Oat Rust Forum 2015 - Roadmap

Executive Summary

Oat rusts (crown and stem) are a major threat to resilient supply of quality oat. Historical research initiatives have built foundational knowledge for management of these diseases but the complexity of the biology of these pathogens and their interaction with oat genetics have made it challenging to deliver a sustained solution. With newly developed genomic tools and computational capability, it is time to revisit this effort and to coordinate a community-wide initiative for the development of short- and long-term genetic and agronomic solutions to managing resistance to rusts in oat. A large team of diverse scientists convened in February 2015 under the auspices of the Stakman-Borlaug Center for Sustainable Plant Health and identified a comprehensive set of activities necessary to this extent. Oat Global is now taking this strategy forward and attempting to create and resource a formal Oat Rust Initiative to drive such activities. A call for strategic and financial support is extended to all those who benefit from or are dedicated to support the oat value chain from seed to its final use.

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Background

Oat stem and crown rust are the most widespread and damaging diseases in oat cultivation. Furthermore, the rapidly evolving nature of these pathogens poses a significant threat to oat cultivation in current and new environments where the diseases could spread aggressively as a consequence of the significant weather pattern changes in the last decade. Production areas where rusts are not a problem today are at high risk to experience rust infections in the future while rainfall patterns and relative humidity levels change.

Extensive research efforts have been undertaken by public and private groups over time to try and address various aspects of these diseases. These efforts resulted in the development of knowledge and experience regarding genetics of oat rust resistance, effective agronomic practices for disease management, and understanding of epidemiology through the use of sentinel plots, breeding nurseries, and production fields. However, despite all the efforts made these two diseases remain unpredictable and race specialization moves faster than deployment of resistance genes or adoption of novel fungicides and agronomic practices. Furthermore, the general reduction in research funding dedicated to oat research worldwide and a wave of loss of expertise due to retirements in the last five years in the U.S. and Canada are cause of concern to the oat industry and research community at large.

In February 2015 the Stakman-Borlaug Center for Sustainable Plant Health at the University of Minnesota invited a group of approximately thirty scientists (breeders, geneticists, and pathologists), growers, and millers to discuss the current status of research in this area and define a forward strategy for a coordinated community-wide effort towards purposeful management of stem and crown rust resistance in oat. The initial scope of the discussion was North America (U.S. and Canada), but international linkages were part of the discussion as well and will be actively explored further. This document summarizes the outcome of the two-day strategy forum and defines a strategic roadmap and a tactical plan for this developing research initiative.

Business Framework

ORF 2015 participants rapidly agreed that there are enough open questions around this topic of research to warrant forming a community-wide initiative with a dedicated, empowered, and funded governance structure (Board of Directors and Administrative Support) responsible for steering future research efforts, seeking funding, administering resources, and facilitating communication. It was agreed that the Stakman-Borlaug Center for Sustainable Plant Health shall help coordinate activities leading to the formation of this initiative's infrastructure. The resulting infrastructure may or may not reside within the center, depending on the most effective options for funding and management.

As overall guiding principle, all participants confirmed that stem and crown rust research in oat is to be considered a pre-competitive activity. As a consequence, commonly known best practices in open sharing of data and platforms, publication of results, and academic and commercial application free of intellectual property encumbrances shall be applied. Furthermore, the International Oat Code of Ethics provides an agreed and community-wide reference for germplasm and genetics exchanges. Examples of output for which use shall not be restricted include (but are not limited to) sequence data, molecular markers, genes and QTLs, resistant accessions and pre-breeding lines, agronomic and physiological data, knowledge of plant and pathogen biology and their interaction, etc.

Strategic Roadmap

The following paragraphs describe target areas for action that were defined during the meeting. This is not meant to be a verbatim report of the discussion but rather a strategic roadmap for the advocated community-wide "Oat Rust Management Initiative".

Although differences in epidemiology, pathogen biology, and host resistance between oat stem and crown rust were discussed, it was concluded that those differences do not warrant the development of separate roadmaps but rather the tailoring of tactical plans.

Ultimately, work-groups of specialists will need to be created in order to translate this roadmap into a set of actionable research and deployment plans fit for funding and activation.

Data & Knowledge Management

There is in oat in general a recognized need to standardize crop ontology to enable sharing of knowledge and, even more, datasets across groups. This holds true in the case of oat rust research as well, especially around gene nomenclature and classification of pathogen biotypes. The gene nomenclature could be standardized via recurrent revision of the published gene list for the crop, although inclusion in the general crop ontology should help drive alignment more routinely. The classification of biotypes is a major opportunity to capitalize on the already excellent exchanges across the community and to crystallize guidelines for future use.

Data should be curated and made available publicly in conjunction with publications or as stand-alone datasets with proper descriptors that allow their use by other researchers. The ORF 2015 team strongly recommended that a uniform and shared IT infrastructure be adopted for this purpose. It seems natural that this should be within the framework of www.oatglobal.org. This will need to be established at the very beginning of any research initiative.

Publications of major achievements will most likely occur traditionally in peer-reviewed journals. For less formal but yet informative publications the Oat Newsletter provides an ideal environment for knowledge and experience sharing.

Pathogen Biology & Epidemiology

Significant work has been done so far by at least the American, Canadian, Brazilian, and Australian communities in collecting rust isolates and characterizing pathotypes. These efforts must be firmly integrated so to have one publicly documented and shared catalogue of isolates that relies on multiple collection and storage sites, redundancy (back-up), and common practices. A reference ontology for naming isolates should be developed and most likely be included in an oat chapter of www.cropontology.org and on the Oat Newsletter.

The global collection of isolates will be used for sequencing a panel representative of the pathogen biodiversity. This sequence information will be used to develop molecular markers for future management of the collection itself and for proactive monitoring of the evolution of pathotypes, the latter becoming a key tool for coordinated regulatory sciences (policies, mitigation efforts, etc.) in addition to more general biological research applications.

The global collection will also be a very useful tool for genetic studies and for the identification of sources of vertical vs. horizontal plant resistance. To date mainly race-specific vs. adult-plant resistance models have been explored in oat, predominately based on plant genetics rather than a systematic study of plant/pathogen interaction. It is strongly recommended that foundational knowledge be developed on the genetics and epidemiology of plant/pathogen interactions in both organisms as a system rather than in the host only. Within this area of research, there is a recognized need to understand pathogen population genetics and dynamics, and to expand the study of alternate hosts beyond buckthorn. Knowledge in these two areas could potentially yield disease management strategies radically different from traditional host genetic resistance (e.g., eradication of alternate hosts, disruption of pathogen allelic frequencies for virulence loci, etc.).

Genomics & Genetics of Plant Resistance

Reference genomes for both oat and the rust pathogens are deemed a foundational resource to enable biopathway discovery and gene identification. A reference genome for oat is a more general need in the community and Oat Global is actively pursuing the initiation of a project in this area. To build references for the pathogen, multiple pathotypes may need to be sequenced and the isolate collections present in Minnesota, Canada, and Australia provide a good starting point.

Genome annotation and curation become another key missing platform to allow the utilization of the reference genomes in biopathway dissection, thus taking the genomic application in the crop well beyond QTL mapping.

A community-wide program for the development, maintenance, sharing, and mining of mapping populations is also necessary. It is suggested that a centralized resource (further described in the pre-breeding chapter) is necessary to maintain a rational and resource-optimized program rather than individual projects in the hands of already overcommitted variety breeding teams.

The design of populations and the direction of gene discovery efforts should be coordinated within the community by leveraging cross-functional expertise and a technical leadership group should be created.

The creation of mapping populations will determine the speed of discovery and pre-breeding programs. Any platform, whether DH or accelerated SSD or other, that can accelerate the speed to inbreeding would be instrumental in increasing the amount of genetic diversity that can be explored, mapped, validated, and deployed over time. Efforts in these areas of breeding techniques have been very limited in oat and should be emphasized more, especially as a foundational capability that carries beyond the scope of this specific initiative.

Molecular-assisted selection will be instrumental both for the introgression of novel alleles in the active breeding pools (pre-breeding) and for rapid deployment via variety breeding. In this area, it was discussed that the generation of data points should also be accompanied by capability for their interpretation and translation in breeding-enabling information. This will require an increase in resources and scope of responsibility of the reference genotyping laboratories in the community.

Phenotyping

Current phenotyping efforts are limited to either the coordinated Buckthorn Nursery in Minnesota (crown rust only) or individual disease nursery sites and opportunistic evaluations of naturally infested variety/line trials. For a concerted discovery effort as described in this document, a more systematic and programmatic approach is deemed critical. A coordinated network of phenotyping sites in strategic locations and open to all researchers would provide the ability to assess, in larger scale and with uniform protocols and rating systems, both the effect of new genetic solutions and the concurrent evolution of the pathogen. The group agreed that there is a need for a network-based governance to be in place in order to effectively manage coordinated phenotyping efforts.

Specifically for stem rust, the Canadian research community has lost resources and infrastructure historically dedicated to seedling screening in greenhouse at the Winnipeg AAFC location. Some facilities are coming back online at the new site in Brandon but it is not certain whether this capability will be sufficient for an invigorated stream of research activities for this pathogen. This platform will likely need to be supported with additional resources for increased capacity.

Pre-Breeding & Germplasm Circulation

As described in the chapter on genetic resources, it is not yet clear whether new genetics for resistance will be discovered in more or less adapted germplasm or even whether in *Avena sativa*. Executing crosses with donor lines that carry lots of genes that can potentially reduce the commercial value of progenies would make breeding for a full portfolio of traits difficult and likely slower than otherwise possible within elite by elite crosses.

The breeding representatives at ORF 2015 felt quite determinedly that a "pre-breeding" effort is necessary for gene introgression. It was discussed extensively how to organize pre-breeding efforts so not to detract the already limited resources dedicated to variety breeding in oat. It was advised that additional resources dedicated for this endeavor, with a headcount similar to what used to be present at USDA-ARS in Minnesota with Dr. Howard Rines. Breeders are willing to help build and manage populations through their crossing and inbreeding nurseries but cannot dedicate the time required at the peak of the selection season for evaluation and selection. Furthermore, it is thought that a centralized expertise applied to pre-breeding would allow for a much faster identification of new genetics and the dissemination to other breeders.

The oat public breeding community has been leveraging for several decades the "Quaker International Oat Nursery" system for exchanging germplasm worldwide. This system has also had an historical focus on rust resistance and could potentially be utilized in a more directed way as an avenue to global distribution of resistant germplasm. This approach will have to be highly connected with the community-wide and targeted deployment of alleles in a "managed" way to prevent the rapid breakdown of resistance.

Agronomy and Chemistry

During the scoping meeting in February 2015, it was largely recognized that addressing management of rust in oat purely from a genetics stand-point is a narrow approach and that parallel investigations in chemical control and agronomic practices should be initiated. It is also likely that the interaction between a genetic and an agronomic solution will have effects currently unforeseen and will shape the direction of research in both fields and opportunity for faster implementation of innovative solutions. In future evolutions of this initiative the appropriate scientists and industry involved in this aspect of disease control should be involved.

Community-Wide Resistance Management

No matter what the solution to rust resistance will be, an uncoordinated and more spontaneous approach to the adoption and deployment of specific genetics or agronomic techniques for resistance at very large scale poses the risk of undue pressure on the pathogen population and the rapid breakdown of resistance or voidance of value of the agronomic techniques applied. Although it was not determined

in detail how a more coordinated approach could be structured, establishing technical leadership in the community was determined to be necessary, and a coordinated approach to the deployment of control approaches based on the newly generated knowledge from studying the epidemiology of the pathogen described herein should be one of the outcomes of this initiative.

Education and Extension

It is recognized that many possible solutions to manage resistance to rusts depends on an active engagement of the grower community. Therefore it is advisable that extension activities are considered as part of a comprehensive community strategy.

The deployment of novel genetics and associated technologies for rust resistance will require distribution of information throughout the research community. Educational activities will be necessary to ensure that breeders and other scientists implementing innovation are enabled to acquire skills and knowledge that may be required.

A community-wide initiative such as this provides ample opportunities for engagement of students and post-doctoral associates in the execution of the research plan. It is highly recommended that this be managed proactively with the purpose of building long-term expertise in oat genetics and breeding and a pipeline of specialists for succession management and for knowledge retention within the community.

Bio-Economics

The current and potential impact of these diseases on the whole oat value chain has not yet been widely assessed. As a consequence it is hard to engage stakeholders and funding sources with the appropriate sense of urgency and relevance. Although the engagement of funding sources in oat is a more general issue, it is likely the factor that could enable or prevent this initiative. The development of a solid business case that demonstrates the impact of these diseases beyond individual players along the value chain, and its value to society in general, are necessary.

Next Steps

The Stakman-Borlaug Center has offered to continue coordinating discussions and interactions up until a formal initiative structure is created. The Oat Global Strategy Committee will engage with the center and various resource owners and key enablers to determine the most effective way to fund a “core” platform for the design, activation, and governance of the public initiative advocated in this document. Current avenues being explored include seeking funding from the USDA-ARS, from the AFRI program, from private funders, or a mix of public and private resources. For engagement in this effort, interested parties should contact the Stakman-Borlaug Center (UMNSBC@umn.edu) or the Oat Global Chairman (Gabe.Gusmini@PepsiCo.com).

Once an administrative infrastructure is created and funded, the community at large will be called upon to volunteer in working groups dedicated to the further development of a research strategy for all of the areas above (after proper prioritization).

Meanwhile, the community is encouraged to pursue any possible opportunity of attracting funding to research in oat rusts without waiting necessarily for the broader initiative to be launched. Publicity and transparency of secured funding and initiation of projects will allow these activities to be connected informally and brought under the overall umbrella of this Oat Rusts Initiative when appropriate.