Chair of the AWAS EWG and we welcome new co-chairs Krishna Jagadish (Kansas State University) and Wuletaw Tadesse Degu (International Center for Agricultural Research in the Dry Areas -ICARDA).

A key development during 2020, was the establishment of new international umbrella organisation, the Alliance for Adaptation of Wheat to Heat and Drought (AHEAD) thanks to support from the Julius Kühn Institute and the German Ministry of Food and Agriculture. The AHEAD organisation is managed by the WI and links major national and international programmes from around the world to address scientific gaps and to establish synergies that will support the development of new wheat varieties that are resilient to heat and drought. The AHEAD Steering Committee held its first meeting in April 2020, and has been meeting regularly since then.

In addition to the EWGs, the Wheat Initiative is managed by three committees: The Institutions' Coordination Committee (ICC), the Research Committee (RC), and the Scientific Board (SB). Due to the COVID-19 restrictions the ICC and RC committees did not meet during 2020. Virtual meetings for both committees are planned for 2021: the ICC in April and the RC in November. However, the Chairs of the committees met via video conferences every month.

The Scientific Board held a face-to-face meeting in early 2020 in Morocco just before the travel restrictions came into force. The SB also meets virtually every month. In 2020, we welcomed new members to the SB: Chris Burt from Rouergue, Auvergne, Gévaudan, Tarnais - RAGT was elected by the industry members as the replacement of Chris Tapsell (KWS) and Alison Bentley joined as the new ex-officio member for WHEAT CRP following the retirement of Hans Braun. However, Hans Braun re-joined the Board to replace Graham Moore whose term concluded at the end of 2020. Graham had been a member of the SB since its inception in 2011. We thank them all, and particularly Graham Moore and Chris Tapsell, who have played such an important role in the success of the Wheat Initiative.

The Wheat Initiative's communication has been focused on offering support and help with new opportunities arising from the challenges posed by the pandemic. Since face-to-face meetings were not feasible, virtual meetings, workshops and training sessions were organised and planned. The [newsletter](#), [media brief](#), [website](#) have continued as planned and the subscriptions to these free services have grown substantially.

During 2020, we welcomed Anja Haudricourt as our Administrative Assistant and Anne T. Xuan Hinzmann back from maternity leave as our Communications Manager. We are grateful for the work of Whitney Buchanan who not only filled in the tasks of Communications Manager while Xuan was away, but also played a key role in helping to manage the Wheat Initiative during the second half of 2019.

The WI Secretariat is now fully staffed to ensure the efficient operation of the organisation and the new people are bringing energy and a fresh view to the operation of the Wheat Initiative.

Dr Nicole Jensen, Chair, Institutions Coordination Committee

Prof. Frank Ordon, Chair, Research Committee

Prof. Peter Langridge, International Science Coordinator & Chair, Scientific Board



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INTRODUCTION

INTRODUCTION

WHAT TO EXPECT IN THE 2020 ANNUAL REPORT

We would like to thank you for your interest in our 2020 Annual Report. Due to the challenges caused by the COVID-19 pandemic, this report will differ from the traditional format in previous reports. The wheat research community had to adapt and move its exchange, communication and meetings to the virtual world. The Wheat Initiative's expert working groups were asked to offer us their viewpoints for 2020.

The 2020 annual report will present information about developments in global wheat research, the Wheat Initiative's profile, a new Associated Programme and the future plans of our Expert Working Groups. Our members, including representatives from member and observer countries, organisations and private companies, provided us with an overview of their activities. The Wheat Initiative's communication section will provide information about media channels being used and the strategic approach for 2021. The annual report finishes with a financial overview of 2020.

Every member of the Wheat Initiative is valuable and helps to shape and achieve success in wheat related research. If you would like to help the Wheat Initiative on its 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](#)
- [Becoming an Expert Working Group Member](#)
- [Signing up for the quarterly newsletter](#)
- [Signing up for the weekly "Wheat In The Media" media digest](#)

WHEAT INITIATIVE BACKGROUND

The Wheat Initiative was founded when research and funding organisations of several countries presented their idea of a coordinating body for wheat research. On September 15, 2011, the G20 agriculture ministers endorsed the project in order to increase wheat research efficiency with the long-term goal of supporting global food security.

The Wheat Initiative Secretariat was hosted from its creation in 2011 and until 2018 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 Wheat Initiative provides a framework to initiate, establish and move strategic wheat research and priorities forward. It connects researchers globally, strengthens communication between the research community, funders and global policy makers. The aim is to secure and increase efficient and long-term investments to meet wheat research goals. The Wheat Initiative aims to provide access to resources, and the latest research results and technologies relevant to wheat research.

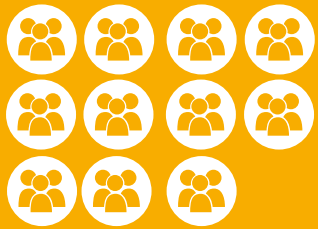
Its mission is to increase food security, wheat nutritional value and safety while taking into account societal demands for sustainable and resilient agricultural production systems; and maximising opportunities for gaining added value internationally.

The Wheat Initiative currently has 14 member countries, 5 observer countries, 2 international research centres and 6 private companies.

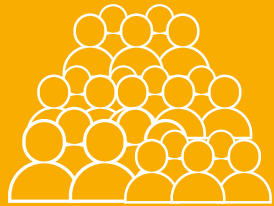
WHEAT INITIATIVE PROFILE

NUMBERS

11 Expert Working Groups (EWG)



600+ EWG members



14 member countries (public)



6 industry members (private)



2 research organisations



5 observer countries



5 Associated Programmes



VISION

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.



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.

PURPOSE

HISTORY



WHEAT RESEARCH BREAKTHROUGHS AND CHALLENGES

Despite the COVID-19 pandemic, wheat research made ground-breaking steps in 2020. In the following section, the Scientific Board offers their perspectives on some major research highlights and topics.

WOLFGANG FRIEDT | Improved pathogen resistance of modern elite varieties is essential for long-term yield increase in winter wheat

Pathogens and pests reduce the yield and quality of major crops and therefore affect agricultural production as a whole. Consequently, they cause substantial economic losses and endanger food security. According to recent estimates, yield loss at a global level and per hotspot for wheat can amount to 28.1%, at an average of 21.5% (Savary et al. 2019). Plant resistance is recognised as the most environmentally friendly and cost-efficient way of plant protection. Therefore, resistance to pathogens has been a major goal in wheat breeding – also in view of constraints in the availability of pesticides. Together with higher yield potential and enhanced production systems, improved resistance has resulted in an average yield increase of 1 to 2% per year on a global scale over the last 50 years. As a stable and environmentally safe wheat production is considered as highly important and an improved yield increase is needed to feed the earth's growing population, the development of more resilient wheat cultivars with durable disease resistances is of prime importance (see Zetzsche et al. 2020).

A recent study based on extended field experiments using a large panel of German winter wheat cultivars released between 1966 and 2013 allows new insights on the practical relevance of disease resistance and grain yield at different levels of N fertilisation in winter wheat. As expected, different fungal pathogens caused varying degrees of crop damage and yield losses. Results allowed quantifying the impact of N fertilisation on the infestation by the fungal pathogens powdery mildew, leaf rust, stripe rust, and Fusarium head blight, and their effects on grain yield as well as yield components. During the last decades, resistance against individual fungal pathogens has been improved significantly so that sustainability of wheat production increased. The slope of improvement of genetic resistance proved to be higher for biotrophic pathogens such as powdery mildew and rusts than for the hemibiotrophic pathogen *Fusarium culmorum*.

The detailed analyses also support the assumption of the accumulation of longer-lasting quantitative resistance loci along with the deployment of race-specific R genes against biotrophic pathogens whereas the latter were mostly overcome. Not unexpected, susceptibility of cultivars to the four fungal pathogens increased at the elevated level of N fertilisation, while the improvement of resistance over time was steeper at the higher N level.

Viewed as a whole, the results strongly indicate that a substantial increase of the genetic yield potential has been achieved independently from the simultaneous improvement of yield stability due to better resistance against different fungal pathogens. Current German elite winter wheat cultivars provide a valuable base for further progress as the sum of trends in fungal resistance shows no signs of slowing down. Future elite wheat cultivars, better suited for farmers' needs and consumers' preferences will allow a more environmentally friendly, sustainable crop production. As a prerequisite for further long-term breeding progress, novel sources of resistance will continuously be required and implemented in wheat breeding.

• Savary S, Willcoquet L, Pethybridge SJ, Esker P, McRoberts N, Nelson A. 2019. The global burden of pathogens and pests on major food crops. *Nat Ecol Evol.* 3(3):430-439. doi: 10.1038/s41559-018-0793-y. Epub 2019 Feb 4. PMID: 30718852

• Zetzsche, H., Friedt, W., Ordon, F. 2020. Breeding progress for pathogen resistance is a second major driver for yield increase in German winter wheat at contrasting N levels. *Sci Rep* 10, 20374. <https://doi.org/10.1038/s41598-020-77200-0>

SEAN WALKOWIAK and CURTIS POZNIAK | Genomic resources in wheat

In the past five years, genomic resources to support discovery and breeding has expanded substantially in wheat. The availability of the annotated reference genome sequences of the hexaploid bread wheat landrace "Chinese Spring", tetraploid durum wheat cultivar "Svevo", and wild emmer wheat "Zavitan" have positioned wheat among major global crops to capitalise on genomic strategies. Although these genome assemblies are valuable resources, they do not fully capture variation that can be used for crop improvement, and comparative genome data from multiple individuals was needed to expedite wheat research and breeding. Recently, the 10+ Wheat Genome Project completed reference level assemblies for nine hexaploid wheat cultivars and breeding lines and a spelt wheat

landrace, in addition to five scaffold level hexaploid wheat genome assemblies (Walkowiak et al. 2020). Together, these genome assemblies provide exciting insights into the genomic diversity from wheat breeding and research programmes spanning several continents. As an Associate Programme of the Wheat Initiative, the genome assemblies generated under the 10+ Wheat Genome Project is equipping researchers and breeders with new tools and is already having an impact on bread wheat improvement, which will help meet future food demands.

The 10+ Genome Project focused on assembly of hexaploid wheat lines from different regions, growth habits and breeding programmes, with the aim of capturing genome diversity typically used in breeding. Comparative analysis of these genomes revealed vast differences, ranging from millions of single nucleotide changes to large-scale structural variants and introgressions from wild relatives of wheat. In fact, one of these, a small introgression from *Aegilops ventricosa*, was associated with a yield increase in the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) and Kansas State Wheat Breeding programmes (Gao et al. 2020). Together, these genome assemblies present an opportunity for breeders and researchers to perform high-resolution manipulation of genomic segments and pave the way to identifying genes responsible for in-demand traits. For example, comparative analysis of the genome assemblies revealed the functional gene conferring resistance to the orange wheat blossom midge, a devastating insect pest that impacts wheat yield and end-use functionality. A similar strategy was used to identify a gene imparting red glume color in spelt wheat (Abrouk et al. 2021). Functional gene studies in wheat will also be facilitated by a comprehensive atlas of the gene space developed using the 10+ Genome Project assemblies, including the NLR immune receptors - genes critical to disease resistance in wheat. Similarly, analysis of the genome assembly for Norin 61, a representative Japanese cultivar of bread wheat, revealed numerous copies of a gene family that is well known to be toxic to plant pathogens (Shimizu et al. 2021). In a much broader context, the genome assemblies have been used to build applied resources that highlight critical haplotype blocks, which provide a framework for defining and exploiting haplotypes to increase the efficiency and precision of genetic markers and wheat breeding (Brinton et al. 2020).

While breeders and researchers are now equipped with new tools that will allow them to advance their work more efficiently than ever before, there is still much work to be done. For example, additional diversity in wheat and its wild relatives remain to be fully described, and the annotations of existing genome resources can still be improved. Most importantly, the impact of genomic diversity and the function of individual genes and gene families can be properly studied and exploited to make significant gains in wheat yield, quality, and performance, and adapt wheat to emerging challenges such as climate change and emerging diseases.

- Abrouk, M., Athiyannan, N., Müller, T. et al. Population genomics and haplotype analysis in spelt and bread wheat identifies a gene regulating glume color. *Commun Biol* 4, 375 (2021). <https://doi.org/10.1038/s42003-021-01908-6>.
- Brinton, J., Ramirez-Gonzalez, R.H., Simmonds, J. et al. A haplotype-led approach to increase the precision of wheat breeding. *Commun Biol* 3, 712 (2020). <https://doi.org/10.1038/s42003-020-01413-2>.
- Gao, L., Koo, D.H., Juliana, P. et al. The *Aegilops ventricosa* 2NvS segment in bread wheat: cytology, genomics and breeding. *Theor Appl Genet* 134, 529–542 (2021). <https://doi.org/10.1007/s00122-020-03712-y>.
- Shimizu, K.K., Copetti, D., Okada, M. et al. De Novo Genome Assembly of the Japanese Wheat Cultivar Norin 61 Highlights Functional Variation in Flowering Time and Fusarium-Resistant Genes in East Asian Genotypes. *Plant and Cell Physiology* 62, 8–27 (2021). <https://doi.org/10.1093/pccp/pcaa152>.
- Walkowiak, S., Gao, L., Monat, C. et al. Multiple wheat genomes reveal global variation in modern breeding. *Nature* 588, 277–283 (2020). <https://doi.org/10.1038/s41586-020-2961-x>.

The “boom-bust cycle” of resistance genes refers to the widespread use of a single rust resistance gene that protects from a disease (boom). With a single mutation of the rust spore followed by selection on the resistant variety, the resistance gene can be overcome and the variety becomes susceptible (bust) often within 3 – 4 years after variety release. To break out from this boom and bust cycle, CIMMYT’s wheat breeding programme has focused on Adult Plant Resistance (APR) genes i.e. genes that each provide less than immunity or have partial effects, which is effective against multiple races of pathogen but when four or five APR genes are combined, a very high levels of resistance can be obtained that lasts much longer. A further benefit from using some of these genes is that they have pleiotropic effects, i.e. they reduce susceptibility for a wide range of diseases. The challenge is to keep the genes together since they are independently inherited and segregate when used in crossing. Marker assisted selection has greatly helped to increase selection efficiency. However, lack of closely linked markers for several APR genes limit their deployment in breeding

To enhance durable rust resistance, four to five major resistance genes should be combined in a stack, i.e. they are inherited as single Mendelian trait and will not segregate when crossed. The probability that all resistance genes are overcome through mutations in one single spore is close to zero and therefore the resistance would be likely durable.

If such varieties would be widely grown, rust spore production would be greatly reduced and the probability for multiple mutations occurring in one spore even further minimised.

However, these genes should not be used alone to prevent stepwise mutation and selection, eventually eroding all genes used in generating combinations. Strategies for a sensible use of these genes are still needed.

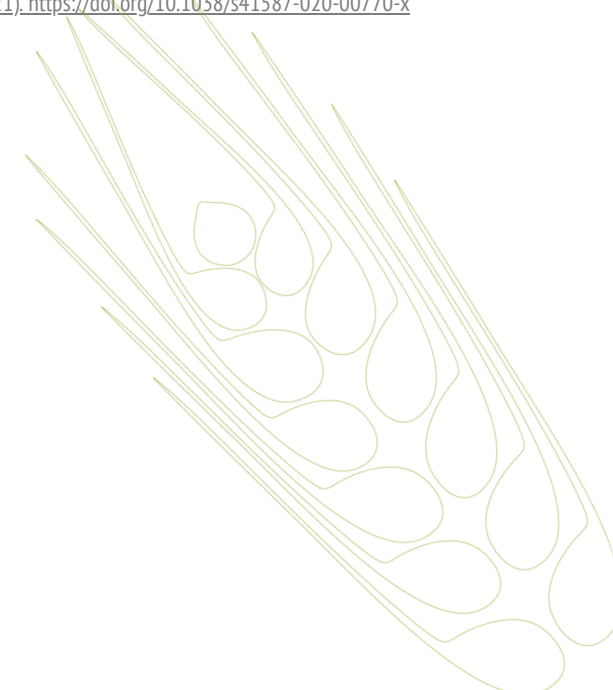
The advent of rapid cloning technologies has facilitated the development of these stacks by a team of wheat scientists from CSIRO, Australia led by Mick Aliffe and the John Innes Center, UK led by Brande Wulff and financially supported by 2Blades

The results were reported in Nature Biotechnology (Luo et al 2021). Stacks with up to 8 genes are now a reality. While current focus is on stem rust, this approach can be expanded to yellow and leaf rust and other wheat diseases.

For wheat, the introgression technology exists now to stack genes into the wheat genome and achieve durable resistance that is unlikely to be overcome by rust spore mutations. The technology used to stack the genes is considered genetic modification (GM), even though the genes used originate from wheat and wheat relatives, i.e. cis-genic. Work is underway, to use genome editing to develop gene stacks, as this technology is not considered GM in some countries.

A solution exists now to basically curtail the most important wheat disease. As a next step, once the optimal stacks have been identified, they can be transferred among others into CIMMYT’s elite lines and distributed internationally for global use, provided policy makes allow use of GM technology and consumers accept the product. Due to COVID-19, the world has been alerted to the risks caused by new diseases and this will hopefully affect the position law makers and consumers take on biotechnologies that allow the control of plant diseases like wheat rust by using wheat genes.

• Luo, M., Xie, L., Chakraborty, S. et al. A five-transgene cassette confers broad-spectrum resistance to a fungal rust pathogen in wheat. *Nat Biotechnol* 39, 561–566 (2021). <https://doi.org/10.1038/s41587-020-00770-x>





2

MILESTONES

MILESTONES

From the launch of a new associated programme focusing on heat and drought, over to Morocco as the first African country member of the Wheat Initiative, to adapting to Virtual Meetings - the following pages show the highlights of 2020.

AHEAD - ALLIANCE FOR WHEAT ADAPTATION TO HEAT AND DROUGHT HEAT AND DROUGHT, WATCH OUT

Heat and drought, as major challenges to wheat production, are the main focus of the programme established in 2020 the Alliance for Wheat Adaptation to Heat and Drought (AHEAD) with the generous support of the JKI, who has kindly provided funds to cover the coordinator position, within the WI.

AHEAD acts as an international umbrella organisation within the WI that coordinates core initiatives and projects that are dedicated to addressing scientific gaps and to establish synergies concerning heat and drought. The long-term goal is research on and development of new wheat varieties that are resilient to heat and drought to ensure food availability for consumers worldwide. Wheat crop losses due to heat and drought affects food availability and increase the costs for billions of consumers around the world.

To properly address this challenge, AHEAD has established a distinguished Steering Committee that provides international advocacy for investment in heat and drought research, along with promoting the relevance of research to policy makers and wheat producers worldwide. The Alliance would like to serve as a lighthouse for wheat for the policy sector, funders, societal and economical stakeholders by sharing scientific knowledge and materials and offering scientists short communication paths and extensive support via an interactive platform.

Currently, the Alliance links international projects to generate high impact and identify innovations for climate resilient wheat. The exchange between projects and initiatives will form the basis of the development of climate resilient wheat. Such projects include the Heat and Drought Wheat Improvement Consortium (HeDWIC), a project by CIMMYT and funded by the "Foundation for Food and Agricultural

Research" and the collaborative project Genome-based strategies to use the tertiary gene-pool for breeding of climate-smart wheat" (TERTIUS) project by the Julius Kühn Institute (JKI), which is funded by the Federal Ministry of Food and Agriculture (BMEL).

The network will be constantly extended with relevant and innovative projects related to heat and drought research. For more information, visit the [AHEAD website](#).

We thank former AHEAD coordinator, Corinna Harms for all her great work and the key role she played in the establishment of AHEAD.

„One way to address the challenges in times of heat and drought is to connect scientists with stakeholders from economic, policy, and non-governmental sectors. A further goal is to help plant scientists exchange information and ideas at meetings and through staff and student exchanges, and to pool resources for efficient, cost effective, and smart science in times of heat and drought.“

Corinna Harms, former AHEAD Coordinator

NEW MEMBER: MOROCCO

The Wheat Initiative Secretariat is pleased to announce that Morocco's National Institute for Agricultural Research (INRA) has been inducted as the newest member of the Wheat Initiative. In February 2020, the Wheat Initiative Secretariat and members of the Scientific Board travelled to Rabat, Morocco as part of the preparations for Morocco's membership. Morocco joined in September 2020 as the first African country to become part of the Wheat Initiative.

The Chair of the Scientific Board, Peter Langridge welcomed Morocco to the Wheat Initiative: "Their membership will bring additional capabilities and extend our global reach. The involvement of Morocco in our activities and decision-making processes will help ensure broad access to wheat research outcomes and add a new and important voice to setting the global research priorities."

The Director of INRA Morocco, Dr Faouzi Bekkaoui, commented "We are glad to be part of this global wheat research network. We are looking forward to fruitful collaboration actions and collaborative programmes".

INRA Morocco's mission is to undertake research for agricultural development. They have made a major contribution to the modernisation of the agricultural sector and agro-systems in the region by improving methods and systems to boost the competitiveness of the country's agriculture. It is a public institution with origins dating back to 1914, with the creation of the first official agricultural research service. INRA is composed of a network of 10 Regional Research Centres and dozens of experimental areas spread over the national territory, covering the various agrosystems of Morocco. Furthermore, INRA Morocco works to maintain strong partnerships with national and international organisations, as well as the private sector and non-governmental organisations. CGIAR, ICARDA and CIMMYT are important members of these strong partnerships.

"There is an urgent need for close cooperation in heat and drought research to address the challenge of a changing climate and the demand for sustainable wheat production globally and in Morocco in particular. The Wheat Initiative could offer this through the development of new collaborative programmes and coordinated actions. The combination of new varieties and agronomic practices will allow farmers to improve and stabilise wheat yields in diverse production environments."

Dr Ferrahi Moha,
Wheat Megaproject Coordinator at INRA Morocco &
member of the AHEAD Steering Committee

VIRTUAL DURUM MEETINGS

In 2020 when the COVID-19 pandemic started, Expert Working Groups cancelled all their face-to-face meetings and workshops. The Durum Wheat Genomics and Breeding Group was the first group to adapt to the COVID-19 restrictions and organised two 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 Chairs of the Durum EWG, Luigi Cattivelli and Roberto Tuberosa, managed to get more than 130 attendees to attend their first VDM session in July, the second one had more than 120. Videos of most of the presentations are published on the Wheat Initiative website, which you can access [here](#).

The session in July featured the following topics:

- Advances in durum wheat breeding at CIMMYT - Dr Karim Amman (CIMMYT, Mexico)
- Candidate genes and genome-wide association study for fibre content in wild and cultivated wheats - Dr Agata Gadaleta (University of Bari, Italy).
- Durum miRNA-mediated networks in response to water-deficit and heat stress during reproduction - Dr Haipei Liu University of Adelaide, Australia).
- The global durum panel as a durum breeding platform - Dr Elisabetta Mazzucotelli CREA, Italy)
- The impact of durum wheat breeding on major genes regulating flowering time and its agronomic implications - Dr Conxita Royo (Spain)
- The tetraploid wheat global collection - Dr Marco Maccaferri (University of Bologna, Italy)
- Sequenced mutant populations and new efficient transformation technologies to empower gene functional studies in durum wheat - Dr Jorge Dubcovsky (UC-Davis, USA)
- Durum breeding in Germany: new programmes and ideas for the near future - Friedrich Longing (University of Hohenheim Germany)

The session in November/December featured the following topics:

- Argentinean durum wheat: quality, yield and yield related traits - Viviana Echenique (CONICET, Argentina)
- G + GxE vs E: experience in phenotyping for stress tolerance - Filippo Bassi (ICARDA, Morocco).
- High-throughput field phenotyping of durum wheat for the QTLome dissection of drought-adaptive traits - Marco Maccaferri (University of Bologna, Italy)
- High-throughput phenotyping for the genetic dissection of root system architecture and canopy traits in durum wheat - Giuseppe Sciara (University of Bologna, Italy)
- A non-invasive chlorophyll fluorescence-based approach for field high throughput phenotyping of durum wheat photosynthetic traits under drought - Nicolas Zendonadi (Forschungszentrum, Jülich, Germany).
- Phenotypic evaluation of the drought response in bread and durum wheat employing non-invasive high-throughput phenotyping - Kerstin Neumann (IPK-Gatersleben, Germany).
- Function and evolution of allelic variation of Sr13 conferring resistance to stem rust in tetraploid wheat - Steve Xue (USDA).
- Implementation of a phenotypic platform for durum wheat breeding - Nicola Pecchioni, Pasquale De Vita (CREA, Italy)
- Stem rust phenotyping in tetraploid wheats - Pablo Oliveira (University of Minnesota, USA)
- Sensor-based high-throughput phenotyping for wheat breeding and pre-breeding - Francisco Pinto (CIMMYT, Mexico)



3

REPORTS & HIGHLIGHTS



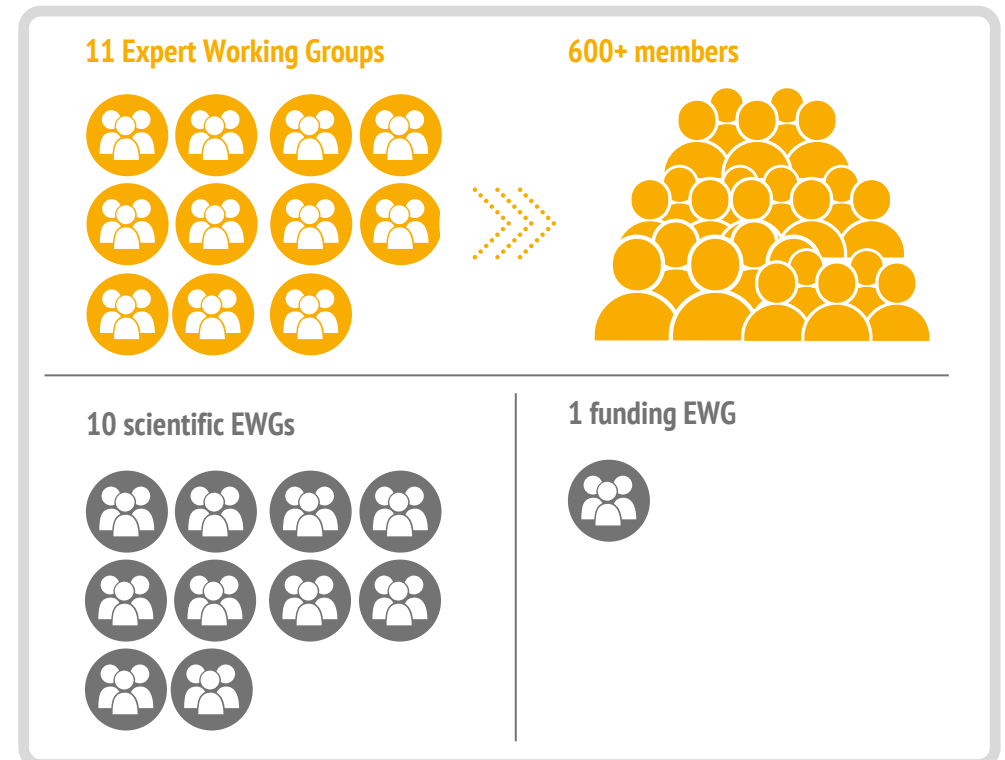
REPORTS & HIGHLIGHTS

On the following pages our scientific working force - the Expert Working Groups, our essential backbone - present a summary of their 2020 year. Furthermore our member countries and organisations also kindly provided an insight into their 2020.

EXPERT WORKING GROUPS (EWGs)

The EWGs 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 the Wheat Initiative's aims and objectives. The numerous EWGs reflect all important research fields for yield improvement and include experts from the public and private sectors.

Image 01: Expert Working Groups in Numbers



ADAPTATION OF WHEAT TO ABIOTIC STRESS

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.

2020 MEETINGS

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

EWG ACTIONS AND PROGRESS IN 2020

It was planned to circulate an abiotic stress priorities poll, finish compilation of the germplasm panel, engage with other EWGs to organise a course on abiotic stress and organise "mentoring" time from experts to the wider scientific community. These plans for 2020 were all delayed due to the COVID-19 pandemic.

MAJOR SCIENTIFIC DEVELOPMENTS IN 2020

Included here are recent highlights from publications volunteered by members:

Using a modified version of APSIM model, average temperature and heat shocks from April to July between 1985-2017, Ababaei and Chenu (2020) in *Agricultural and Forest Meteorology*, revealed heat shocks to increasingly impede grain filling but having little effect on grain setting across the Australian wheatbelt.
(DOI: <https://doi.org/10.1016/j.agrformet.2019.107889>)

Kumar et al (2020), carried out a meta-QTL analysis for drought tolerance in bread wheat and identified two major MQTLs, namely MQTL4 and MQTL12; identified 14 important candidate genes based on insilico expression analysis indicating their potential to be considered in marker assisted breeding.
(DOI: <https://doi.org/10.1007/s12298-020-00847-6>)

AWAS

- 134 members from 28 countries
- Chairs: Fernanda Dreccer (Australia), Simon Griffiths (UK) / Late in 2020, Simon Griffiths withdrew as Co-chair and Krishna Jagadish (USA) & Tadesse Wuletaw Degu (Lebanon) became Co-chairs
- Vice-Chair: Matthew Reynolds
- SB Liaisons: Wolfgang Friedt, Peter Langridge

Important quantitative traits including yield and its components, tolerance to abiotic stresses (heat, drought, salinity and pre-harvest sprouting) and biofortification (Fe/Zn and phytate contents with HarvestPlus Programme) in wheat was reviewed by Gupta et al (2020).

(DOI: <https://doi.org/10.1007/s00122-020-03583-3>)

Tyagi et al (2021) developed and used miRNA-derived SSRmarkers for studying genetic diversity, population structure, and characterisation of genotypes for breeding heat tolerant wheat varieties.

(DOI: <https://doi.org/10.1371/journal.pone.0231063>)

Rascio et al (2020) developed a low-cost method for phenotyping wilting and recovery of wheat leaves under heat stress using semi-automated image analysis. The method uses a free time-lapse application in a smartphone camera.

(DOI: [10.3390/plants9060718](https://doi.org/10.3390/plants9060718))

Tura et al (2020) carried out QTL analysis and fine mapping of a QTL for yield-related traits in wheat grown in dry and hot environments. A total of 128 QTL were identified for four traits: grain yield, thousand grain weight (TGW), days to heading and grain filling duration. Chromosome 1B was focussed where two main effect QTL were found for yield and TGW without confound by phenology. NILs were developed and evaluated under semi-controlled conditions. The QYld.aww-1B.2 was narrowed down to 2.9 cM which corresponded to a 2.2Mbp genomic region on the chromosome 1B which contained 39 predicted genes.

(DOI: <https://doi.org/10.1007/s00122-019-03454-6>)

An improved cyber-physical system was developed and used to capture post-flowering high night temperature impact on yield and quality of field grown wheat by Hein et al (2020). All related Raspberry Pi algorithms, equipment and tools needed to establish such a system elsewhere are accessible through the supplementary documents.

(DOI: <https://doi.org/10.1038/s41598-020-79179-0>)

Sebela et al (2020) captured the impact of heat stress-induced changes in photosynthetic pigments and QY in leaves and spikes at high temporal frequency in wheat grown under field conditions and stress imposed using heat tents.

(DOI: <https://doi.org/10.1002/agj2.20360>)

HEDWIC UPDATE (Programme led by Matthew Reynolds)

The key activity of HeDWIC in 2020 was the development of a proposal to request FFAR funding for the HeDWIC-Hub: "Harnessing translational research across a global wheat improvement network for climate resilience"; the project has 9 main goals with 28 research objectives, for a total of \$5m new money and a cash match of \$12.5m (from CRP-WHEAT and AGG). The proposal was successful.

Associated activities include:

- Initiated a 3-way collaboration for a spring x winter wheat crossing programme involving JIC, JKI and H-Hub, with winter wheat activities led by Simon Griffiths and Bernd Hackauf in UK and Germany, respectively.
- Initiated collaborative research plans with Tadesse Wuletaw at ICARDA to grow the HeDWIC "Elite Diversity Panel" in CWANA -among other international sites- to understand GxE and its genetic bases in different heat and drought stressed profiles.
- Collaborated on the submission of 4 more research proposals aligned to HeDWIC.
- Obtained one CONACYT scholarship (Purdue and HeDWIC-Hub) for the HeDWIC Doctoral Training Programme; and submitting 2 more scholarship opportunities (Hohenheim and H-Hub).

- Wrote a multi-author review of the case for HeDWIC research, "Harnessing translational research in wheat for climate resilience" submitted to JEB, ID6 Special Issue.
- Presented a talk about HeDWIC to ID6 "Targets of the Heat and Drought Wheat Improvement Consortium (HeDWIC)"; ID6 Virtual Platform.
- Shared feedback on the HeDWIC international nursery -SATYN- with Julie Nicol for the CAIGE Newsletter.
- Formed a strategic advisory board (SAB) that met twice with activity leaders to review the goals and objectives (the second meeting was this year).
- Initiated the first season's research at HeDWIC Hub.

PLANS FOR 2021

The Chairs of the AWAS EWG plan to hold online meetings in 2021, there are no face-to-face meetings planned.

In 2021, the AWAS EWG plans to: run a poll to see what activities members want to do in the absence of face-to-face meetings; form small groups to discuss papers for journals and organise a competition to attract PhD students and post-docs and encourage their participation in the WI.

BREEDING METHODS AND STRATEGIES

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 utilisation of cultivated and wild genetic resources (to cross with GR-EWG).

2020 MEETINGS

The planned face-to-face meeting in Norwich, UK was postponed due to the COVID-19 pandemic.

EWG ACTIONS AND PROGRESS IN 2020

EWG members worked on a special issue of the journal "Crop Breeding, Genetics and Genomics" titled "Genomic Selection in Wheat", papers were submitted by January 2021 (extension of original 2020 deadline).

The current chair, Gilles Charmet is retiring, and he will be replaced by Sanjay Kumar Singh, from ICAR-IWBR, Karnal, India. 2021 will be used as a transitional period, therefore both will act as Chairs. Chris Burt, Co-Chair has accepted to become part of the Scientific Board and in 2021 will leave as Chair of the Breeding EWG.

MAJOR SCIENTIFIC DEVELOPMENTS IN 2020

The EWG provided a summary of 2 papers which they considered of significance to their area in 2020.

- A mini review on usefulness of genome editing (broad sense), published in October 2020 Improving Nutritional and Functional Quality by Genome Editing of Crops: Status and Perspectives. Hyung-Keun Ku and Sun-Hwa Ha, *Frontiers in Plant Science*.

(DOI: <https://doi.org/10.3389/fpls.2020.577313>)

BREEDING

- 33 Members from 13 countries
- Chair: Gilles Charmet (France)
- Vice-Chair: Chris Burt (UK)
- SB Liaisons: Curtis Pozniak, Chris Tapsell

In this study, the current applications of genome editing technologies were reviewed to improve the nutritional and functional quality and preferred traits of various crops. Combining this rapidly advancing genome-editing technology and conventional breeding will greatly extend the potential of genome-edited crops and their commercialisation.

- On wheat evolution "Triticum population sequencing provides insights into wheat adaptation" published in *Nature Genetics*, December 2020.
(DOI: <https://doi.org/10.1038/s41588-020-00722-w>)

Bread wheat expanded its habitat from a core area of the Fertile Crescent to global environments within ~10,000 years. These results showed the genetic necessities of wheat as a global crop and provided new perspectives on transferring adaptive success across species for crop improvement.

The significance of this paper is: just as man who inherited genes from other Homo species (*H neandertalensis*), current wheat crop is a mosaic of genomes from many related species. Thus, these secondary gene pools should be paid more attention to by scientists and breeders.

PLANS FOR 2021

If circumstances permit, a face-to face meeting (the postponed 2020 Norwich meeting) will be organised for the end of the year. Alternatively, an online meeting of members will be held.

An online training workshop was held in February 2021 over 6 days, titled "Transforming wheat breeding through integrated data management with GOBii and analysis in Flapjack". The aim was to achieve autonomous handling and efficient use of online tools for data organisation and exploitation.

CONTROL OF WHEAT PEST AND PATHOGENS

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.

2020 MEETINGS

A subgroup of 24 global experts of the WI EWG on Pests and Diseases met remotely on two occasions (April and June 2020) to gather existing knowledge and define research priorities on the major pathogen threats for wheat production. The goal of the EWG is to reduce losses in wheat to pests and diseases utilising easily adopted genetic resistance technologies and thereby improving global food security.

A series of follow-up meetings were held with the WI Secretariat to develop a plan for building a global disease monitoring strategy.

EWG ACTIONS AND PROGRESS IN 2020

The scale of the pest and disease problem was recently estimated at current losses averaging 21.5% of wheat production. This translates to about 180 million tonnes, enough to provide the wheat needs of about 1.8 billion people. These losses are primarily due to 11 diseases - leaf rust (LR), *Septoria tritici blotch* (STB), stripe/yellow rust (YR), spot blotch (SB), tan spot (TS), cereal aphids/yellow dwarf viruses (YDV), powdery mildew (PM,) *Septoria nodorum blotch* (SNB), stem rust (SR), blast (WB) and Fusarium head blight (FHB). In all areas of the world, only two or three of these diseases can cause more than 50% of the losses.

PandD

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

The EWG members believe that wheat researchers should aim to reduce losses by 50% to these diseases using existing and new sources of genetic resistance. Controlling the diseases in all areas of the world will not only increase local wheat production, but it would also reduce the risk and impact of transcontinental movement of pathogen populations and disease epidemics. A three-stage research plan was developed:

- Mapping the global distribution of the major diseases.
- Cataloguing isolate collections.
- Identification and distribution of resistant cultivars and existing sources of resistance.

The EWG now hopes to initiate work on the first two stages of the plan during 2021.

PLANS FOR 2021

The research plan developed in 2020 provides a framework for building a global collaborative programme. During 2021, the detailed work plan needs to be prepared and the full engagement of research community and funding organisations sought. Two major tasks for 2021 will be:

- Defining the most appropriate disease diagnostic system to be deployed either through specific screens for each of the diseases or through a pan-genomic approach.
- Cataloguing global isolate collections. This second task includes identification of suitable screening locations and enhancing access to collection or sequence data on isolates held in collections.

DURUM WHEAT GENOMICS AND BREEDING

AIMS

The Durum EWG aims to promote synergies 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 organisation 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 pan genome.

2020 MEETINGS

- 27-28 July, Webinar, Virtual Durum Meeting (VDM)

Open to all wheat scientists and followed by about 130 participants

- 30 November-1 December, Webinar, VDM

Open to all wheat scientists and followed by about 110 participants

EWG ACTIONS AND PROGRESS IN 2020

The initial work plan for the Durum EWG for 2020 suggested organisation of a short-term fellowship programme to promote the collaboration among EWG members. Although the proposal was accepted and a budget was allocated to the EWG, the situation with the COVID-19 pandemic during 2020 clearly did not allow to implement the planned fellowship programme for this year. It is hoped to restore the fellowship programme in 2022.

To keep the EWG active and to provide an update while promoting some discussion on the latest scientific advancements on durum wheat genomics and breeding, the EWG launched a new initiative called Virtual Durum Meeting (VDM). The VDMs are webinars where 4-5 short presentations are given in about 2 hrs followed by time for discussion. Each VDM was organised in two days with a session of about 2 hrs for each day.

DURUM

- 106 members from 26 countries
- Chairs: Luigi Cattivelli (Italy), Roberto Tuberosa (Italy)
- Vice-Chairs: Jason Able (Australia), Karim Ammar (Mexico)
- SB Liaisons: Peter Langridge, Curtis Pozniak

The 1st VDM was organised on 27 and 28 July 2020 and was dedicated to durum wheat breeding (first day) and durum wheat genomics (second day), while the 2nd VDM was held 30 November and 1 December 2020 and focused on wheat phenotyping for genomics studies.

There was advancement in the international initiative for the characterisation of the Global Durum Wheat Panel (GDP). There were more than 40 scientists who requested the GDP panel in 2019-2020. A significant amount of work (SNP calling and data analysis) has been carried out to investigate the main features of the GDP (i.e. population structure) and to provide essential information for GWAS analysis of traits of interest. A manuscript describing the GDP, was completed and published in 2020 in the *Frontiers in Plant Science* special issue on "A Sustainable Durum Wheat Chain for Food Security and Healthy Lives". The manuscript was titled "The Global Durum Wheat Panel (GDP): An International Platform to Identify and Exchange Beneficial Allele", by Mazzucotelli et al (DOI: <https://doi.org/10.3389/fpls.2020.569905>). The special issue also included the publication of 14 manuscripts; five members of the Durum EWG and one member from the Agronomy EWG acted as Topic editors.

After an informal meeting at PAG in 2020, a consortium has been organised in the frame of the EWG to carry out the sequencing of the pangenome of tetraploid wheat. As a first step, a work plan for sequencing the reference cultivar Svevo at "platinum quality" level (PacBio HiFi + Optical map) has been made and an agreement with CORTEVA is in progress for genome sequencing. The Svevo platinum quality genome will act as proof of concept before sequencing additional 15-20 genotypes representing the genetic diversity of tetraploid wheat. A letter of interest for the creation of the Svevo Platinum Genome Consortium has been signed by 15 different institutions worldwide.

A proposal entitled 'A global platform for leveraging durum wheat diversity (Global-durum) was submitted by L Cattivelli, R Tuberosa and F Bassi in April 2020 and accepted by DivSeek. Global-durum aims to take advantage of the International Pilot Hub for coordinating the ongoing phenotyping and genotype-phenotype data basing activities dedicated to the GDP and to the Tetraploid wheat Global Collection (TGC). GDP and TGC are highly complementary in terms of genetic diversity explored and potential use also in view of the lower LD of the TGC and are proposed as reference for breeding and gene discovery in tetraploid wheat. The International Pilot Hub will provide the frame for collecting all data that will be made publicly available and make them available through internationally recognised repositories (i.e. GrainGenes, ENSEMBL-Plants).

PLANS FOR 2021

In 2021, it is planned to continue the Virtual Durum Meetings in place of the traditional face-to-face meetings. They will be held in July and October-November and will promote discussion on the latest scientific advancements on durum wheat genomics and breeding.

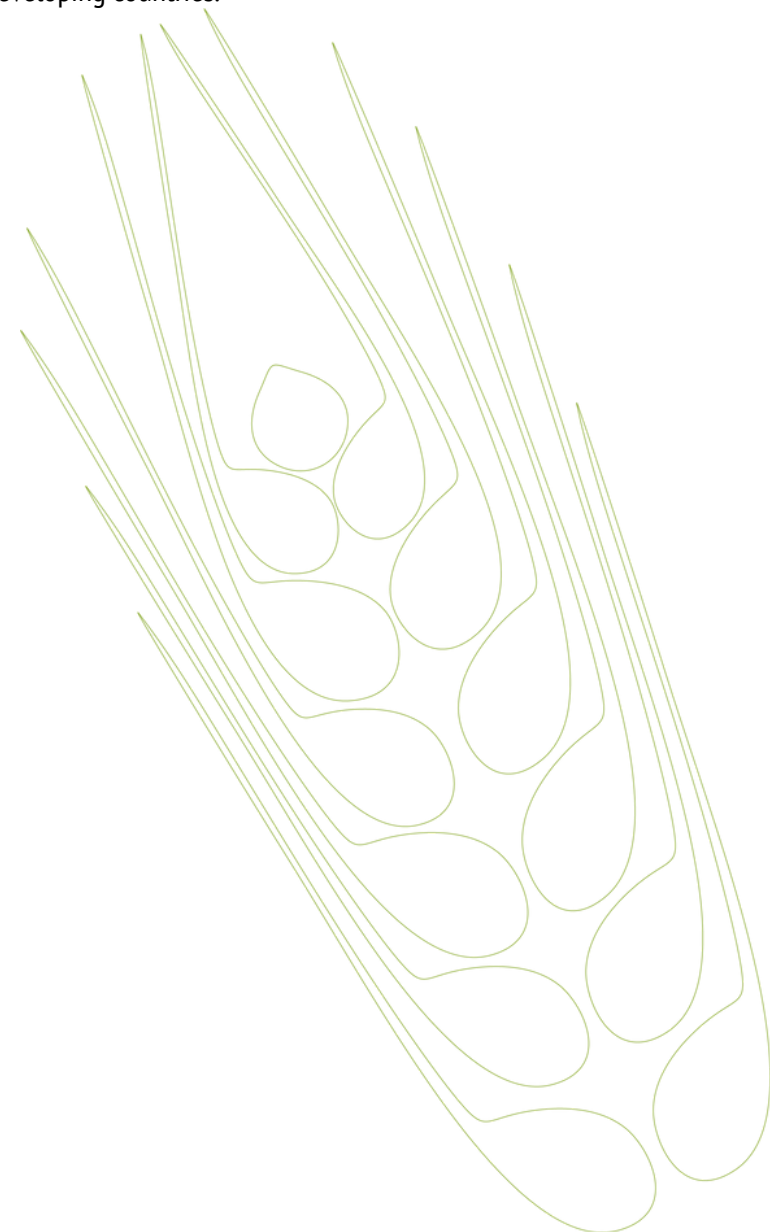
If the COVID-19 pandemic is over by the end of 2021, the Durum EWG plans to organise a half day face-to-face meeting shoulder-to-shoulder with PAG to launch the activities for 2022.

The sequencing of the tetraploid wheat pan genome will be completed in 2021. The platinum quality sequence of the durum wheat reference cultivar Svevo will be produced and made available to the durum wheat community. Then, the strategic plan for the sequencing of the tetraploid wheat pan genome will be shared within the EWG members, with those having relevant expertise, invited to contribute.

The GDP will be used as a reference panel for durum wheat genomics and breeding. In order to do this, work will be carried out to monitor the ongoing GDP phenotyping activities and promote coordination/analyses of the data. Phenotyping of GDP will be repeated in the 2020-2021 growing seasons.

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 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.

It is also planned to support open access publications of durum wheat works from research groups working in developing countries.



GLOBAL WHEAT GERMPLASM CONSERVATION AND USE COMMUNITY

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 gene banks, 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.

2020 MEETINGS

The Germplasm EWG did not hold any formal meetings during 2020. However, the Scientific Board met with Dr Amri in February in Morocco and visited field sites where the Durum Reference Germplasm collections were grown. There were also several virtual meetings with the Programme Director of DivSeek to explore opportunities for collaboration.

Plans for a workshop in partnership with the Breeding EWG were deferred due to the COVID-19 pandemic.

EWG ACTIONS AND PROGRESS IN 2020

In late 2019, the EWG undertook a survey of the wheat research community gauging interest in the development and use of reference germplasm collections. The outcome was strong support for targeted collections. Consequently, in 2020 each EWG was approached to seek input into the structure and size of collections that would be needed to address the needs of their communities. In some cases, such as the Durum and Quality EWGs, the identification and collection of germplasm has already commenced. In other cases, additional work is needed to define the nature of the collections needed.

GERMPLASM

- 46 members from 24 countries
- Chair: Thomas Payne (Mexico)
- Vice-Chair: Ahmed Amri (Morocco)
- SB Liaisons: Hans Braun, Chris Tapsell

During 2020, discussion on both the reference collections and strategies for the characterisation and utilisation of genetic resources were initiated with Dr Katy Navabi, Programme Director DivSeek International Network. The objective is to explore options for sharing resources and developing a common approach to enhancing the use of germplasm collections.

PLANS FOR 2021

The Chairs of the Germplasm EWG will change during 2021 with the transfer from Amhed Amri and Tom Payne to Benjamin Kilian from the CropTrust, in addition, Shivali Sharma (ICRISAT), Peter Civan (INRAE) and Hakan Ozkan (Uni Cucurova) joining as Vice-chairs.

The EWG is planning to hold virtual workshops during 2021 on the implications for wheat breeding and research community of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPRFA), the Standard Material Transfer Agreement (SMTA) and the Nagoya Protocol.

Plans for a workshop late in 2021 linked to a workshop being organised by DivSeek are now likely to be deferred to 2022. This workshop, sponsored by the Organisation for Economic Co-operation and Development (OECD), "Barcodes to Bushels" will be focussed on the technicalities of using modern Omics technologies to bridge the gap between gene banks and breeding programmes.

The EWG will also continue the development of the reference germplasm collections and discuss the future of the Wheat Gene Catalogue. There are also plans in 2021 to revise the "Global Strategy for the ex situ Conservation with Enhanced Access to Wheat Rye and Triticale Genetic Resources". This strategy document was prepared in 2007 and, with the major changes in technology and regulation, there is a need to develop an updated document.

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 organisations 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.

2020 MEETINGS

- 19-21 October 2020, MycoKey Final International Conference, online, 1 EWG member
- 8 September 2020, Joint Wheat Gene Nomenclature Workshop with WheatIS EWG, 4 EWG members

EWG ACTIONS AND PROGRESS IN 2020

A great success of the whole EWG, was the publishing of a Springer book, "Wheat Quality for improving processing and human health" covering all wheat quality topics. The whole book was written by EWG members and a large percentage of the EWG contributed to the book.

The Quality EWG consists of six subgroups that have identified research priorities in each of the target areas.

QUALITY

- 81 members from 23 countries
- Chair: Tatsuya Ikeda (Japan)
- Vice-Chair: Carlos Guzman (Spain)
- SB Liaisons: Hirokazu Handa, John Snape

The Genetic Resources and Gene Nomenclature subgroup developed a master set for waxy and puroindoline genes and registered the genetic stocks in the USDA gene bank. This resulted in an article by Morris et al (2020), "Registration of six partial waxy near-isogenic hexaploid wheat genetic stock lines lacking one or two granule bound starch synthase I genes" in Journal of Plant Growth Regulation (DOI: <https://doi.org/10.1002/plr2.20010>). This subgroup also organised a joint meeting of Wheat Gene Nomenclature with the WheatIS EWG, discussed renewing the wheat gene nomenclature and developed a lab protocol repository for EWG members to upload lab protocols.

The Nutrition and Carbohydrates subgroup multiplied the master set for dietary fibre in Hungary and shared the set with the IPK gene bank.

The Safety subgroup made advances on biocontrol in wheat to reduce Fusarium head blight and deoxynivalenol accumulation using a bioformulate based on *Bacillus velezensis* RC 218 both in durum and bread wheat. This resulted in 4 articles being published:

- Yerkovich et al (2020) "Fusarium head blight in Argentina: Pathogen aggressiveness, triazole tolerance and biocontrol-cultivar combined strategy to reduce disease and deoxynivalenol in wheat". Crop Protection. (DOI: <https://doi.org/10.1016/j.cropro.2020.105300>)
- Palazzini et al (2020) "Spray-drying process as a suitable tool for the formulation of *Bacillus velezensis* RC218, a proved biocontrol agent to reduce Fusarium Head Blight and deoxynivalenol accumulation in wheat". Biocontrol Science and Technology. (DOI: <https://doi.org/10.1080/09583157.2019.1709621>)

- Yerkovich et al (2020) “Population structure and genetic diversity of *Fusarium graminearum sensu stricto* the main wheat pathogen producing Fusarium head blight in Argentina”. European Journal of Plant Pathology. (DOI: <https://doi.org/10.1007/s10658-019-01913-w>)
- Cantoro et al (2020) “*Bacillus velezensis* RC 218 as a biocontrol agent against *Fusarium graminearum* effect on penetration, growth and TRI5 expression in wheat spikes”. BioControl. (DOI: <https://doi.org/10.1007/s10526-020-10062-7>)

PLANS FOR 2021

It is planned to hold a face-to-face meeting in UK in August 2021, if circumstances permit.

The Quality EWG plans to develop a strategy for the training of new grain quality experts and other wheat scientists. It also plans to organise different webinars targeting wheat quality researchers and students.

The Genetic Resources and Gene Nomenclature subgroup will complete the lab protocol repository; decide on the alleles/genotypes for the Master set for grain starch proteins and start collection and analysis of the accessions.

The Seed Protein subgroup plans to produce a method repository for SDS-PAGE, A-PAGE, and molecular markers. They also plan to identify quality-related ideotypes (gluten, waxy, Pin, polyphenol oxidase (PPO) alleles) for each end use, which will help breeders for high quality wheat varieties.

The Allergy subgroup will select and develop a Master set for low allergen and low toxic genotypes.

The Safety subgroup will 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).

The Nutrition and Carbohydrates subgroup will be refining the Master Set for dietary fibre and multiplication of seeds.

The Processing subgroup plan to 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

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.

2020 MEETINGS

- 7 October, Annual EWG Meeting, online with 22 EWG attendees.

EWG ACTIONS AND PROGRESS IN 2020

At the annual EWG meeting in October, there was brainstorming of ideas for future focus, agreement on partners and roles, and discussion of plans going forward.

A grant application led by Jean-Pierre Cohan and involving multiple EWG members to obtain funding for genetic survey of NUE in European Wheat was successful. This project was initiated in autumn of 2020 and will run for 3 years. Multiple trials will be run and supplemented by other subprojects.

There will be further discussions on collaboration on wheat roots and NUE.

NUE

- 50 members from 19 countries
- Chair: Malcolm Hawkesford (UK)
- Vice Chairs: Jacques Le Gouis (France), Ivan Ortiz-Monasterio (Mexico)
- SB Liaisons: Graham Moore, John Snape

MAJOR SCIENTIFIC DEVELOPMENTS IN 2020

Included here are new studies on wheat and NUE in 2020.

Two key papers were published for tackling the N-use issues in India:

- Swarbreck et al (2019) "A roadmap for lowering crop nitrogen requirement". Trends Plant Science.
(DOI: <https://doi.org/10.1016/j.tplants.2019.06.006>)
- Moring et al (2021) "Nitrogen challenges and opportunities for agriculture and environmental science in India". Frontiers in Sustainable Food Systems.
(DOI: <https://doi.org/10.3389/fsufs.2021.505347>)

A summary of NUE related trends in a long-term study (2004-19) of wheat cultivars at Rothamsted in the UK was published.

- An evaluation of recent trends in nitrogen use efficiency of UK wheat (Defra Report, 2020).

There were two new genetic studies reporting on chromosomal regions associated to nitrogen use efficiency. Both were conducted at different nitrogen levels. They report new marker-trait associations for US (Brasier et al 2020) and Chinese (Zhang et al 2020) accessions.

- Brasier et al (2020) "Genotypic variation and stability for nitrogen use efficiency in winter wheat". Crop Science.
(DOI: <https://doi.org/10.1002/csc2.20006>)
- Liu, H., Zhang, X., Xu, Y. et al. (2020) "Identification and validation of the superior alleles for wheat kernel traits detected by genome-wide association study under different nitrogen environments". Euphytica.
(DOI: <https://doi.org/10.1186/s12870-020-02661-4>)

In Tian et al (2020), a study analysed root growth in relation to nitrogen application stages. Postponing the nitrogen fertilisation period under nitrogen deficiency promoted deeper root growth during the post-jointing period and increased basal nitrogen uptake, as well as reducing basal nitrogen loss and increasing grain yield and nitrogen use efficiency.

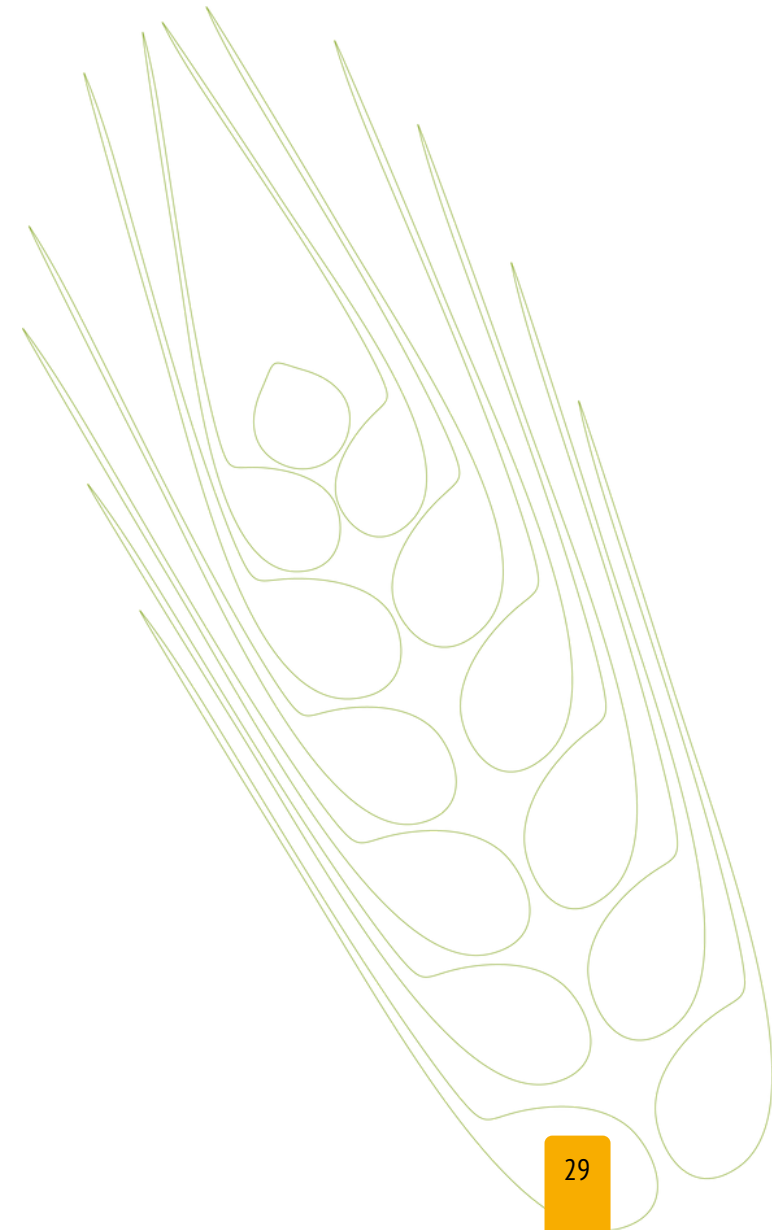
- Tian et al (2020) "Early nitrogen deficiency favours high nitrogen recovery efficiency by improving deeper soil root growth and reducing nitrogen loss in wheat." Archives of Agronomy and Soil Science.
(DOI: <https://doi.org/10.1080/03650340.2019.1671972>)

Two general review papers on genetic variation of NUE including G x E x M components:

- Hawkesford, Griffiths (2019) "Exploiting genetic variation in nitrogen use efficiency for cereal crop improvement." Current Opinion in Plant Biology.
(DOI: <https://doi.org/10.1016/j.cpb.2019.05.003>)
- Hawkesford, Riche (2020) "Impacts of GxExM on Nitrogen Use Efficiency in Wheat and Future Prospects." Frontiers in Plant Science.
(DOI: <https://doi.org/10.3389/fpls.2020.01157>)

PLANS FOR 2021

It is planned to hold a half day online meeting in summer/autumn 2021 to discuss the future action plan. If circumstances permit, it is planned to hold a face-to-face meeting at the International Wheat Conference in 2022. It is also planned to have a joint meeting with the Agronomy EWG on low input systems and to explore the possibility of training workshops.



WHEAT AGRONOMY

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.

2020 MEETINGS

- August 2020, EWG Strategy meeting with Science Board advisors and Secretariat, online, 5 EWG members
- August 2020, Special issue, wrap-up meeting, online, 5 EWG members
- 7-13 November 2020, ASA-CSSA-SSSA International Annual Meeting, online, attended by members of the ASA Wheat Initiative Agronomist Community and conference attendees including EWG members.
- December 2020, EWG Jamboree, online, 1 EWG member

EWG ACTIONS AND PROGRESS IN 2020

The project "Wheat yield gaps: magnitude and opportunities to sustainably improve yield" has continued and was originally to finish at the end of 2021. EWG members R Romulo and B Beres head up the project with support from other members. Yield gap assessment data developed as a learning and measurement tool for yield enhancement of wheat, knowledge regarding wheat yield gaps will be established and accessible to the general public (see <https://www.yieldgap.org/>).

AGRONOMY

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

While this project experienced some delays related to the COVID-19 pandemic and staff turnover in Canada, the objective is proceeding and will continue in 2021-22. Work on global wheat yield gaps is also being conducted by ICARDA GEOAGRO <https://geoagro.users.earthengine.app/view/yieldgapwhakes-egy>. The work is ongoing to improve accuracy when it comes to farm and pixel level (10-30m), but work has progressed with respect to ongoing GT data collection and algorithm refinements.

The Frontiers GxExM Special Issue "Exploring GxExM Synergies in World-Wide Wheat Production and the Opportunities for International Collaboration" was published. The EWG solicited an international, cross-disciplinary panel of experts to submit manuscripts of works fostering the aims of a GxExM systems approach to agronomy. The EWG contributed, edited and reviewed content for the special issue. The EWG recognises all contributing authors of the special issue for their exemplary research.

The strategic plan for the Agronomy EWG was developed with four key areas established and summarised in a policy paper. The four key areas are: 1) Development of Sustainable Wheat Cropping Systems; 2) Improved Management of Biotic and Abiotic threats to Sustainable Production; 3) Tools to Support Improved Management Systems and 4) Improved Knowledge Mobilisation and Knowledge Transfer. The outputs include a paper by Beres et al (2020). Toward a Better Understanding of Genotype × Environment × Management Interactions – A Global Wheat Initiative Agronomic Research Strategy (DOI: <https://doi.org/10.3389/fpls.2020.00828>) and the presentation of survey results priority area 4 at the ASA-CSSA-SSSA meetings, as part of the Wheat Initiative Agronomists Symposium. The outputs will serve as the catalyst to drive the synthesis of a theme around one or more of the stated priority areas, and from which a coordinated call for global agronomy research would emerge.

At the ASA-CSSA-SSSA International Annual Meeting, online, there was a presentation titled “Developing credible digital extension tools for wheat farmers”.

MAJOR SCIENTIFIC DEVELOPMENTS IN 2020

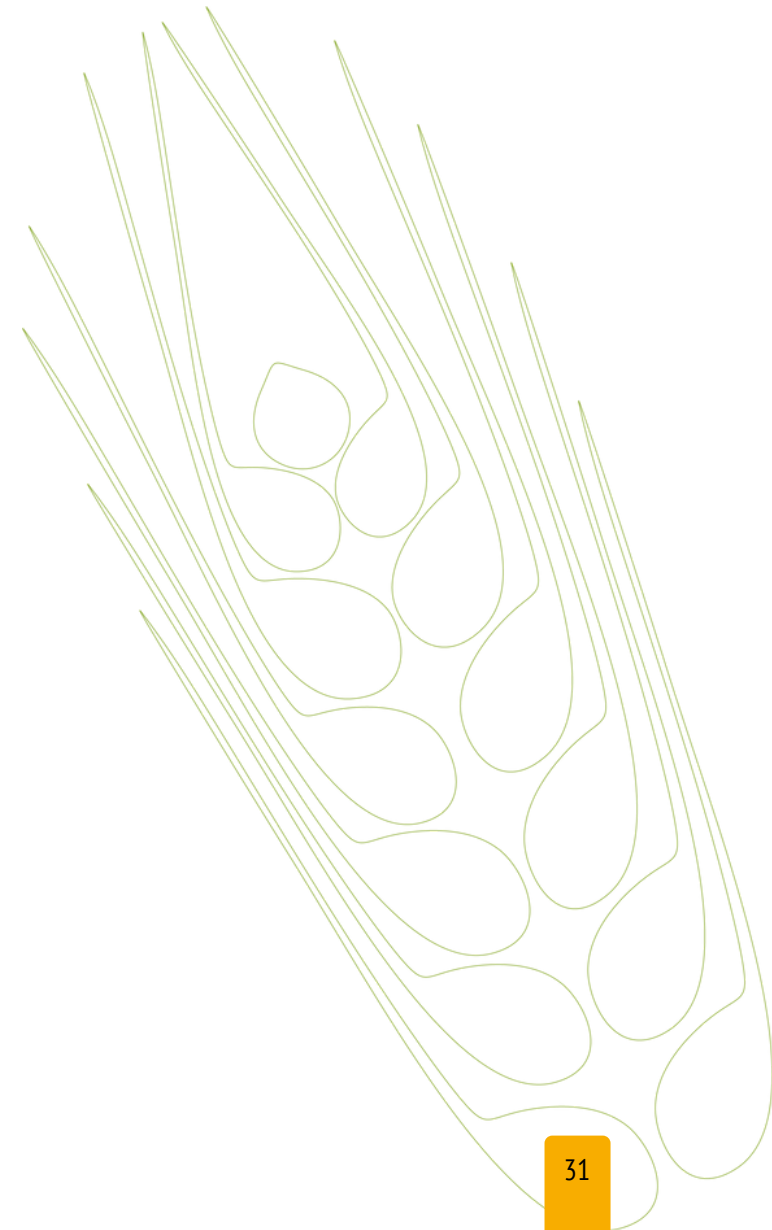
The primary highlight would be the development of a policy paper outlining priority areas for future wheat agronomy research.

While the following is a canola-based scientific highlight, it is a model easily adopted to wheat research and production. Details of this milestone can be found here (<https://www.miragenews.com/record-breaking-canola-crop-credited-to-science-518404/>) where it describes a world record for canola yield (7.2 t/ha!) recently attained in Australia. The farmer who is now the world record holder, gives credit to the adoption of practices based on the principles of an applied and integrated systems approach to canola production from a CSIRO project led by John Kirkegaard.

PLANS FOR 2021

The meetings planned for 2021 include the ASA-CSSA-SSSA Annual Meeting in November (either in Salt Lake City or online depending on travel restrictions); a 1-day online meeting to discuss the pilot research project and an online webinar with EWG and stakeholders summarising priority areas and pilot project development.

The EWG will continue with the project “Wheat yield gaps: magnitude and opportunities to sustainably improve yield”, work on the strategic plan for the EWG with outreach to policy makers, funding agencies and stakeholders for input. The Agronomy EWG will undertake outreach activities to obtain at least 6 new members and 3 organisations/institutes from areas such as China, India and South America.



WHEAT INFORMATION SYSTEM

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.

2020 MEETINGS

- 10 January 2020, Face-to-face, WheatIS EWG annual meeting, in San Diego, USA, 15 EWG members
- 12-13 February, Face-to-face, Training workshop on data management for wheat phenotyping data, in Versailles, France, 18 attendees (EWG and non-EWG members)
- 28 September, online, Wheat Gene Nomenclature workshop, 32 attendees (EWG and non-EWG members)

WHEAT IS

- 22 members from 7 countries
- Chair: Taner Sen (USA)
- Vice-Chairs: Hadi Quesneville (France), Mario Caccamo (UK), Dave Edwards (Australia)
- SB Liaisons: Graham Moore, Hirokazu Handa

EWG ACTIONS AND PROGRESS IN 2020

A new WheatIS interface was released <https://urgi.versailles.inrae.fr/wheatis/> and it is now faster, provides more search filters, and is streamlined.

In 2020, the WheatIS chair and co-chairs submitted a paper on WheatIS EWG to F1000Research, entitled "Building a successful international research community through data sharing: The case of the Wheat Information System (WheatIS)".

PLANS FOR 2021

WheatIS plans to have their Annual meeting online in spring/summer 2021. They also plan to finalise the selection of a WheatIS new logo, prepare for a face-to-face Annual Meeting at Plant and Animal Genomics Conference in January 2022 in San Diego, USA and to add more datasets through <http://wheatis.org/>.

WHEAT PHENOTYPING TO SUPPORT WHEAT IMPROVEMENT

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 programmes and engage experts from non-plant disciplines in wheat phenotyping.

2020 MEETINGS

- October 9 and 20, 2020, an online symposium on phenotyping and abiotic stress was organized by ICAR-NIASM, India. Speakers and organisers were EWG members (3), approximately 450 attendees each time.

There were various online webinars on phenotyping organised by International Plant Phenotyping Network (IPPN), plus online video archive, the organising committee included 2 EWG members and average attendance was 500-8,000 Chinese and 50-100 rest of the world.

EWG ACTIONS AND PROGRESS IN 2020

There were online seminars and webinars presented to several thousand participants. The Symposia were directly organised by EWG members (ICAR-NIASM) and the webinars were provided through close links with and joint membership in IPPN. The advantage of online training is the global reach and ability for participation from developing countries where normally travel costs and visa restrictions would limit access.

MAJOR SCIENTIFIC DEVELOPMENTS IN 2020

There were numerous publications by EWG members in 2020 including:

- David et al (2020) "Global Wheat Head Detection (GWHD) dataset: a large and diverse dataset of high-resolution RGB-labelled images to develop and benchmark wheat head detection methods". Plant Phenomics. (DOI: <https://doi.org/10.34133/2020/3521852>)

PHENOTYPING

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

- Sanchez-Bragado et al (2020) "New avenues for increasing yield and stability in C3 cereals: exploring ear photosynthesis". Current opinion in plant biology. (DOI: <https://doi.org/10.1016/j.pbi.2020.01.001>)
- Watt et al (2020) "Phenotyping: new windows into the plant for breeders". Annual review of plant biology. (DOI: <https://doi.org/10.1146/annurev-arplant-042916-041124>)
- Fernandez-Gallego et al (2020) "Automatic wheat ear counting using machine learning based on RGB UAV imagery". The Plant Journal. (DOI: <https://doi.org/10.1111/tpj.14799>)
- Reynolds et al (2020) "Breeder friendly phenotyping". Plant Science. (DOI: <https://doi.org/10.1016/j.plantsci.2019.110396>)

Members of the EWG remain amongst the highest published researchers in wheat phenotyping.

PLANS FOR 2021

The Phenotyping EWG held a NAPPN annual meeting online in February and plan to hold an online or hybrid meeting: International Plant Phenotyping Symposium (IPPS), in October, the main host will be Wageningen University & Research. This EWG plans to continue with online webinars and symposia, participate in the Global Wheat Challenge, produce training videos (with a competition for the best training video held jointly with AWAS EWG) and exchange ideas and support with other EWGs, xPPNs and WI. They will also continue to publish papers and plan to work on a special issue on plant phenotyping organised by IPPN with EWG members as editors and contributors.

FUNDING EXPERT WORKING GROUP

AIMS

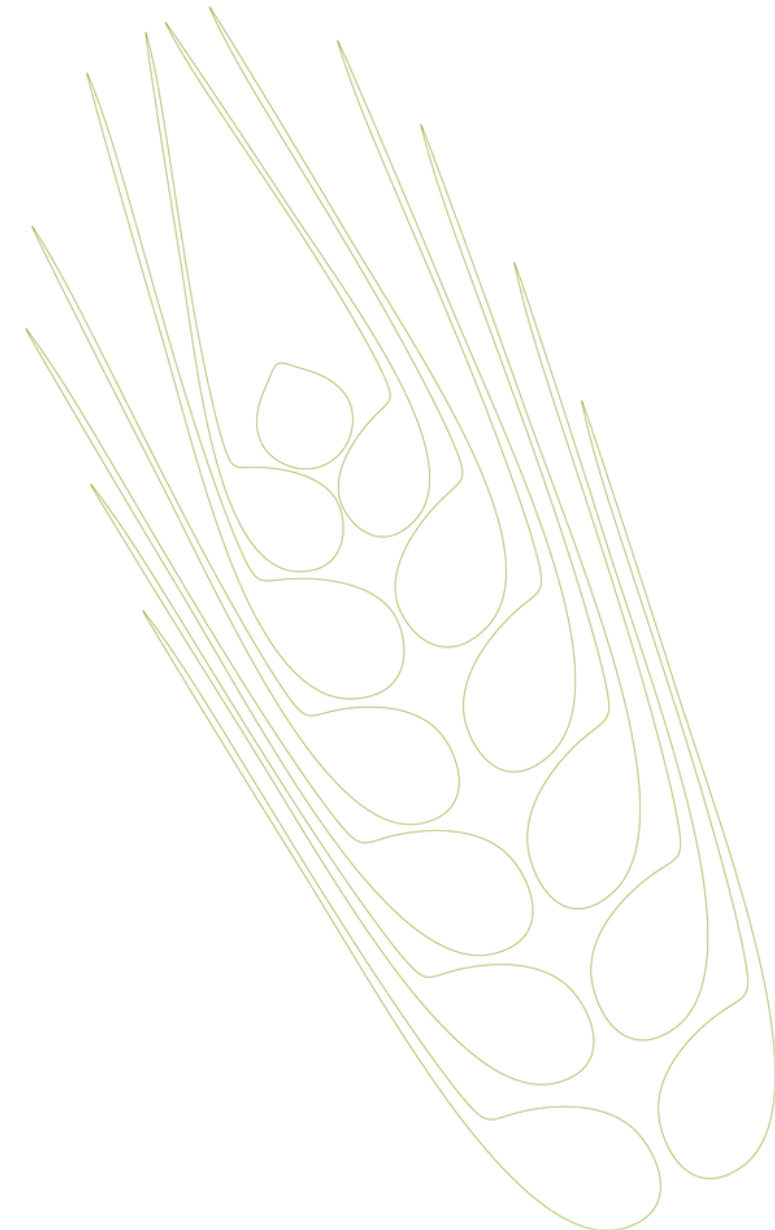
The FEWG aims to identify and disseminate information on funding mechanisms and tools available to support multi and bilateral international collaboration in wheat research, for the benefit of WI's EWGs. The EWG aims to enable dialogue and coordination at a funder-to-funder level with an aim to explore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

EWG COMMENTS for 2020

Funders of research have had to respond to the COVID-19 pandemic in many ways, from convening and catalysing efforts to respond to the pandemic through new research, innovation and development activities, through to managing and repurposing current investments and capability. An immediate priority was mitigating the impact of the pandemic on research programmes being delayed or requiring more funding to get through additional growing seasons or maintain collections. Understanding how global food systems are coping in response to the shock has also been important to predict emerging challenges, inform recovery and provide important data for managing future shocks, especially in the context of climate change.

FEWG

- 9 Members from 7 countries
- Chair: Evangelia Kougioumoutzi (UK) until late 2020, then chaired by Tim Willis (UK)



MEMBER HIGHLIGHTS 2020

AUSTRALIA (GRDC)



WHEAT PRODUCTION AND MAJOR PRODUCTION ISSUES

Australia is estimated to have produced one of the biggest wheat crop on record in 2020–21 as a result of favourable seasonal conditions, driven by a mild La Niña event bringing increased rainfall. The production is estimated at above 33 million tonnes from an area of 12.9 million hectares, with an average yield of 2.6 tonnes per hectare (t/ha).

SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

GRDC has this year established "INVITA" (INnovations in plant Variety Testing in Australia), a new investment of \$5.39 million over five years that will support more profitable crop variety selection decisions by Australian grain growers. INVITA will achieve this by bringing together an internationally renowned team of scientists led by The University of Queensland and significant intellectual property to enhance the quality, timeliness and utility of National Variety Trials varietal performance data, including for wheat.

INVITA was designed to leverage a parallel European Union Horizon 2020 project, "INVITE" (INnovations in plant Variety Testing in Europe), a scientific consortium of 28 European partners led by INRAe in France in which the European Union is investing €8m in cash. The consortium partners are providing in the order of €12m of its kind. Through INVITE, there is also a connection to another European Union Horizon 2020 funded project, "INNOVAR" (€7.9m cash), a consortium led by the Agri-food & Biosciences Institute (AFBI) in Northern Ireland, which aims to augment and improve the efficacy and accuracy of European crop variety testing and decision-making.

RESEARCH HIGHLIGHTS

The "10+ Wheat Genomes Project", an international research collaboration including scientists from the University of Adelaide and led by Prof. Curtis Pozniak (University of Saskatchewan, Canada),

completed the sequencing and assembly of 15 wheat genomes, unlocking new genetic variation that is expected to boost wheat breeding globally. The results were published last year in Nature (Walkowiak et al., 2020).

Researchers at Agriculture Victoria Research (AVR, Melbourne), who also participated in the initiative, have incorporated the data arising from the pangenome sequencing into bioinformatic tools such as Pretzel to enhance the capacity of high-throughput genotyping platforms.

Late maturity alpha-amylase (LMA) is a grain quality trait that results in a low falling number in the absence of pre-harvest sprouting, resulting in downgrades. Researchers at the University of Adelaide have identified a major gene underlying the LMA trait. Major haplotypes have also been identified and diagnostic markers developed to help breeders select against LMA.

There are currently limited control options for crown rot, a significant wheat disease for winter cereals in Australia, costing the nation's grains industry an estimated \$404 million in lost yield annually. A recently completed project, involving four Australian research organisations, has combined multiple resistance loci to achieve resistance scores up to 30 per cent greater than benchmark varieties.

WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMMES

There has traditionally been a focus of Australian wheat research investment on protecting wheat yields through improved resistance and tolerance to abiotic constraints. A Rust Landscape Analysis, commissioned by GRDC and led by the Australian National University with support from Cornell University, highlighted the Australian Cereal Rust Control Program contribution to world-class genetic solutions, diagnostics and surveillance to control cereal rusts. In recent years, significant progress has been made in speed in which new cereal rust resistance genes are identified, characterised and cloned, with a focus on durable resistance. International collaborations between Australian and CIMMYT researchers have facilitated the development and testing of new resistance sources against the most virulent rust pathogens globally.

Australia remains committed to addressing abiotic stress in wheat. Dr Greg Rebetzke became the Chair of the Alliance for Wheat Adaptation to Heat and Drought (AHEAD) Steering Committee in 2020 and Australian scientists participated in the 2021 AHEAD workshop to provide an overview of on-going projects on heat and drought in wheat in Australia; and Dr Fernanda Dreccer is the co-chair of the Adaptation of Wheat to Abiotic Stress Expert Working Group.

The major bottleneck for the improvement of crown rot resistance and tolerance in wheat breeding programmes is the lack of high throughput, robust phenotyping methodologies. GRDC has just co-invested in a project to deliver high-throughput, repeatable, accurate, low-cost crown rot phenotyping to the Australian breeding community.

CANADA (AAFC)



WHEAT PRODUCTION AND MAJOR PRODUCTION ISSUES.

In 2020, Canada benefited from warm temperatures, good ground moisture, well timed rains and above average crop yields. Over 35 million tonnes of wheat were produced on 25.2 million acres, with over 80% achieving No. 1 and No. 2 grades.

SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

AAFC has become a member of the Alliance for Wheat Adaptation to Heat and Drought (AHEAD). AAFC Director of Research, Development and Technology, Felicitas Katepa-Mupondwa, became a member of the AHEAD steering committee in 2020 and AAFC scientists participated in the 2021 AHEAD workshop to provide an overview of on-going projects on heat and drought in wheat at AAFC.

RESEARCH HIGHLIGHTS

AAFC has achieved a major breakthrough with Fusarium Head Blight (FHB) resistance in durum. They have developed the first Canadian durum variety with intermediate FHB resistance. Improved FHB resistance will increase Canada's capacity to supply high-quality durum to international markets and increase producer profitability.

AAFC scientists are leading three International Wheat Yield Partnership (IWYP) collaborations with United Kingdom and Australian researchers. Collaborators include the University of Essex and University of Adelaide - Stomata signalling pathways for increasing yield potential in wheat; the John Innes Centre and Rothamsted Research - Leveraging phenomics and genomics approaches for efficient allele mining and deployment to increase yield in wheat; and the University of Cambridge - Circadian clock editing to increase wheat yield.

A University of Saskatchewan-led international team published the genomes for 15 wheat varieties representing breeding programmes around the world in the journal Nature. The results will enable scientists and breeders to identify more quickly influential genes for improved yield, pest resistance and other important crop traits.

WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMMES

The University of British Columbia (UBC) has established new wheat and barley research programmes in Vancouver, BC. Dr Gurcharn Brar will work on genetics, pathology & pre-breeding with a focus on stripe rust and FHB. In stripe rust, Dr Brar will work on pathogen virulence characterisation and identifying sources of resistance, gene mapping & cloning. Southern BC is the epi-centre for stripe rust in Canada and provides perfect conditions for screening.

CHINA (CAAS)



WHEAT PRODUCTION AND MAJOR PRODUCTION ISSUES

In 2020, China produced 131 million tonnes wheat, harvest acreage was 23 millionhectares, the yield 5.46 t/ha. Due to the high temperatures in early spring, and epidemics of leaf rust and yellow rust, the grain filling time became shortened to approximately 5-6 days less than in normal years.

SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

One new joint research programme between ICS-CAAS and CIMMYT was launched on drought tolerance and Water Use Efficiency (WUE), which was supported by NSFC (Natural Science Foundation of China).

RESEARCH HIGHLIGHTS

Wheat genomics and applied genomics research achieved great progress in 2020. Professor Kong's group in Shandong Agricultural University has successfully cloned a new important head blight resistant gene *Fhb7*, which was derived from *Thinnopyrum elongatum* (EE) in collaboration with scientists of the United States of America and Israel. This work was published by Science as a cover story (Science, 2020, 368: e5435 DOI: [10.1126/science.aba5435](https://doi.org/10.1126/science.aba5435)). Another important disease resistant gene Pm24 was successfully isolated from a Chinese land race, which was a gain of function mutant of a kinase gene with wide scope resistance to powdery mildew races (Nature Commun, 2020, 11:680 DOI: <https://doi.org/10.1038/s41467-020-14294-0>). Chinese scientists also revealed the genetic base of Tibetan semi-wild wheat, which evolved through de-domestication of common wheat in high plateau environments with a 0.8 Mb deletion on 3D (Nature Commun, 2020, 11: 5085 DOI: <https://doi.org/10.1038/s41467-020-18738-5>). Two groups (CAU, ICS-CAAS) found that NAC019 strongly regulates starch and gluten in synthesis in developing grains, which was published in Plant Cell and Journal of Experimental Botany independently. Moreover, Dr Zhang's group in ICS-CAAS, re-sequenced 145 landmark cultivars released between 1950s-2000s. The big data clearly indicated the cultivar evolutionary progress and contribution of European cultivars to the national wheat breeding from 1960-1980s. Their work also showed very strong founder genotype effect and asymmetric selection in wheat breeding (Molecular Plant, 2020, 13:1733 DOI: [10.1016/j.molp.2020.09.001](https://doi.org/10.1016/j.molp.2020.09.001)). Fine mapping of quantitative trait locus (QTLs) based on resequencing and Diversity Arrays Technologies (DARTs) in natural populations and inbred recombination lines has successfully identified the causative genes for phenotypic variation of complex traits (Molecular Plant, 2020, 13 : 1311 DOI: <https://doi.org/10.1016/j.molp.2020.07.008>). Dr Lu's group in IGDB-CAS provided new evidence for inter-introgression between species of *Triticum* genus in adaptation to diverse environments (Nature Genetics, 2020, 52:1412 DOI: <https://doi.org/10.1038/s41588-020-00722-w>).

WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMMES

2020 is the last year of the 13th Five-year Plan of China, and no new major funding was provided to wheat scientists. 2021 is the first year of the 14th Five-year Plan of China, and major competitive and mandatory funding will be launched in 2021 and 2022, covering germplasm evaluation and enhancement, functional genomics and breeding of all major crops, such as wheat, rice, maize and soybean.

FRANCE (INRAe)



WHEAT PRODUCTION AND MAJOR PRODUCTION ISSUES

In 2020, 30.07 Million tonnes were harvested (average 2010-2019: 37.72 Mt) on 4.51 million hectares (Mha) (average 2010-2019: 5.36 Mha). Globally, 2020 is a poor year in terms of production mainly because of the very wet autumn that prevented farmers to sow winter cereals. In addition, the average grain yield was also quite low (6.66 tonnes per hectare (t/ha) compared to the average 2010-2019 of 7.10 t/ha).

SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

INRAE is part of the steering committee of the Alliance for Wheat Adaptation to Heat and Drought (AHEAD) under the Wheat Initiative.

RESEARCH HIGHLIGHTS

- Significant results were obtained concerning breeding for wheat bread-making quality: (i) Single nucleotide polymorphisms (SNP) markers for early identification of high molecular weight glutenin subunits (HMW-GSs) were developed (Ravel et al. 2020 DOI: [10.1007/s00122-019-03505-y](https://doi.org/10.1007/s00122-019-03505-y)), and (ii) different strategies of genomic prediction to optimise resource allocation in breeding schemes were compared showing the value of adding information on dough strength in the genomic selection model (Ben-Sadoun et al. 2020 DOI: [10.1007/s00122-020-03590-4](https://doi.org/10.1007/s00122-020-03590-4)).

- Sixteen fungal QTL associated to disease resistance (septoria tritici blotch, septoria nodorum blotch, leaf rust, and an emerging wheat blast) through genome-wide association mapping of 180 inbred lines sampled from a durum wheat Composite Cross-population (Ballini et al. 2020 DOI: <https://doi.org/10.1007/s10681-020-02631-9>).
- Major advances in participatory breeding of wheat and cereals have been performed:
 - i) development of new statistical methods to track selection in participatory plant breeding (David et al. 2020. DOI: <https://doi.org/10.1016/j.tpb.2019.11.007>),
 - ii) release of a web tool dedicated to seed exchanges (De Oliveira et al. 2020. DOI: <https://doi.org/10.1186/s13007-020-00640-2>),
 - iii) demonstration of the performance and robustness of developed populations (Goldringer et al. 2020. DOI: <https://doi.org/10.3390/su12010128>; Van Frank et al. 2020 DOI: <https://doi.org/10.3390/su12010384>), and
 - iv) description of knowledge commons produced in farmers seed exchange networks (Mazé et al.2020. DOI: <https://doi.org/10.1007/s10460-020-10172-z>).
- Montazeaud et al. (2020) (DOI: <https://doi.org/10.1111/1365-2664.13735>) investigated the effect of functional trait composition on productivity and grain quality of varietal mixtures by growing diverse genotypes in pure stands and two-way mixtures in field conditions. Functional traits explained a significant part of the relative agronomic performance of mixtures compared to monocultures (12%–22%, depending on the yield component).

WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMMES

- The French National Research Agency (ANR) has funded 10 projects in a call which objective is to better protect and cultivate crops (limiting the use of pesticides). Among these is the project MoBiDiv (Mobilising and selecting intra- and inter-specific crop diversity for systemic change towards pesticide-free agriculture), coordinated by INRAE, for 6 years (3M€). It will trigger a paradigm shift toward diversification through breeding for variety and crop mixtures, focusing on wheat, pea and fodder species.

This interdisciplinary project involves 20 partners from French Universities, CNRS, CIRAD, IRD, MNHN and INRAE.

- The French Funds to support Plant Breeding (FSOV) has selected 13 cereal projects for a budget of ~4M € in its 2020 call (www.fsov.org). They are to develop methods to increase resistance to wheat dwarf virus, barley Helminthosporium, triticale yellow rust, tolerance to drought and heat of durum wheat, cold tolerance, competition to weeds, phosphorus use efficiency and to characterise the response to mycorrhiza.
- The Phenome-Emphasis project (French plant phenomic Infrastructure) has been extended for 5 years (2021-2025 with an additional budget of 5M€. The objective is to develop platforms and methods to phenotype plants in the field and in controlled conditions for adaptation to climate change and agroecology.

GERMANY (BMEL)



WHEAT PRODUCTION AND MAJOR PRODUCTION ISSUES

Wheat is the most widely cultivated crop in Germany. Based on preliminary representative results, wheat was grown on an acreage of 2.83 million hectares in 2020, which corresponds to a share of 46.6 percent of total cereal cultivation. Thus, the area sown for winter wheat decreased by seven percent in 2020. The decline in winter wheat cultivation was probably caused by wet weather conditions at the time of sowing in autumn 2019 followed by a relatively dry vegetation period in spring 2020 with local-scale heavy precipitation. The average yield is estimated at 7.83 tons per hectare, hence average yield increased by five percent compared to last year. In 2020, 21 new wheat varieties (17 winter types, 4 spring types), were registered in Germany. They combine high yield with a high level of resistance and different qualities (E, A, B, C).

SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

In 2020, 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 optimised 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 Adaptation to Heat and Drought (AHEAD).

RESEARCH HIGHLIGHTS

The 10+ Genome Project has sequenced the genomes of 15 wheat varieties and created a comprehensive genome atlas for wheat. In 2020, the research results on genomic diversity among wheat lines from global breeding programmes obtained also with the involvement of WHEATSEQ were published in "Nature".

WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMMES

The last four out of 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 Programme started in 2020.

A call promoting innovative ideas for the breeding of climate-adapted varieties and crops within the Innovation Programme is currently being prepared. Funding will focus on strategies for adapting crops to climate change, improving resource-use efficiency and resistance to pests as well as implementing innovative methods and techniques.

ITALY (CREA)



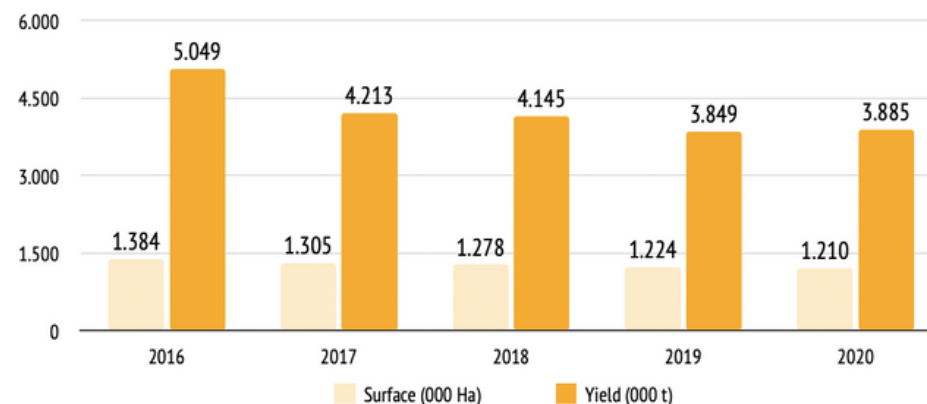
WHEAT PRODUCTION AND MAJOR PRODUCTION ISSUES

Durum Wheat

The main areas sown to durum wheat are south and central regions (Sicilia, Basilicata, Puglia, Marche). In 2020, the area sown to durum wheat in Italy decreased slightly compared to the previous year (-1.1%) to just over 1.2 million hectares (Fig. 1). There were slight variations in Puglia (-0.2% to 344,300 hectares) and Sicilia (+0.4% to 264,500 hectares), while they remained stable in Basilicata (115,160 hectares) and Marche (107,000 hectares). The weather and climate trend in autumn-winter 2019/2020 was characterised by normal temperatures and generally adequate and well distributed rainfall;

thus, field operations were not hampered. Rather, the effect of grain prices on farm choices should be considered. Crop development continued under optimal conditions in the following months, leading to an increase in yields per hectare from 3.1 tonnes per hectare (t/ha) in 2019 to 3.2 tonnes in 2020 (+2.1%). Durum wheat harvests increased by almost 1% year-on-year to around 3.9 million tonnes despite a slight decrease in area (Source: ISMEA from ISTAT data).

Chart 01: Durum wheat production variables



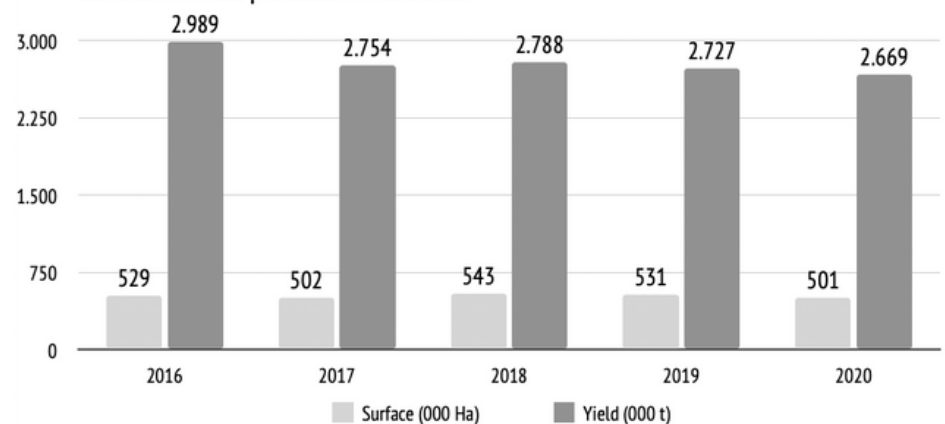
Source: Ismea elaborations on Istat data

Common Wheat

In 2020, the areas destined for soft wheat in Italy is just over 500 thousand hectares recording a more marked decline (-5.6%) than durum wheat (Fig. 2) and is mainly sown in the north of Italy. The contraction in area was observed in a rather widespread manner at a national level and, with particular reference to the most representative areas. . It is worth noting the decrease in Emilia-Romagna (- 1.5% to 141 thousand hectares), Veneto (- 6.7% to just over 85 thousand hectares), Piemonte (- 10.3% to 60 thousand hectares) and Lombardia (-5.3% to 52 thousand hectares). Also, for soft wheat, the weather and climate trend in autumn-winter 2019/2020 was substantially favourable and did not affect sowing operations. Even more so than for durum wheat, for soft wheat the effect of grain prices on farm choices should be considered; in fact, between September and October 2019, the period in which the decision on what to sow is made, prices were influenced by the sharp fall in the previous year.

During the subsequent phases of crop development, weather and climate conditions were satisfactory, allowing yields per hectare to recover in 2020 compared to the previous year (+3.7% to 5.3 t/ha in 2020), which partially offset the drop in areas. Crops were down 2.2% on 2019 to just under 2.7 million tonnes.

Chart 02: Common wheat production variables



Source: Ismea elaborations on Istat data

SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

Among the most important partnerships, Italy has been involved (through the participation of the Mipaaaf) in European initiatives and actions (JPIs - Joint Programme Initiatives, Eranet - European Research Area Networks) launched under European Programming for research and innovation (FP6, FP7). Among those connected with the crop production, in particular through the JPI FACCE (Agriculture, Food Security and Climate Change), in 2020 Italy has been involved in two knowledge hubs (see after). Within the ERANETS, through the ERANET co-fund Susfood 2 and Core-Organic, Italy have been part of a strong network born with the aim to support research/increase cooperation between national research activities respectively in the field of SUSTainable FOOD production and consumption and on organic food systems. In addition, Italy is also involved in the Operational Groups (OG) of the European Innovation Partnership for Agricultural productivity and Sustainability (EIP-AGRI), supported at regional level by Rural Development Programmes (RDP - European agriculture rural development fund - EARDF).

This includes projects on agricultural productivity and sustainability. The voluntary aggregation of producers and researchers, from which the spirit of GO projects stems, allows them to work in cooperation to introduce, apply and transfer innovations already available in the agricultural and agri-food sector. Among the most related to wheat and currently in progress we find: “ReVaViLoVGra - Recovery and valorisation of old local Venetian varieties of soft wheat”, “Strengthening the sustainable supply chain of wheat according to the rules of the Mill Charter”, “FRUDUR-0 Zero residue Martesana durum wheat chain” (www.innovarurale.it); “BIODURUM - Strengthening Italian organic durum wheat production systems” (<http://www.sinab.it>). Seventy seven Italian scientists in the Durum EWG, have been very active in programmes facing the climatic change impact on wheat production.

RESEARCH HIGHLIGHTS

In Italy, durum wheat cultivation is considerably larger than that of bread wheat, thus research investments are mainly focused on durum wheat. The 2019-2020 growing season has been characterised by a warm winter and almost no rain from January to April. These conditions had a negative impact on crop yield and quality. Through the WI Durum EWG, Italy played a major role in the assembly of a global platform for leveraging the genetic diversity of tetraploid wheat. University of Bologna and CREA research centre for Genomics and Bioinformatics, in collaboration with other members of the EWG on durum wheat, have assembled two major diversity panels: (i) Tetraploid wheat Global Collection (TGC), a tool for evolutionary studies and gene/QTL cloning that includes wild relatives and tetraploid subspecies (1,856 accessions in total, Maccaferri et al, 2019 <https://www.nature.com/articles/s41588-019-0381-3>) and (ii) Global Durum Panel (GDP, Mazzucotelli et al, 2020), a breeding dedicated tool suitable for GWAS, mainly focused on landraces and modern varieties (1,056 accessions in total). GDP has been developed as the reference panel for durum genetics. In general, the most important challenges on research could be addressed to improve the competitiveness of enterprises through research and innovation and to increase in

technological parameters (% protein, % gluten, gluten quality, yellow index, hectolitre weight, lower ash content). In particular, study on genome will play a key role in the development of sustainable agriculture and the whole bioeconomy.

WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMMES

Even if not specifically addressed to wheat, the mentioned JPIs and ERANET have allowed to fund research projects. If we consider the JPIs, the participation to FACCE JPI achieved in 2020 the starting of 2 knowledge hubs: MACSUR (Modelling Agriculture with Climate Change for Food Security) Science-Policy Knowledge Hub. This is a follow-up exercise intended to put into service the expertise acquired with MACSUR to help the member countries to design strategically their responses to the climate change adaptation and mitigation challenges, included the strategies to be implemented for crops as wheat and other cereals. This network is expected to start its work in the second half of 2021; the SYSTEMIC project, funded within the Knowledge hub among the three JPIs - FACCE JPI, JPI Oceans and JPI HDHL which aims to implement adaptive strategies for sustainable food production, consumption, and public health by addressing the diverse impact of climate change on nutrition quality and composition of food and defining standards to achieve food and nutrition security. Among crops, cereals and wheat are included. Within the PRIMA initiative involving Italian funders and researchers, some projects on wheat have been funded. In 2020, CEREALMED a new project dedicated to durum wheat and to enhancing diversity in Mediterranean cereal farming systems coordinated by University of Bari, has been funded.

Regarding the new future research programmes, Mipaaf is involved in the process for the establishment of networks within the partnerships of the new Horizon Europe, in particular within the Pillar 2 - Cluster 6 - Food, bioeconomy, natural resources, agriculture and environment, that aims to advance knowledge, build capacity as well as develop and demonstrate innovative solutions that will accelerate the transition to a sustainable and circular management and use of natural resources ensuring ecosystem integrity.

JAPAN (AFFRC-JIRCAS)



WHEAT PRODUCTION AND MAJOR PRODUCTION ISSUES

In Japan, annual wheat consumption is 5.8 million tonnes, of which 0.8 million tonnes are produced within Japan (13.8%). The main production areas are Hokkaido, Kyushu, and northern Kanto. 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 4.4 tonnes per hectare (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%). Wheat varieties suitable for each use are cultivated. Domestic wheat has a high brand value due to the movement toward food safety and security. Bread and noodles produced only from domestic wheat are sold as popular brand products. Recently, a macaroni wheat variety suitable for the Japanese environment has also been registered.

SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

Wheat breeding in Japan is carried out by the National Agriculture and Food Research Organisation (NARO) breeding programmes and the agricultural experimental stations of each prefecture. Therefore, cooperation with international organisations in other countries is not extensive. Wheat research in Japan has a long history. The discovery of wheat chromosome number, hexaploidy, evolution by interspecific hybridisation, 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 strains are very accurate because they are carefully maintained by bagging paper bags 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 and CIMMYT.

RESEARCH HIGHLIGHTS

The genome assembly of bread wheat is still a challenging research topic because of its large size and complex allohexaploid nature. A Japanese group consisting of several universities and research organisations have for the first time completed the chromosome-level genome assembly of a representative Japanese cultivar, Norin 61, in the framework of the 10+ Wheat Genomes Project (Shimizu et al. 2020, Plant and Cell Physiology, pcaa152, <https://doi.org/10.1093/pcp/pcaa152>). They made novel findings specific to Asian bread wheat through the comparison of Norin 61 genome sequence with other assemblies of the 10+ Wheat Genomes Project. The Norin 61 genome sequence will reveal the genetic variation in Asian wheat lines that has not been fully understood, and also will be an excellent resource to introduce useful traits into future breeding programmes that have not been utilised in breeding globally.

WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMMES

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

MOROCCO (INRA)



WHEAT PRODUCTION AND MAJOR PRODUCTIONS ISSUES

The 2019-2020 cropping season has recorded a very limited rainfall, which is 31% lower than the 30-year average (323.7 mm) and 19% lower than the previous season with a very long dry period (40 days) during the tillering phase. The impact of this low volume of rainfall was exacerbated by its poor and irregular spatial and temporal distribution. The cropping season was characterised by low rainfall at all stages of cereal development. The rainfall deficit affected all cereal-growing regions in the country to varying degrees. In Settat and Marrakech regions, this deficit was 50% on average. In Meknès regions and the Northern part of Morocco, the deficit varied between 30 and 45%, recording a rainfall level that was relatively favourable for cereal growth and development.

The total area of wheat cultivated in 2020 is 4.3 million hectares, of which 2 million hectares were completely lost in terms of cereal production in rainfed areas. In some areas, part of it was converted into animal fodder. The total cereal production was around 3.2 million tonnes that is 42% less than 2018-2019 and 57% less than the “Moroccan Green Plan” fixed target. The cereal production by commodity was as follows: 1.65 million tonnes of soft wheat, 0.75 million tonnes of durum wheat and 0.58 million tonnes of barley. It should be noted that in spite of this production decline, the cereal supply in the market remains guaranteed, with stocks covering the country’s supply for more than 4.5 months. This stock is constantly renewed through the various measures taken at this level in order to maintain a regularity in the availability of cereals on the national market.

SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

During the year 2020, The National Seed Marketing Company (SONACOS) has purchased six new released INRA varieties of cereals. The following table gives the name of these varieties.

Table 01: List of new purchased INRA cereal varieties in 2020

CROP	VARIETY NAME	YEAR OF RELEASE
Barley	Assiya: naked barley (6 rows)	2017
	Khната: covered barely (6 rows)	2016
Durum wheat	Itri	2016
	Hammadi	2017
Bread wheat	Snina	2017
	Malika	2016

RESEARCH HIGHLIGHTS

During this year, INRA has released a new bread wheat variety. The following table gives the variety main characteristics.

Table 02: Characteristics of INRA LIN 144

TRAITS	CHARACTERISTICS
Research Institution	INRA Morocco
Commercial Name	LINA
Variety Name or code	INRA LIN 144
Method of selection	pedigree
Pedigree	PRINIA / BAV92 // HUITES
Variety Distinctive characteristics	Resistant to fungal diseases (leaf and yellow rusts and septoria); Resistant to Hessian fly; Wide adaptation;
Genetic gain	40%

Image 02: Bread wheat variety Lina seed increase



The importance of wheat certified seed

The new Strategy "Generation Green 2020-2030" has given priority to wheat certified seed of the national varieties to enhance food security (at least 70% of national portfolio should be from national varieties). Therefore, seed multiplication of national varieties have been more emphasised within INRA programmes to meet the "Generation Green" strategy requirements. INRA has committed to provide sufficient breeder and foundation seed to public and private companies in the next years. By the year 2020 the provided percentage was around 70% of generation 1 and generation 2 and will reach 100% by the year 2030 (objective set by the new strategy).

On the other hand, INRA is committed to boost the adoption of wheat new released varieties through several actions. The main actions are: (i) the use of "Innovation Platforms" to further advertise the INRA new released varieties; (ii) the creation of security stocks of INRA varieties to prevent the loss of genetic material, particularly of old varieties; (iii) the designation of a mechanism for the multiplication and promotion of breeder and foundation seeds and (iv) the development of a business plan for a seed marketing unit at INRA.

Wheat certified seed in 2020

During 2020, the seed increase and the share of INRA varieties (public sector) is about 33%. We can notice that private companies are becoming very active in developing new varieties in the country and their share is increasing. Ten years before seed increase was dominated by the public varieties and the private sector did not exceed 10% share.

Wheat Midterm Research Programme 2017-2020

During this year, we have wrapped up the Midterm Research Programme 2017-2020. In this programme, we were able to develop three durum wheat varieties that are productive, resistant to Hessian fly and leaf rust, and with a good grain quality. Three bread wheat varieties that are productive, resistant to Hessian fly and leaf rust and to septoria and four varieties of barley (including two barley naked varieties).

For the first time, Morocco has been able to develop such barley varieties with high protein and beta glucan content and which could be used in human consumption. In addition, INRA has developed high-performance technology packages for conventional and direct seeding.

WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMMES

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

1. Morocco Collaborative Grants Programme 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 programme (PRMT2021-2024): the expected funding for the 4-year term is around 40 million MAD.

The main components of this research programme are:

1. Wheat Genetic improvement and biotechnology (smart breeding and new technologies);
2. Wheat crop management (Production, Protection);
3. Agro-industrial valorisation, 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 Organisations (FIAC, FNIS, AMMS, SONACOS, COMADER), National Universities (IAV Hassan II, ENA and others).

TURKEY



WHEAT PRODUCTION AND MAJOR PRODUCTION ISSUES

Bread wheat and durum wheat production in 2020 was 20.5million tonnes. Bread and durum wheat total production area: 6.92 million hectares. The mean yield of bread and durum wheat is 3.15 t/ha.

Major production issues decreasing yield and fluctuation of quality are due to various environmental conditions such as soil structure, drought and fluctuation of temperature. Bread wheat and durum wheat production were affected mainly by drought stress conditions in the Central Anatolia region. In the South-eastern Anatolia region, drought and heat stress are mainly abiotic stress factors. The presence of pests (Sunny pest) and diseases (leaf rusts and septoria leaf blotch and root diseases) affected crop establishment in some regions in the country.

SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

Breeding cooperation will continue between the National Research Institute, Universities and TÜBİTAK on breeding bread wheat and durum wheat for yield potential, biotechnology, agronomic applications, higher tolerance on biotic and abiotic stresses. At multi-locations throughout the country, field tests continue to measure higher yield, quality, disease resistance, and adaptability.

The annual evaluation meeting of the International Winter Wheat Improvement Programme (IWWIP) will be continued with the partnership of international research institutions CIMMYT and ICARDA with international participation. On behalf of our Ministry, IWWIP sends breeding material to 55-60 countries every year. All material was distributed in 2020.

RESEARCH HIGHLIGHTS

During 2020, forty-seven (47) new bread wheat varieties and four (4) durum wheat varieties, originating from official agricultural research institutes and different private sector seed companies, were registered in Turkey.

Some research highlights such as workshops and meetings have been affected by the COVID-19 pandemic.

Some research projects with TAGEM and TÜBİTAK-supported Turkey participation were completed in 2020, with expected results. A total of 8 TAGEM projects on breeding, physiology, quality and agronomy were completed in 2020.

WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMMES

The main funding institutions in Turkey are TAGEM and TÜBİTAK. Our aim is to further scientific knowledge, to promote economic growth, wealth and job creation and to improve the quality of life in Turkey.

To provide economic, social and environmental benefits to Turkey through concluding high-quality agricultural research that meets the country needs.

Wheat research and breeding are important topics in Turkey. In 2020, there were many ongoing projects concerning wheat research that was funded by the public. The projects focus on wheat breeding to face current challenges such as adaptation to climate change and quality, biotechnology and resistance to biotic and abiotic stresses. Furthermore, 7 TAGEM collaborative projects began in 2020 which focus on molecular, physiology, local durum wheat and agronomy.

UNITED KINGDOM (BBSRC)



WHEAT PRODUCTION AND MAJOR PRODUCTIONS ISSUES

Wheat production in the UK decreased by 40%, from 16.2 million tonnes in 2019 to 9.7 million tonnes in 2020. The UK yield of 7.0 tonnes per hectare is lower than the five-year average of 8.4 tonnes per hectare and 22.1% lower than 2019's (8.9 tonnes per hectare; [click here for source](#)). Between 2019 and 2020 the wheat agriculture area fell by 24% to 1.4 million hectares, the smallest area of wheat recorded since the 1970s. This decrease was mainly driven by the wet weather during the winter planting.

SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

In 2020, the BBSRC has awarded ~£127k for international collaborative research focused on wheat through its international schemes ([bbsrc.ukri.org](https://www.bbsrc.ukri.org))

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

BBSRC continues to lead and support the coordination of the International Wheat Yield Partnership (IWYP), in collaboration with major funding agencies in research intensive and developing countries and the private sector.

RESEARCH HIGHLIGHTS

MARPLE: the real-time cereal killer detective

Researchers at the John Innes Centre have created an advanced plant disease diagnosis system to help protect Ethiopia's wheat crops from wheat yellow rust fungus. The portable device, called MARPLE (Mobile and Real-time PLant disEase) diagnostics, detects which strain of the fungus pathogen is infecting a wheat crop in just two days, so users can make fast decisions to control the disease and protect harvests.

Increasing photosynthetic efficiency: From phenotype to genotype and back

Anthony Hall, at the Earlham Institute, with colleagues in the UK, Mexico, and Australia has combined cutting edge de novo genomics technologies with state-of-the-art precision phenotyping to discover the genes responsible for controlling these complex traits and define molecular markers genetically linked to these genes. Thanks to this IWYP-funded project, a recommended subset of molecular genetic markers and several lines containing them have been transferred to Wheat Improvement Pipelines to enable their validation in elite germplasm in high yielding environments.

WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMMES

In 2019-20, UKRI-BBSRC expenditure on wheat totalled £23M supporting 72 new projects spanning broad areas of wheat research including wheat immunity and

defence upon infectious diseases, harnessing genetic variation available in wild relatives for genetic improvement and understanding how photosynthesis can maximise productivity. At the time of writing this report, the 2020 reporting exercise has not yet closed as UK's financial years run from April to March and overall funding over the past year will need to be determined.

URUGUAY (INIA)



WHEAT PRODUCTION AND MAJOR PRODUCTIONS ISSUES.

Uruguay set in 2020 a new historic national yield record averaging 4.2 t/ha, breaking for the first time the 4 t/ha mark. This represents a 28% increase from last year 3.3 t/ha, and an impressive 14% jump from previous record, of 3.7 t/ha, set in 2018. With an estimated harvested area of 224 kha, 6% lower than previous season, the estimated production however increased by 20%, reaching 936 kt. Lower than normal precipitations during the entire crop cycle (May-December), except for June, in most parts of the wheat area, and average temperatures, characterised the growing season. In addition, almost optimal weather conditions during the grain filling period, in most areas where water availability was not critical, resulted in very high yields. On average, good levels of protein content (11.8%) and test weight (80.8 kg/hL) were achieved. New genetics and crop management, particularly Nitrogen use and applications, are key elements explaining these results.

Stripe rust is for the third consecutive year the most important constraint to wheat production in farmer fields.

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 Programme on Wheat, continues to deliver high quality data for regional and international, public and private research institutions and breeding companies. In total, 1,599 lines were phenotyped for *Septoria tritici blotch* (STB), 1,840 for leaf rust, and 1,683 lines for *Fusarium Head Blight* (FHB).

UNITED STATES OF AMERICA REPORT (USDA)



WHEAT PRODUCTION AND MAJOR PRODUCTIONS ISSUES.

Wheat planted area in the US decreased slightly in 2020 from 2019 to 44.4 million acres and production was estimated at 50 million tonnes. Higher prices have led to more wheat being planted in the 20/21 season.

SIGNIFICANT NEW NATIONAL/INTERNATIONAL ENGAGEMENT OR PARTNERSHIPS

USDA-ARS invests US\$50M/year on long-term wheat research. This includes US germplasm bank, four genotyping centres, disease and insect resistance laboratories, four wheat quality laboratories, the Graingenes database as well as agronomic phenotyping, physiology, agronomic practices, abiotic stress and disease research in the US and Africa for Ug99 stem rust.

The USDA-NIFA funded US\$9.7M Wheat Coordinated Agricultural Project (WheatCAP) led by the University of California-Davis. It includes 35 participants from 19 institutions in 15 US states and CIMMYT in Mexico, "Validation, Characterisation and Deployment of QTL For Grain Yield Components In Wheat", uses cutting edge genomic tools to rapidly identify, validate and deploy genes, currently from 21 genomic regions, into elite germplasm. These mainly "sink-based" genes are currently being combined in wheat lines with genes for "source-based" traits such as high biomass to explore boosting grain yield.

Furthermore, NSF supports the NSF I/UCRC Wheat Genetics Resource Centre at Kansas State University. Also, several universities and seed companies support wheat research with investments estimated at more than US\$50M. Additionally, public and private US Wheat breeding programmes work in close collaboration through wheat class-specific Uniform Regional Nurseries that result in new improved varieties every year.

RESEARCH HIGHLIGHTS

USDA-ARS scientists discovered a DNA marker for identifying sterile plants at the seedling stage that is breeder-friendly and efficient.

Also, in cooperation with University scientists, here are a few examples:

- A D-genome nested association mapping panel comprising multiple and diverse *Aegilops tauschii* developed;
- New breeder-friendly DNA markers for Hessian fly resistance genes h4, H7, H35, and H36;
- Cultivars identified with stable high resistance to low falling number identified. Susceptibility to late-maturity alpha-amylase is a likely cause of poor wheat end-product quality in U.S. wheat;
- Resistance to three wheat rusts identified in wheat wild relative *Amblyopyrum muticum*;
- Dual resistant transgenic wheat against synergistically interacting Wheat streak mosaic virus and *Triticum mosaic* virus identified;
- An accession of wild emmer wheat resistant to all strains of the tan spot pathogen identified;
- Q gene is a master regulator controlling numerous traits including plant architecture, cell wall thickness, photosynthesis, pollen fertility, and ultimately, seed production and yield.

During USDA-NIFA WheatCAP's fourth year of funding, several new genes for the sink traits were identified affecting grain size and grain number. The most promising sink genes are being combined into elite wheat varieties and a set of high biomass (source) wheat lines for subsequent yield testing. In addition, WheatCAP published 35 peer-reviewed papers and identified 9 candidate genes for grain yield components. WheatCAP breeders released 22 new improved commercial varieties in all wheat market classes, 4 improved germplasm, and 5 mapping populations. The complete lists of released varieties and publications are available through the WheatCAP web site (www.triticeaecap.org)

WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMMES

Although not specifically directed to wheat, there are several new funding opportunities through the Agricultural and Food Research Initiative that include:

- Partnership grants that include significant collaboration with specific minority serving institutions, small-mid size institutions, under-funded state institutions, and international partners;
- Coordinated Agricultural Project grants to address "Innovation in Genomic Technology to Accelerate Breeding Progress" to catalyse and coordinate research linking genome design, predictive breeding and capacity building to achieve advances that generate societal and environmental benefits;
- Cultivar development grants for "Later Stages of Cultivar Development" specifically aimed at testing and evaluation to help "finish off the cultivar" and get them out to farmers;
- New Investigator seed grants to help provide support for researchers who are beginning their careers and to attract and retain promising new scientists to agricultural research.

WHEAT - CRP

CGIAR is going through OneCGIAR change process. CGIAR Research Programmes, including WHEAT, will close down by December 2021, and are to be replaced by a portfolio of CGIAR Global and Regionally Integrated Initiatives. Breeding research to be bundled in an operational unit (Genetic Innovation Science Group), across Centres. This will also incorporate today's Excellence-in-Breeding Platform. CIMMYT, JIRCAS and others are advocating for a pre-breeding/novel genetic diversity for climate change adaptation and mitigation initiative.

March 2021: CGIAR System Council approved or endorsed all items that the CGIAR Executive Management Team proposed, e.g. high-level OneCGIAR operational structure, 3-yr Investment Plan timetable and updating key CGIAR system frameworks and reference documents. For more info visit: www.cgiar.org

OBSERVER COUNTRIES

ARGENTINA (CONICET)



WHEAT PRODUCTION AND MAJOR PRODUCTION ISSUES.

The wheat season 2020-21 in Argentina ended with a production estimate of 17 million tonnes, which was 13% lower than 2019-20. The sown area was 6.5 million hectares, and the harvested region was 7% lower, mainly due to losses in the northern area. Thus, the national average yield reached 2800 kilograms per hectare also lower than last year. Unlike the three previous seasons where diseases (mainly rusts) affected the development of wheat crop, in this last season, climatic conditions were the main limitation of production. Wheat yield in the north central region was affected by magnitude and combination of two main limiting factors, water and nutrient availability. On the other hand, in the southern area, the climatic conditions were more favourable and the achieved yields made it possible to compensate losses of the north central region.

RESEARCH HIGHLIGHTS

Cultivars

During 2020, 13 new bread wheat varieties from 6 different breeding companies, and 3 new durum wheat varieties from 2 breeding programmes were registered in Argentina. Selected Journal Articles:

- "Using anthesis date as a covariate to accurately assessing type II resistance to Fusarium head blight in field-grown bread wheat" (Franco, M. F. et al. 2020. DOI <https://doi.org/10.1016/j.cropro.2020.105504>)
- "Optimizing wheat (*Triticum aestivum* L.) management under dry environments: A case study in the West Pampas of Argentina (Gastaldi, A. et al. 2020. DOI: <https://doi.org/10.1016/j.agwat.2020.106092>)
- "An Interdisciplinary Approach to Study the Performance of Second-generation Genetically Modified Crops in Field Trials: A Case Study With Soybean and Wheat Carrying the Sunflower HaHB4 Transcription Factor" (González, F. G. et al. 2020. DOI: <https://doi.org/10.3389/fpls.2020.00178>)

- "The Global Durum Wheat Panel (GDP): An International Platform to Identify and Exchange Beneficial Alleles" (Mazzucotelli E. et al. 2020. DOI: <https://doi.org/10.3389/fpls.2020.569905>)
- "Waterlogging differentially affects yield and its components in wheat, barley, rapeseed and field pea depending on the timing of occurrence" (Ploschuk R. et al. 2020. DOI: <https://doi.org/10.1111/jac.12396>)
- "A comprehensive study of spike fruiting efficiency in wheat" (Pretini, N. et al. 2020. DOI: <https://doi.org/10.1002/csc2.20143>)
- "Identification and validation of QTL for spike fertile floret and fruiting efficiencies in hexaploid wheat (*Triticum aestivum* L.)" (Pretini, N. et al. 2020b. DOI: <https://doi.org/10.1007/s00122-020-03623-y>)
- "Localization of QTL for resistance to *Pyrenophora teres* f. *maculata*, a new wheat pathogen" (Uranga, J. P. et al. 2020. DOI: <https://doi.org/10.1007/s10681-020-02593-y>)
- "Fusarium head blight in Argentina: Pathogen aggressiveness, triazole tolerance and biocontrol-cultivar combined strategy to reduce disease and deoxynivalenol in wheat" (Yerkovich, N. et al. 2020. DOI: <https://doi.org/10.1016/j.cropro.2020.105300>)
- "Population structure and genetic diversity of *Fusarium graminearum* sensu stricto, the main wheat pathogen producing Fusarium head blight in Argentina" (Yerkovich, N. et al. 2020b. DOI: <https://doi.org/10.1007/s10658-019-01913-w>)

WHEAT RESEARCH FUNDING AND NEW RESEARCH PROGRAMMES

Funding:

In 2020, 7 wheat related research projects (PICT2019-2019-04064; PICT2019-2019-02440; PICT2019-2019-02852, PICT2019-2019-03302, PICT2019-2019-02576, PICT2019-2019-04333 and PICT2019-2019-03256) were financed through the Fund for Scientific and Technological Research (FONCYT) belonging to the National Agency for the Promotion of Research, Technological Development and Innovation.

PRIVATE MEMBERS

ARVALIS-INSTITUT DU VEGETAL



WHEAT PRODUCTION

For bread wheat, the French production was 29.1 Million tonnes for a cultivated area of 4.3 Million hectares (mean yield of 6.8 t/ha). The average grain protein content was 11.6 %. For durum wheat, the production was 1.3 Mt for a cultivated area of 250 kha (mean yield of 5.2 t/ha). The average grain protein content was 14.2%. Beside the quite low yield performance under the mean yield of the last three harvests (2017-2018-2019), the main aspect of the campaign is the high heterogeneity of the production across the country. The agronomic highlights of the campaign are 1) the drought event in shallow soils during spring, 2) a low disease pressure except for yellow dwarf virus attacks (barley more impacted than wheat) and a high photosynthetic activity of wheat located in deep soil without drought stress during spring.

ENGAGEMENT AND PARTNERSHIPS

The first fact to mention is the launch of the PGEN-BW project. Funded by the FSOV (French Fund to support plant breeding, see below), this project has been built inside the NUE EWG of the Wheat Initiative. It started in October 2020 for a 3 year period. Bringing together the effort of 9 international partners (INRAE, ROTHAMSTED Research, ADAS, IPSP-CNR, NIAB, CIMMYT, SYNGENTA, EMBRAPA, ARVALIS-lead), the objective is to determine the genetic components of the Phosphorus Use Efficiency in bread wheat to, at the end, help the breeding programmes to propose more tolerant cultivars against Phosphorus Deficiency in Western Europe and South/Central America.

ARVALIS, with 8 other international partners (University of Tokyo, NARO, INRAE, University of Saskatchewan, ETH Zürich, ROTHAMSTED Research, Univ. of Queensland and Agricultural Univ. of Nanjing), has been strongly involved in the Global wheat dataset challenge aiming to obtain the best deep-learning algorithms to count wheat head with phenotyping sensors (www.global-wheat.com).

RESEARCH HIGHLIGHTS

An original study on the joined use of molecular markers and a crop-model has been carried out to propose a new method to design bread wheat ideotype to avoid abiotic stress (Bogard et al. 2020. DOI: <https://doi.org/10.1093/jxb/eraa477>). The wheat head datasets used in the global wheat challenges has been described in David et al. (2020. DOI: <https://doi.org/10.1016/j.tpb.2019.11.007>). A collaboration with the Michigan State University led to the publication on a data-driven simulation platform to predict cultivars' performances under uncertain weather conditions (de los Campos et al. 2020 DOI: <https://doi.org/10.1038/s41467-020-18480-y>).

FUNDING AND RESEARCH PROGRAMMES

The French Fund to support plant breeding (FSOV) has granted 13 multi-partnership research projects (breeders, public research, non-profit research organisations) on cereals crops in three main areas: disease resistance, adaptation to abiotic stress and breeding/phenotyping methodologies. All the projects are due to start between October 2020 to January 2021 for a period of at least three years for each project. ARVALIS will lead 5 of them on wheat (bread and/or durum) focusing on Phosphorus Use Efficiency, adaptation to abiotic stress linked to climate changes and innovative phenotyping and envirotyping methodologies.

ASUR PLANT BREEDING



In 2020, ASUR Plant Breeding maintained its wheat breeding and seed production effort both with lines and hybrids while giving a new dynamic in its R&D projects in seed production.

RESEARCH HIGHLIGHTS

Either with its "Breeding for Europe" partners NORDSAAT GmbH (Germany) and ELSOMS WHEAT Ltd (United Kingdom), or within Public/Private workgroups, ASUR is engaged in several key wheat breeding research projects, some of which are supported by the French FSOV financing scheme.

Among the main subjects investigated in 2020 were: trait-associated markers for baking quality, BYDV and WDV resistance, weed/wheat competition, genomic selection for the hybrid wheat and the conventional (inbred line) wheat programmes.

ACHIEVEMENTS

In wheat lines, ASUR's winter wheat CHEVIGNON's popularity among European farmers reached new heights. It was the most grown wheat variety in France for the second year, with more than 10% market share, and thanks to additional development in Germany, Belgium, Denmark, Hungary and other half a dozen countries, it became the most multiplied wheat in the EU (harvest '21) with close to 10,000 ha.

In hybrid wheat, ASUR added 4 varieties to the French national list and another 2 in the Czech Republic, while its main shareholder and partner, NORDSAAT added 2 to the German national list.

SEED PRODUCTION RESEARCH

Two mature projects were spun off in 2020. The "SAFET'HY" vacuum-packing process aimed at preserving wheat and other crop seeds against insects and germination losses, which ASUR's technology department had developed, was put into TAMIA PACK, a 100% owned subsidiary specially dedicated to its commercial development. And the start-up POLLINOVA was set up as a J.V. between ASUR, Syngenta and INRAe, with the aim to develop pollen supplementation devices for hybrid seed production of wheat and other crops, based on a patent co-owned by the three partners.

Another R&D project aimed at improving the precision and readability of hybridity rate control in hybrid cereal seed production by substituting the pollen bags technique by a PCR analysis of DNA extracted from immature seeds sampled from production fields is about to be launched after validation by certification authorities.

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. 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 UK LIMITED



WHEAT PRODUCTION

- The wheat acreage in key European markets are back up to long term average after a significant drop during 2019/20 due to poor drilling conditions
- Despite increase in acreage, many farmers had unused seed from previous year, which will result in budgetary pressure
- Reports on crop establishment are encouraging

ENGAGEMENT AND PARTNERSHIPS

- KWS is exploring possibilities for involvement in Horizon Europe project proposals
- KWS continues to be part of academic project collaborations in especially Germany and UK. However, some academic partners are becoming less attractive due to unrealistic IP expectations
- FSVO projects in France remain key targets for KWS due to their industrial focus
- Partnerships and PhD-studentships on hybrid wheat research are continuously being initiated

RESEARCH HIGHLIGHTS

- The French variety KWS Extase is becoming widespread across northern Europe due to its broad adaptation and solid bread making quality
- Progress on hybrid wheat research and breeding is encouraging, and KWS is fully committed to developing successful commercial wheat hybrids in due course

RAGT



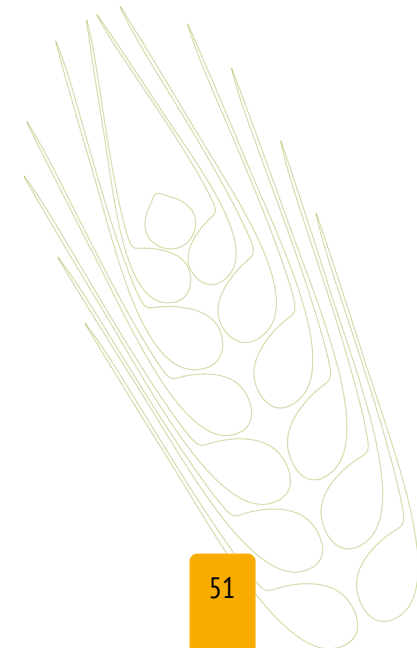
Founded in 1919 and established in all major European agricultural regions, RAGT researches, breeds, produces and sells seeds including wheat, corn, barley, oilseed crops, oats, pulses, forage grass and soil health crops. Innovation is vital to us, and we spend over 15% of our turnover in research, supporting 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 also participate in national research efforts such as Breedwheat in France, Designing Future Wheat in the UK and proWeizen in Germany. 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. Highlights for wheat breeding and research at RAGT in 2020 include: the release of RGT Wolverine, Europe's first wheat resistant to BYDV, winning a grant award from the UKRI Future Leader Fellowship programme to apply the latest genomic methods to wheat breeding, and the launch of the IWYP Winter Wheat hub to translate outputs from IWYP research to breeding. RAGT is also investing to develop Hybrid Wheat product as innovation for growers.

SYNGENTA



Syngenta Seeds retains a strong market position for wheat in Europe and North America. We have been increasing our market share across EAME with a strong position in the UK, where we also maintain a leading position in the feed segment. In North America, we remain a market leader in wheat with well-known varieties, such as SY Monument, widely grown from Oklahoma to Montana – the largest acreage of any wheat variety in the US. In parallel to our work on inbred varieties, Syngenta Seeds continues to pioneer the development of hybrid wheat. We have programmes developing high-performing products for the primary wheat markets in Europe – the UK, France and Germany – as well as the main US markets of Hard Red Winter, Hard Red Spring and Soft White Winter.

In France, we submitted two hybrids in 2019, which are now in the second year of official testing with a pipeline immediately following. We are also involved in many public-private partnerships across Europe, as well as the International Wheat Yield Partnership (IWYP), where Syngenta Seeds is a strategic partner and sponsor. These research collaborations address pre-competitive topics, which private companies cannot tackle efficiently on their own. For example, IWYP explores new avenues of increasing yield potential in wheat. Syngenta spends about \$1.5 billion annually on R&D across Seeds and Crop Protection, of which a portion of that is allocated to ongoing innovation in wheat breeding.



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.

Image 03: Associated Programmes of the Wheat Initiative



10+ WHEAT GENOMES PROJECT



In 2020, The 10+ Wheat Genomes Project completed a major milestone with the publication of a manuscript in the journal Nature that describes and releases 15 wheat genomes: Multiple wheat genomes reveal global variation in modern breeding. The manuscript details the comparative analysis of the ten chromosome pseudomolecule and five scaffold assemblies of hexaploid wheat and provides the most comprehensive atlas of wheat genome sequences reported to date. The 10+ Wheat Genomes Project represents the start of a larger effort to generate thousands of genome sequences of wheat, including wheat's wild relatives that are used in wheat improvement and breeding. Several companion papers were also published, including a detailed analysis of the Norin61 genome assembly, the 2NvS introgression from *Aegilops ventricosa*, and a comprehensive atlas of haplotype variation within the 15 assemblies.

With the assemblies now complete, the 10+ Wheat Genomes Project is now focusing its efforts to update gene annotations for each of the genomes. A comprehensive dataset of annotated genes is now complete and will be released to the community shortly.

The project represents an international collaboration comprised of researchers from Canada, Germany, UK, Australia, USA, Japan, Israel, Saudi Arabia and Switzerland, and industry partner Syngenta. For more information on partners and funders to the project, please visit the project website at www.10wheatgenomes.com.

The assemblies are available for direct user download at <https://wheat.ipk-gatersleben.de/> and are available for comparative analysis at Ensembl Plants (<https://plants.ensembl.org/index.html>). Comparative analysis viewers are also online for synteny (<https://kiranbandi.github.io/10wheatgenomes/>, <http://10wheatgenomes.plantinformatics.io/>) and haplotypes (<http://www.crop-haplotypes.com/>).

Seed of all the wheat lines from the 10+ Wheat Genomes Project are now available through the Germplasm Resources Unit in the UK, available as Collection 35 at www.seedstor.ac.uk/search-browseaccessions.php?idCollection=35 or through the 10+Wheat Genomes Website.

WHEAT PLANT AND CROP MODELLING

WHEAT PLANT AND CROP MODELLING

COLLABORATION AND PARTNERSHIPS

The activities of the Crop Modeling Programme in 2020 have focused on AgMIP-Wheat and aligned with the IWYP Project Modelling Traits for Increasing Wheat Grain Yield. The IWYP partners in this project include: Pierre Martre and Sybille Dueri (INRAE, France), Frank Ewert, Heidi Webber and Tommaso Stella (ZALF), Senthold Asseng (TUM, Germany), Jose Guarin and MD Ali Babar, University of Florida, USA, Matthew Reynolds, Gemma Molero (now KWS) and Diego Pequeno (CIMMYT), Mexico, Benjamin Dumont, ULG, Belgium Hamish E. Brown, Plant and Food Research, New Zealand, Jeremy Derory, Limagrain Europe, France, Roger Sylvester-Bradley and Daniel Kindred, Crop Performance, UK and Jean-Pierre Cohan, ARVALIS, France. In addition, we collaborated closely with Daniel Calderini, University of Valdivia, Chile and Daniel Mirrales, University of Buenos Aires, Argentina on field data exchange. About 50 crop modellers from across the world contributed with about 25 wheat crop models and simulations.

KEY RESEARCH ACTIVITIES

Detailed simulation protocols have been sent in 2020 to crop modelling teams with instructions to simulate field experiments in France, NZ and CIMMYT (includes Chile, Argentina and Mexico) by holding back many of the outcomes, eg yield data, as a "blind" simulation exercise. About 25 modelling groups have participated. The aim of the simulation exercise was to confront wheat crop models with observed, very high yield and growth data, compare their response to inter-annual variability, sowing date, density, seasons, and varying geographic conditions and crop characteristics, including measured high-yielding traits, to understand crop model performance under favourable but varying growing environments.

The task also included the simulation of crosses with specific high yielding traits. In addition, protocols were developed and distributed to the modelling teams to expand the simulations to 34 representative locations across the world for high-yielding wheat environments with daily climate data from the past and for future climate change scenarios to up-scale simulated impacts to the globe.

A smaller number of the modellers also simulated additional N supply treatments to explore the interactions of new traits and possible additional crop N demand.

OVERALL PROJECT OUTPUT

The initial analysis indicated that the global high yielding environments could improve yields with the new RUE traits by about 30-50 %, but crops will require more nutrient resources, in particularly more N fertiliser to sustain an additional growth. As these results are still analysed and quality-checked, we suggest that the above numbers should not be quoted yet.

IWYP - INTERNATIONAL WHEAT YIELD PARTNERSHIP

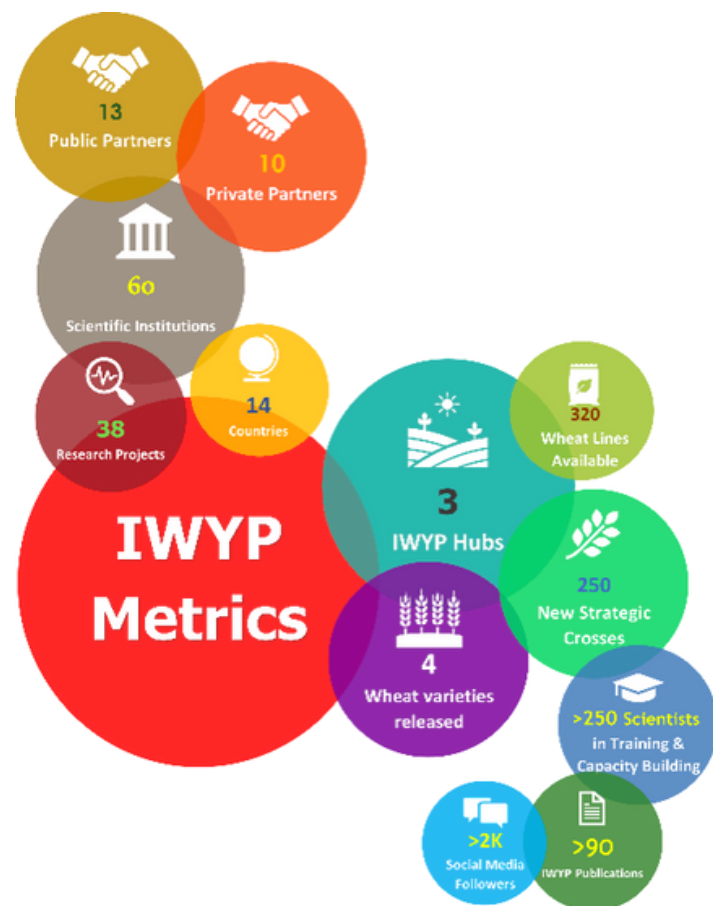


In 2020, the International Wheat Yield Partnership (IWYP) continued to make significant progress in its goal of boosting the genetic yield potential of wheat above the current rates of genetic gain. Selected highlights include:

- Welcomed InterGrain, a significant player in wheat breeding in Australia, as a new Private Partner to IWYP, bringing the number of leading wheat industry members of IWYP to 10. This advances the aims of IWYP by further strengthening the public-private partnership foundation of the initiative.
- Continued to ramp up trait stacking within the Stage Gated pre-breeding pipeline at the IWYP Hub at CIMMYT by making hundreds of new crosses targeting multiple new trait combinations using phenotypic and/or genomic knowledge to select the parents. Most crosses were aimed at combining increased biomass with high harvest index, introducing novel genetic variation for photosynthetic and yield component traits, and overall combining multiple different source and sink traits into elite backgrounds. The newest lines tested resulting from this strategy of combining selected source and sink traits has been shown to increase grain yields up to ~15% over Borlaug 100, the current elite check variety.

- Analysed the overall performance of new IWYP lines tested in 32 locations around the world for 2018/19 which revealed that most new IWYP lines tested had yields comparable to or greater than the CIMMYT and local check varieties with the best new lines significantly out-yielding all check varieties across many environments.

Image 04: IWYP Metrics



- Analysed the percent genetic yield gain achieved by new IWYP lines over many locations since 2015 when IWYP was initiated. This revealed an upward trend over time with an average genetic gain of ~1.3% over the last 4 years when compared to standard and elite check varieties. This value indicates that the strategy of combining selected new trait combinations is valid and results in higher average genetic gains than are being currently reported for varietal breeding programmes.
- Established two new “IWYP Hubs” for the development of winter wheat germplasm to complement the main IWYP Hub at CIMMYT that is focused on spring wheat types. The IWYP North American Winter Wheat Hub is being led by Kansas State University in the US and is supported by a grant from USDA NIFA and supplemented by the private sector. The IWYP European Winter Wheat Hub is being led by IWYP Private Members and aligned with the BBSRC funded Designing Future Wheat Institute Strategic Programme (ISP) and the National Institute of Agricultural Botany (NIAB) in the UK.

Image 05: Dr Muhammad Sohail at NARC with new IWYP Yield Potential Trait Experiment (IYPTE), Islamabad



- Initiated a dedicated international field trialling system for new IWYP lines called the “IWYP Yield Potential Trait Experiment” (IYPTE) network specially for IWYP. The IWYP Hub at CIMMYT contracts trials at specific locations, prescribes agronomic practices and has specific phenotypic data collected. 10-12 sites are targeted this year to assess the reliability of the system and quality of the data returned. The number of locations is expected to increase.
- Generated a new and comprehensive framework for approaching wheat improvement, resulting in a series of “Wiring Diagrams” defining the major steps and variables determining yield, as currently understood. This new decision tool to guide wheat breeding, to be published this year, describes in detail the relationships of the known and hypothesised developmental and physiological features that determine the “source and sink” traits underlying grain yield of wheat from emergence to harvest.
- Enhanced the IWYP communication programme to promote IWYP and the range of available research outputs delivered, including (i) an updated Asset Catalogue, (ii) a new series of monthly 1-page IWYP Science Briefs, (iii) a new Annual Report, and (iv) an updated scientific publication list showcasing the technical progress being made by the IWYP Science Programme.

For more information: www.iwyp.org or [@IWYP_wheat](https://twitter.com/IWYP_wheat).

INTERNATIONAL WHEAT GENOME SEQUENCING CONSORTIUM (IWGSC)



Founded in 2005, the 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) non-profit organisation registered in the United States.

Board of Directors in 2020

- 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)
- Etienne Paux (INRAE, France)
- Sébastien Prud (Limagrain, France)

Coordinating Committee: 52 members from academia and industry who develop the strategic objectives of the consortium and requirements for IWGSC projects.

Number of members: 3,200 in 71 countries, representing 884 institutions/companies

2020 ACTIVITIES AND PROGRESS

IWGSC RefSeq Assembly and Annotation

- The IWGSC teams continued updating and improving the reference sequence assembly and annotation by incorporating additional datasets, with new de novo annotation of transposable elements and mapping of key marker sets, as well as integration of manually curated genes submitted from the wheat community.
- Updated versions of the wheat genome reference sequence assembly (IWGSC RefSeq v2.1) and annotation (IWGSC RefSeq annotation v2.1) will be available to the community at the IWGSC data repository hosted by URGI-INRAE in 2021.

IWGSC-Arbor-Bioscience collaboration

- In June, Arbor Biosciences joined the IWGSC as a sponsoring partner.
- Arbor Biosciences and the IWGSC worked on the design of a promoter capture that is scheduled to be released in the spring of 2021.
- Plans to develop add-on modules for the exome panel, incorporating the updated and annotated IWGSC RefSeq v2.1 and genome-wide SNPs, are underway.



Wheat Diversity project

- In this project, the genomes of eight landraces, representing the full breadth of genetic diversity in bread wheat, will be sequenced at high quality. These core sequences, in conjunction with the IWGSC RefSeq, will serve as the foundation for a diversity panel and haplotype map to provide breeders with access to a much broader gene pool.
- The IWGSC team obtained quotes for sequencing and assembling of the eight landraces at high quality and has been seeking funding for the project, while putting together an analyses team.

Webinar series

- The IWGSC organised 10 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: www.wheatgenome.org.



4

WHEAT INITIATIVE SECRETARIAT INSIGHTS

WHEAT INITIATIVE SECRETARIAT INSIGHTS

NEW ORGANISATIONAL CHART

In 2020, an update of the WI Organisational Chart was made to reflect the importance of all stakeholders involved in the WI and the path for interaction between committees and the WI Secretariat. Below you can find the old organisational chart and the newly designed version.

Image 06: Old organisational chart version

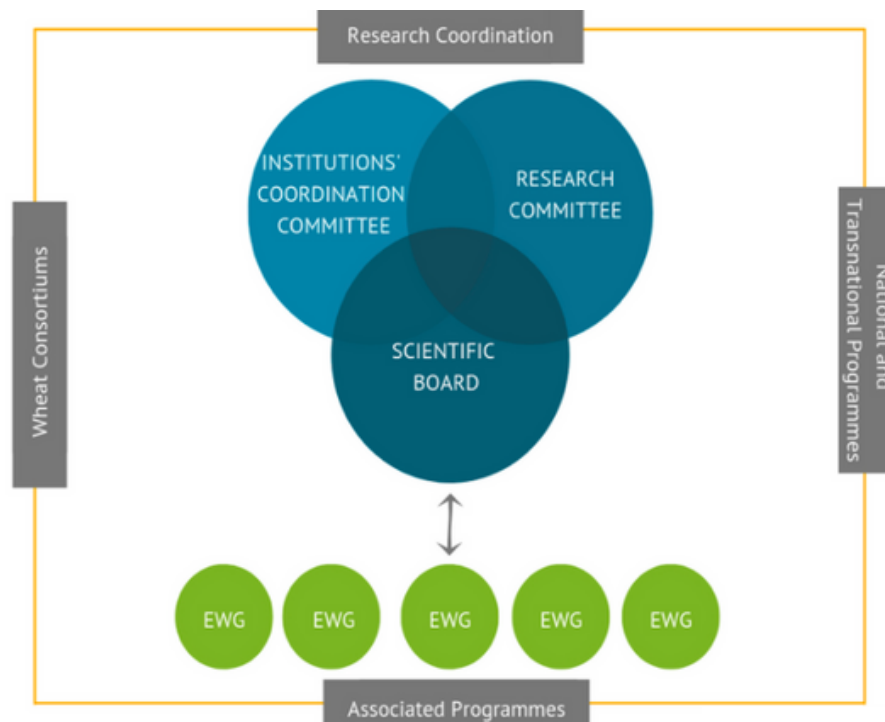
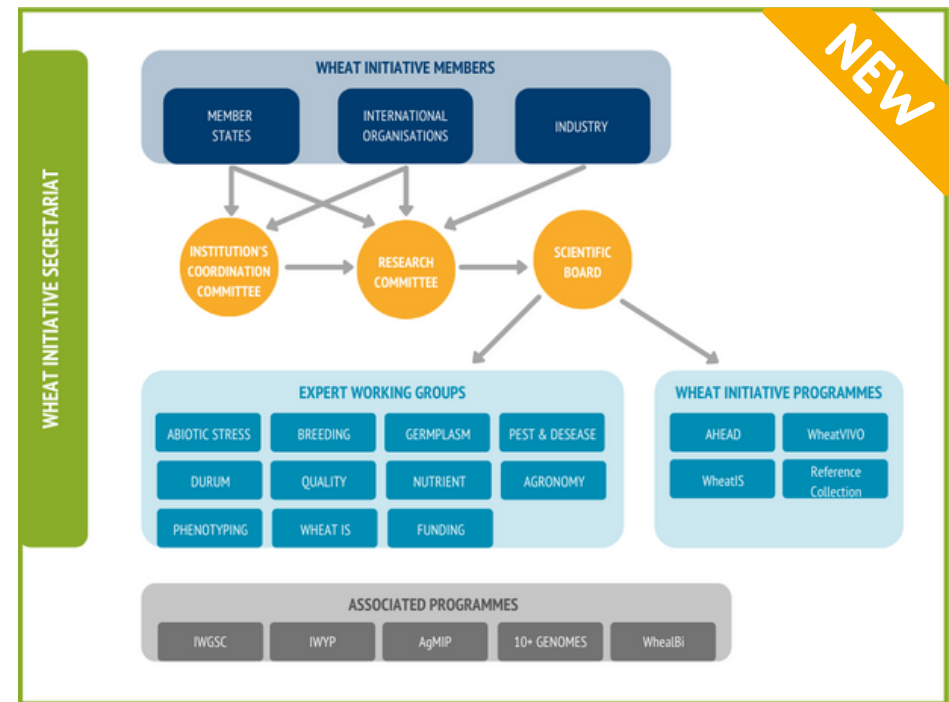


Image 07: New organisational chart



WHEAT INITIATIVE COMMUNICATION

The Wheat Initiative's communication in 2020 was focused on offering support and help with new challenges caused by the COVID-19 pandemic. Since face-to-face meetings were difficult, virtual meetings were organised and planned. The newsletter, media brief, website were produced and maintained as usual.

NEWSLETTER

The Wheat Initiative is proud to have continued the Wheat Initiative's newsletter despite the COVID-19 pandemic. In 2020, the newsletter continued to be sent out quarterly. The opening rate compared to 2019 had decreased, which might be caused by subscribers being occupied with the uncertainty of the pandemic. Nevertheless, the opening rate stayed well above average (according to MailChimp, a newsletter tool, the average newsletter opening rate lies at 21.33%). The Wheat Initiative's newsletter opening rate in 2020 was in January 41.2%, April 34.9%, July 37.9% and October 34.1%.

The newsletter gained 230 new subscribers in 2020, making a total of 753 subscribers by January 2021.

MEDIA DIGEST – WHEAT IN THE MEDIA

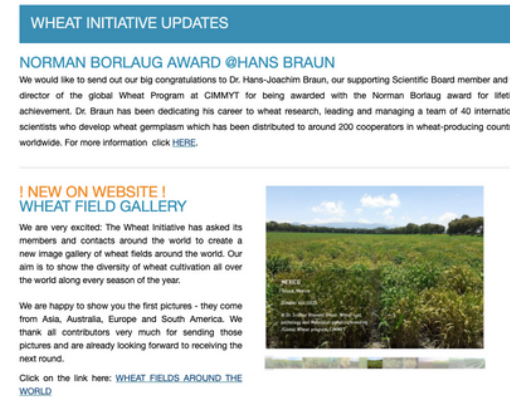
The weekly media digest was re-designed and re-launched in 2019. In 2020, the weekly media digest continued being sent out on Fridays by the Genome Canada Programme 4D: Diversity, Discovery, Design and Delivery. The tool has been used to support and advertise other initiatives as for example surveys for WheatVIVO, IPPN and EMPHASIS. Total number of followers in January 2021: 343

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, sharing publications of interests and of our members. The platform is also used to promote the Wheat Initiatives own events, newsletter, videos, projects and virtual workshops. In 2020 the Wheat Initiative Twitter account gained +390 new followers. In January 2021 there were 2,532 followers.

Image 08: Communications impressions

Newsletter



Media digest

Twitter



WEBSITE

At the beginning of 2020, the Wheat Initiative's website moved to Squarespace, an all-in-one content management system. The move allows the communications manager to manage the website herself without relying on external support. This way the website's content can be adjusted, replaced and published more easily, quickly and at less cost than previously.

The old website was hard to navigate, making it difficult for visitors to easily find information. For this reason, the content structure has been adjusted and changed. The new website will be launched in the first quarter of 2021 (www.wheatinitiative.org). The Website currently includes the following two major projects that started in 2020:

Wheat Field Gallery

The idea of a Wheat Field Gallery was born in 2020. The gallery is meant to show different wheat fields around the world and their development throughout the 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 will show the diversity and progress of wheat fields being sown, growing and harvested.

Image 09: Wheat Field Gallery



In October, the first pictures of wheat fields from Argentina, Australia, Brazil, Chile, Germany, Japan, Mexico, Paraguay, UK and Uruguay arrived and were immediately launched on the website. In December, all participants were asked to go to the same field and take a picture from the same position and angle. The pictures are being published on the website, making use of the newsletter as a cross communication tool advertising the gallery.

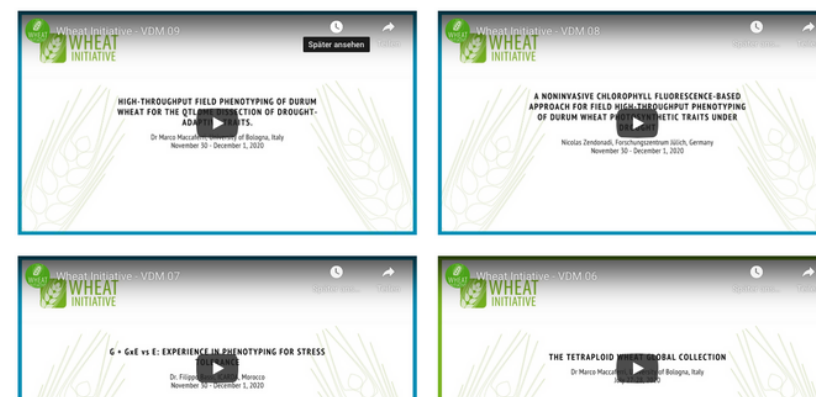
Virtual Durum Meetings

The second major website project came from an initiative launched by the Durum Expert Working Group in 2020. The Durum EWG organised the Virtual Durum Meetings (VDMs) where experts presented their work related to durum wheat. VDMs were held in July and November-December, 2020. Sessions were recorded and edited to single clips and, with the permission of speakers, the Virtual Durum Meeting Video Library was created. Videos of presentations were published on the website offering to the public interesting and valuable content for the wheat research area. Videos were promoted on the WI Twitter and Newsletter.

Image 10: Virtual Durum Meetings- Video Gallery

VIRTUAL DURUM MEETINGS (VDM) - VIDEO GALLERY

VDMs ARE VIDEO CONFERENCES WHERE 4-5 SHORT PRESENTATIONS ARE GIVEN IN ABOUT 2 HRS FOLLOWED BY TIME FOR DISCUSSION.
PLEASE FIND BELOW RECORDED PRESENTATIONS FROM OUR WORKSHOPS.

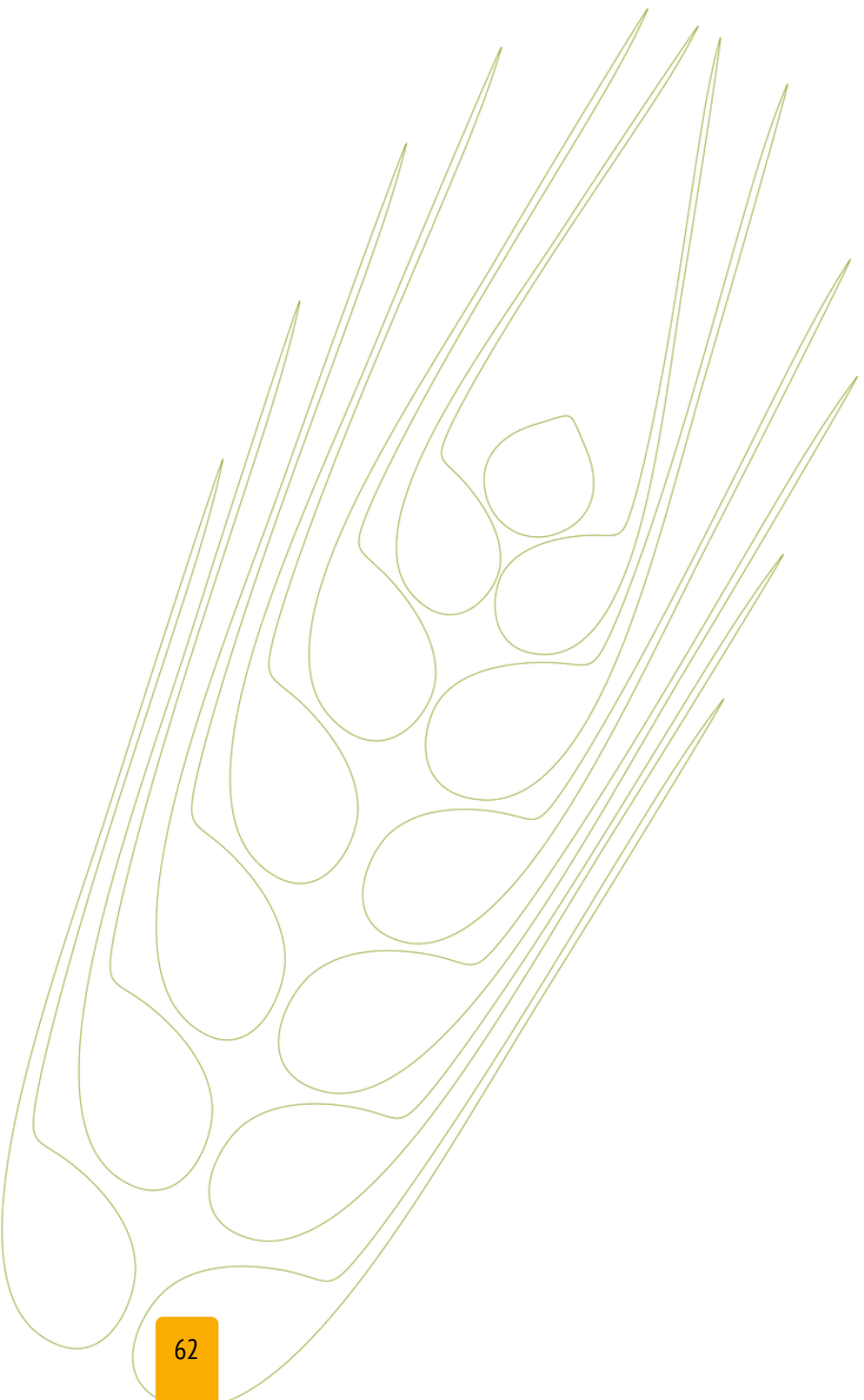


WheatVIVO

In 2020, actions were taken to move forward with the WheatVIVO database. WheatVIVO is an open-access web portal that will provide information on wheat researchers, organisations, publications and national and international projects. It was hosted on INRA servers in France and after discussions between the WI Secretariat and The University of Adelaide, it has been transferred to Amazon Web Services (AWS) through the support of the University of Adelaide. This will enable greater flexibility in the maintenance of the database.

WheatVIVO required further development to be fully functional. Ontocale (who originally developed WheatVIVO) have been engaged to assist in the transfer of WheatVIVO to enable data harvesting from Microsoft Academic, RCUK, ORCID, CORDIS, Florida, OpenAire, and Concepts. It is planned to have a soft launch in 2021 to make sure all is working well before it is promoted. Surveys were sent out in November 2020 to the WI Members and to the WI Newsletter and Media Brief subscribers asking for their participation in WheatVIVO. A plan for collecting metrics on WheatVIVO use has been prepared, and will be implemented with the first 3 months of full access to WheatVIVO used to set a baseline for evaluation.





FINANCIAL STATEMENT 2020

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 2020 Annual Financial Report which includes a summary of the financial activities from 1 January to 31 December 2020. When reflecting on the Expert Working Group expenditure, a more meaningful analysis is obtained by comparing expenditure against the relevant year's budget (this means that some expenditure that occurred in 2020 relates to the 2019 budget). See Expert Working Group expenditure section for this analysis.

Financial Key Points

- The Wheat Initiative Secretariat posted a budgetary surplus of 22,926 Euros (€) for 2020 compared to an estimated deficit of -315,436 Euros, due to substantial underspending of the budget in most areas.
- When including the 2019 carry forward of 753,217 Euros, the Wheat Initiative has a positive balance at the end of 2020 of 776,143 Euros.
- An original budget was finalised in February for 2020, however due to the COVID-19 pandemic and the subsequent travel restrictions, a revised budget was produced in June 2020.

**Table 03: Wheat Initiative Income and Expenditure Summary 2020
(Cash Basis-Euros) 1/1/2020-31/12/2020**

REVENUE	ORIGINAL BUDGET (FEB 2020)	REVISED BUDGET (JUNE 2020)	ACTUAL
Membership fees (includes outstanding fees) (1)	204,000	204,000	172,543
Exceptional contributions (2)	239,229	239,229	238,131
Total Revenue 2020	443,229	443,229	410,674
Expenditure			
Secretariat			
Personnel (3)	338,490	315,596	301,717
Travel Reimbursements (WI Staff)	30,000	15,000	9,459
Communication	17,000	17,000	138
Consumables	1,000	1,000	1,625
Equipment	1,500	1,500	468
AHEAD- Support (4)	30,000	30,000	21,702
AHEAD – Consumables (5)	25,000	10,000	1,407
Staff Training	5,000	3,000	986
Contingency	20,000	10,000	-
Expert Working Groups Expenses			
Expenses for 2019 Meetings, paid in 2020 (6)			42,536
Expenses for 2020 Meetings (7)	188,675	47,525	1,357
Meetings & Workshops (8)	82,000	10,000	6,353
Education & Training	20,000	-	-
Total Expenditure 2020	758,665	460,621	387,748
Balance 2020	-315,436	-17,392	22,926

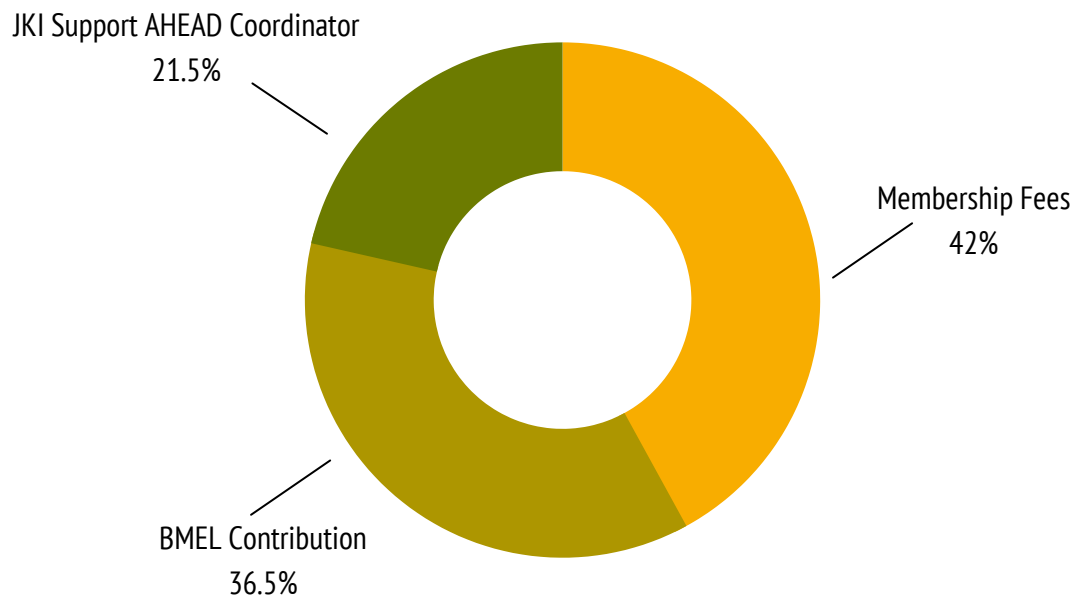
1. Includes 199,000€ for 2020 membership fees plus an outstanding fee of 5,000€.
2. Exceptional contributions include BMEL contribution to Wheat Initiative salaries of 150,000 and JKI Support for the AHEAD Coordinator salary.
3. Personnel expenditure includes:
 - 1.0 Programme Manager (salary for November and December 2019 was delayed and paid in 2020), 1.0 Foreign Language Secretary (Sept-Dec), 1.0 Communications Manager (Jan-Oct), then .5 Communications Manager (Oct-Dec), .5 Chair, Scientific Board, 1.0 AHEAD Coordinator
4. The expenditure for AHEAD support relates to the agreement reached to assist in the development of the HeDWIC programme in collaboration with Wheat-CRP.
5. The AHEAD consumables expenditure includes meeting and training costs for the AHEAD Coordinator.
6. Expenses relating to 2019 EWG Meetings and 2019 EWG budget.
7. Expenses relating to 2020 EWG activities (WheatIS EWG only) and 2020 EWG budget.
8. Expenses for the SB meeting held in February, in Morocco

Revenue

Revenue for the Wheat Initiative in 2020 is comprised of Membership Fees (42%), including Morocco's first fee as WI newest member, BMEL contribution (36.5%) and JKI Support (21.5%). The BMEL contribution up to 150,000 is used to cover Secretariat Personnel salaries. Revenue in 2020 was 410,674 Euros which was a 9.8% increase from 2019. This was mainly due to the JKI support for the AHEAD Coordinator salary being for all of 2020, compared to only 3 months in 2019, an increase of 68,075 Euros.

The difference from the budget to the actual income for membership fees was due to the unpaid fees from 2 members (one being paid in January 2021). The membership fees received decreased from 2019 by 29,455 Euros (-14.6%) due to the withdrawal of a member, late payment (2021) of one member and non-payment of one member.

Chart 03: Breakdown of Wheat Initiative Revenue in 2020 (410,674 Euros)

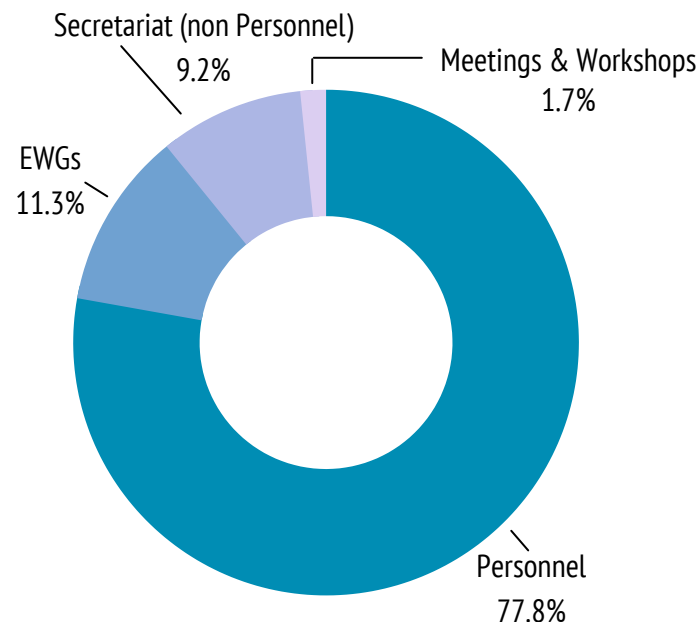


Expenditure

The total expenditure for the Wheat Initiative for 2020 amounted to 387,748 Euros. This was an increase of 92,476 Euros (31%) from 2019. The majority of expenditure was for Personnel, making up 77.8% of all expenditure. Personnel expenditure increased 121,084 Euros (62%) from 2019 due to the AHEAD Coordinator position being appointed for all of 2020 (in 2019, it was for 3 months), the Programme Manager salaries including November and December 2019 (delay in processing) and the Foreign Language Secretary salaries (for 4 months) being full time in 2020 compared to being part-time in 2019. Note that the AHEAD coordinator salary is funded directly by the Julius Kühn Institute while the Wheat Initiative covers the AHEAD operating costs.

The Wheat Initiative expenditure (non-personnel) increased 16,837 Euros (88.86%), this was mainly due to the 21,702 Euros spent on AHEAD support. Due to the COVID-19 pandemic, Meeting and Education/Training expenditure in 2020 were less than in 2019, a decrease of 5,948 Euros (48%) for Meetings and 6,297 Euros (100%) for Education/Training.

Chart 04: Breakdown of Wheat Initiative Expenses in 2020 (387,748 Euros)



Expert Working Group Expenditure*

Expenses for 2020

For expenses against the 2020 Budget, expenditure by the Expert Working Groups was 1,357 Euros. Only 3% of the revised budget for EWG expenditure was spent on 2020 activities. Expenditure decreased by 68,978 Euros (98%) from 2019. This massive decrease was due to the COVID-19 pandemic and travel restrictions meaning face-to-face meetings after the first few months of the year, were unable to occur. The only expenditure against the 2020 budget was for the WheatIS EWG, for meetings held in January and the Data Management Workshop held in February.

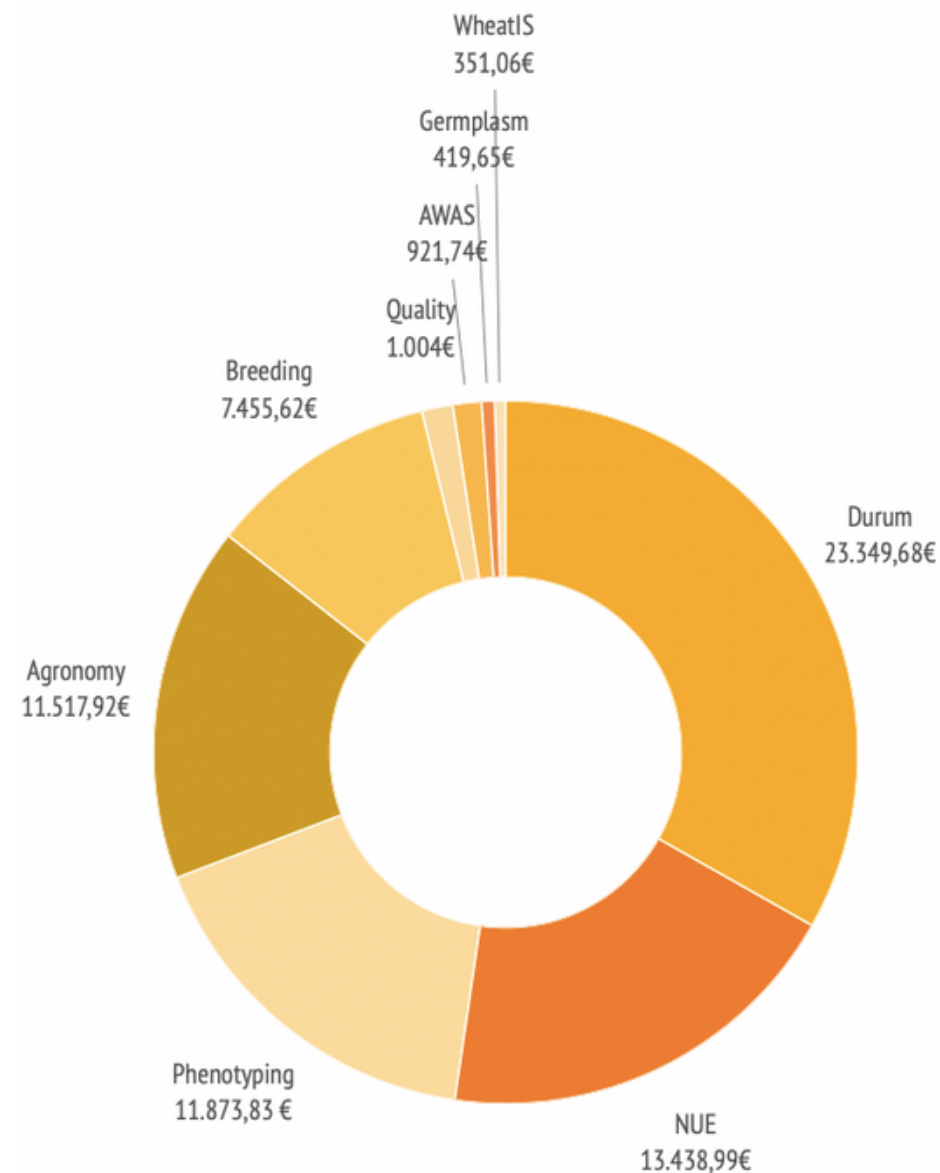
Expenses for 2019

Further to the EWG expenditure reported in the [2019 Annual Report](#) (Figure 09, Expert Working Group Expenditure on page 49), expenditure against the 2019 EWG Budget has now been finalised. The final total expenditure for the 2019 budget was 70,332 Euros, an increase of 26% to what was reported in the 2019 Annual Report. Therefore, 38% of the total EWG budget was expended, compared to 42% in 2018. The Durum EWG has the largest expenditure of all the EWGs, with 33% of the total expenditure, spending 94% of its budget. The three EWGs with the next highest expenditure are NUE with 19% of the total budget, expending 61% of their budget, Phenotyping with 17% of the total budget, expending 51% of their budget and Agronomy with 16% of the budget and expending 48% of their budget. In most cases, the expenditure of EWGs relates to the costs for arranging for meetings/workshops/training. For the Agronomy EWG, 32% of its expenditure was for publishing the Frontiers Special Issue.

When expenditure of the EWGs is compared between 2018 and 2019 (against the relevant year's budget), NUE, Phenotyping, Agronomy, AWAS and Breeding all had increased expenditure in 2019.

*Note in this section, Expenses for 2020 refers to the expenditure against the EWG's 2020 budget and Expenses for 2019 refers to expenditure against the EWG's 2019 budget. Some expenditure against the 2019 budget occurred in 2020 but is reflected in the 2019 expenses to allow for a more meaningful analysis (i.e. expenditure against relevant budget).

Chart 05: 2019 Expert Working Group Expenditure (70,332 Euros)





5

APPENDIX



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 Center for Agricultural Research in the Dry Areas
ICC	Institutions' Coordination Committee

ABBREVIATIONS

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



REFERENCES

Abrouk, M., Athiyannan, N., Müller, T. et al. Population genomics and haplotype analysis in spelt and bread wheat identifies a gene regulating glume color. *Commun Biol* 4, 375 (2021). DOI: <https://doi.org/10.1038/s42003-021-01908-6>

Asseng S, Martre P, Ewert F, Dreccer MF, Beres BL, Reynolds M, Braun HJ, Langridge P, Le Gouis J, Salse J, Baenziger PS (2019a) Model-Driven Multidisciplinary Global Research to Meet Future Needs: The Case for "Improving Radiation Use Efficiency to Increase Yield". *Crop Science* 59: 843-849. DOI: <https://doi.org/10.2135/cropsci2018.09.0562>

Asseng S, Martre P, Maiorano A, Rotter RP, O'Leary GJ, Fitzgerald GJ, Girousse C, Motzo R, Giunta F, Babar MA, Reynolds MP, Kheir AMS, Thorburn PJ, Waha K, Ruane AC, Aggarwal PK, Ahmed M, Balkovic J, Basso B, Biernath C, Bindi M, Cammarano D, Challinor AJ, De Sanctis G, Dumont B, Rezaei EE, Fereres E, Ferrise R, Garcia-Vila M, Gayler S, Gao YJ, Horan H, Hoogenboom G, Izaurralde RC, Jabloun M, Jones CD, Kassie BT, Kersebaum KC, Klein C, Koehler AK, Liu B, Minoli S, San Martin MM, Muller C, Kumar SN, Nendel C, Olesen JE, Palosuo T, Porter JR, Priesack E, Ripoche D, Semenov MA, Stockle C, Stratonovitch P, Streck T, Supit I, Tao FL, Van der Velde M, Wallach D, Wang EL, Webber H, Wolf J, Xiao LJ, Zhang Z, Zhao ZG, Zhu Y, Ewert F (2019b) Climate change impact and adaptation for wheat protein. *Global Change Biology* 25: 155-173. DOI: <https://doi.org/10.1111/gcb.14481>

BBSRC 24 April 2019 : <https://bbsrc.ukri.org/news/food-security/2019/190424-pr-targeting-how-fungi-taste-wheat-could-be-key-to-developing-control/>

Brinton, J., Ramirez-Gonzalez, R.H., Simmonds, J. et al. A haplotype-led approach to increase the precision of wheat breeding. *Commun Biol* 3, 712 (2020). DOI: <https://doi.org/10.1038/s42003-020-01413-2>

DEFRA-National Statistics, 10 October 2019: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/868943/structure-jun2019prov-UK-28feb20.pdf

Gao, L., Koo, DH., Juliana, P. et al. The *Aegilops ventricosa* 2NvS segment in bread wheat: cytology, genomics and breeding. *Theor Appl Genet* 134, 529–542 (2021). DOI: <https://doi.org/10.1007/s00122-020-03712-y>

IWYP Science Brief, Number 1, April 2020: <https://iwyp.org/wp-content/uploads/sites/34/2020/04/IWYP48-Science-Brief-FINAL.pdf>

Liu B, Martre P, Ewert F, Porter JR, Challinor AJ, Mueller C, Ruane AC, Waha K, Thorburn PJ, Aggarwal PK, Ahmed M, Balkovic J, Basso B, Biernath C, Bindi M, Cammarano D, De Sanctis G, Dumont B, Espadafor M, Rezaei EE, Ferrise R, Garcia-Vila M, Gayler S, Gao YJ, Horan H, Hoogenboom G, Izaurralde RC, Jones CD, Kassie BT, Kersebaum KC, Klein C, Koehler AK, Maiorano A, Minoli S, San Martin MM, Kumar SN, Nendel C, O'Leary GJ, Palosuo T, Priesack E, Ripoche D, Rotter RP, Semenov MA, Stockle C, Streck T, Supit I, Tao F, Van der Velde M, Wallach D, Wang EL, Webber H, Wolf J, Xiao LJ, Zhang Z, Zhao ZG, Zhu Y, Asseng S (2019) Global wheat production with 1.5 and 2.0 degrees C above pre-industrial warming. *Global Change Biology* 25: 1428-1444. doi: 10.1111/gcb.14542.

Luo, M., Xie, L., Chakraborty, S. et al. A five-transgene cassette confers broad-spectrum resistance to a fungal rust pathogen in wheat. *Nat Biotechnol* 39, 561–566 (2021). DOI: <https://doi.org/10.1038/s41587-020-00770-x>

Savary S, Willocquet L, Pethybridge SJ, Esker P, McRoberts N, Nelson A. 2019. The global burden of pathogens and pests on major food crops. *Nat Ecol Evol.* 3(3):430-439. DOI: <https://doi.org/10.1038/s41559-018-0793-y>. Epub 2019 Feb 4. PMID: 30718852

Shimizu, K.K., Copetti, D., Okada, M. et al. De Novo Genome Assembly of the Japanese Wheat Cultivar Norin 61 Highlights Functional Variation in Flowering Time and Fusarium-Resistant Genes in East Asian Genotypes. *Plant and Cell Physiology* 62, 8–27 (2021). DOI <https://doi.org/10.1093/pcp/pcaa152>

Walkowiak, S., Gao, L., Monat, C. et al. Multiple wheat genomes reveal global variation in modern breeding. *Nature* 588, 277–283 (2020). DOI <https://doi.org/10.1038/s41586-020-2961-x>

Zetzsche, H., Friedt, W., Ordon, F. 2020. Breeding progress for pathogen resistance is a second major driver for yield increase in German winter wheat at contrasting N levels. *Sci Rep* 10, 20374. DOI <https://doi.org/10.1038/s41598-020-77200-0>.





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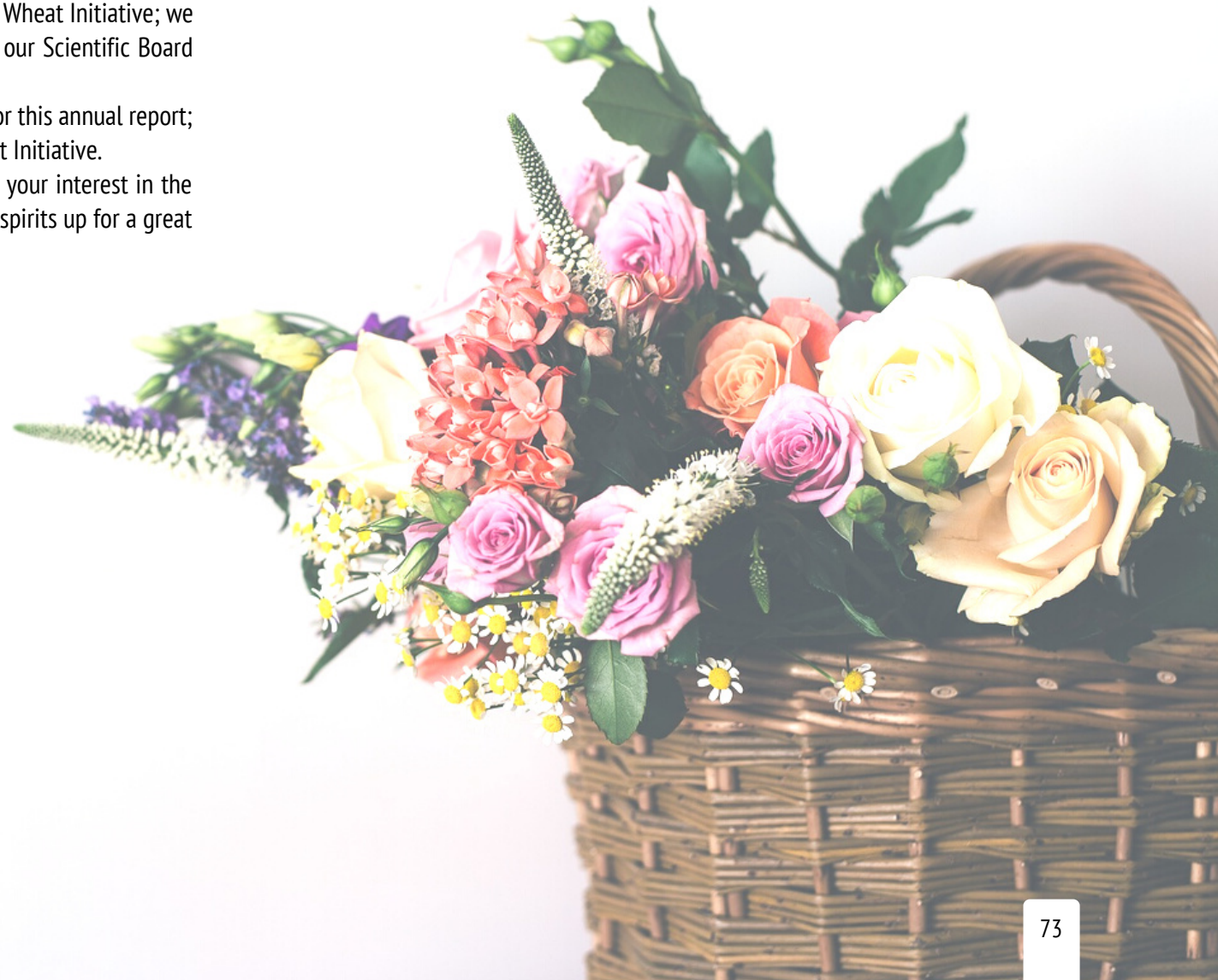
THANK YOU

It has been a different, challenging year for everyone. Therefore, the note of thanks comes with even more gratitude than usual. We would like to thank the Expert Working Group Chairs, Co-Chairs and all Expert Working Group members for their dedication to wheat research and for working hard during the challenges that arose in 2020.

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We thank Lisa Incoll as well for her support and contributions for this annual report; and we would like to welcome Morocco once again to the Wheat Initiative.

And finally, but not least, many thanks to you, our readers, for your interest in the Wheat Initiative and in our Annual Report 2020. Let's keep the spirits up for a great 2021.





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