Managing Global Crop Disease Data

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ABSTRACT

In the frame of Borlaug Global Rust Initiative (BGRI), a web-based data management system - the Wheat Rust Toolbox - was developed to support surveillance, monitoring and early warning of new aggressive wheat rusts on a global scale. On-line data entry permits quality controlled and standardized data to be entered into the system. Once validated and approved, data are published and automatically disseminated via a series of interactive graphical and mapping web tools. The wheat rust single tools are embedded and integrated with other information in the Global Rust Reference Centre (GRRC) hosted by Aarhus University and in RustTracker – a global wheat rust monitoring system hosted by CIMMYT. The targeted countries for RustTracker are Central and West Asia and Africa. The backbone of the system is a Host-pathogen Microsoft SQL Database and Web system, combining host and pathogen data in a flexible way. After login to the toolbox a user management system controls the access rights to user-group specified tools and features. To stimulate partners to supply new data, dedicated login protected tools that analyse and summarise the raw data on country level, are available for data owners. The importance and distribution of new aggressive wheat rust in a global context are available for the wheat growing community in interactive maps, graphs and tables. The target for information is the farming community, breeders as well as scientist working on wheat rust and other crop disease. To reach the target user groups, dedicated tools and results are embedded in external web pages i.e. the RustTracker (http://rusttracker.cimmyt.org/) and the web site for the Global Rust Reference Centre (http://www.wheatrust.org). The wheat rust toolbox integrates and analyses more and more data from new tools related to phenotyping and genotyping of the pathogen and for the characterisation of host resistance. The challenge is to understand the interaction between the host and the pathogen, and to be able to monitor and predict the evolution and spread of new aggressive races. In Europe farmers can apply agrochemicals when new aggressive pathogens attack the crops. In the developing countries the majority of farmers must heavily rely on resistant cultivars.

Keywords: Wheat rust, data management, web tools, decision support, global

1. INTRODUCTION

The appearance and spread of stem rust *Puccinia graminis* f. sp. *Tritici*, race Ug99 from East Africa (Pretorius et al. 2000) was the catalyst to put in place a global monitoring system for wheat rusts in the frame of the Borlaug Global Rust Initiative (BGRI). A large proportion of commercial wheat cultivars were susceptible to this new race and food security in many countries in Africa, Central and West Asia were threatened. The

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signal was clear, - that tracking rust pathogen races and monitoring disease status on a global basis was a high priority (Hodson 2012, Park 2011).
A Global Wheat Rust Monitoring System, created under the Durable Rust resistance in Wheat (DRRW) project - initiated in 2005 - is now in place and still expanding globally. It represents a unique and increasingly comprehensive resource of rust information. A suite of tools are now available giving access to information on stripe rust, leaf rust and stem rust attacking wheat: Where is the disease, how much and what type of rust (e.g. aggressiveness and pathotyping, SSR analysis and DNA sequencing), which cultivars can it attack etc. Standardized protocols for data collection have permitted the development of a comprehensive data management system, named the Wheat Rust Toolbox. Data access is facilitated via dedicated web portals supporting the global wheat growing community. This paper describes the Wheat Rust Toolbox, how data are stored, managed and disseminated to target user audiences.

2. SYSTEM DESCRIPTION

The backbone of the system is a Host-Pathogen Microsoft SQL Database and a Web system, combining host and pathogen data in a flexible way. Web tools are programmed using .NET technology. Mapping tools use KML and Google maps and graphics are produced with ChartDirector, a server based Graphics Software package. Data are exchanged and exported using the XML standard. To reach the target user groups, dedicated tools and results are embedded in external web pages i.e. RustTracker and the Global Rust Reference Centre (Figure 1)

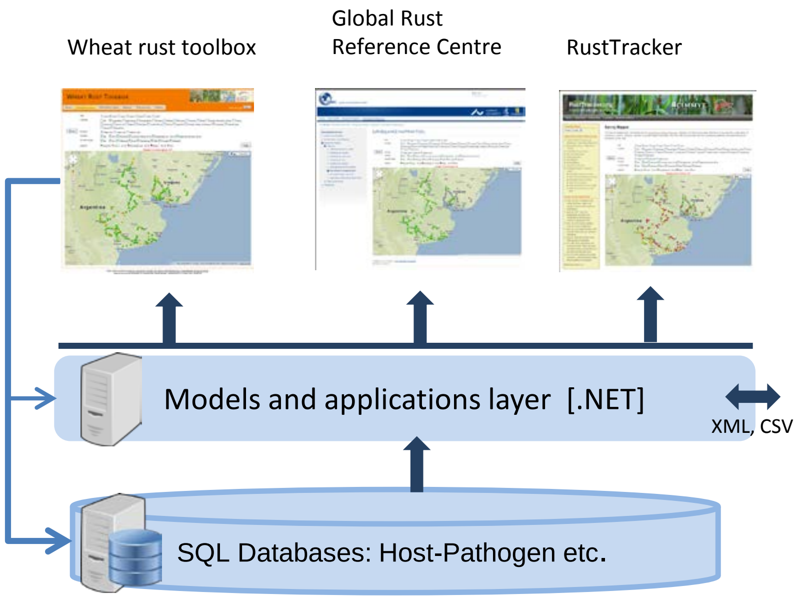


Figure 1. The Wheat Rust Toolbox controls the database, the models and application layer using .NET technology. Tools are embedded in external web pages. The example shows the same Survey Mapper with data for three different wheat rusts in Argentine.

2.1 Database structure

Two major core types of data are currently implemented and populated within the Wheat Rust Toolbox – rust survey data and data about the pathogen isolates sampled.

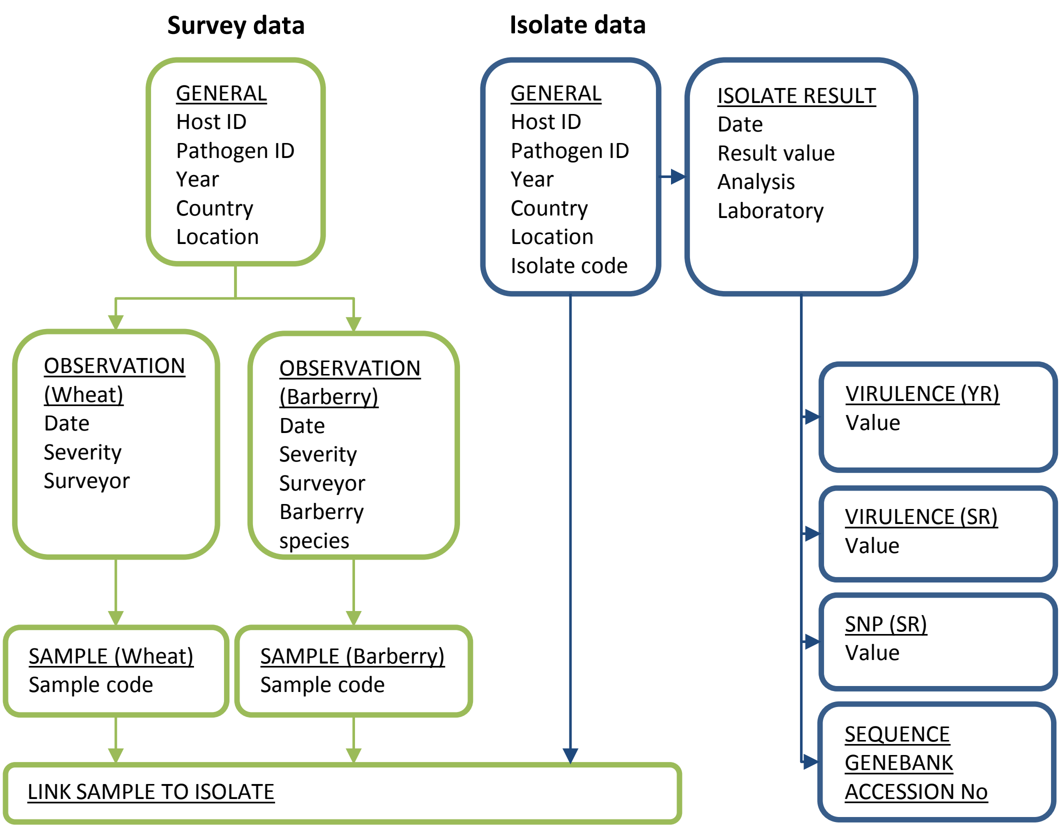


Figure 2. Host-pathogen database tables.

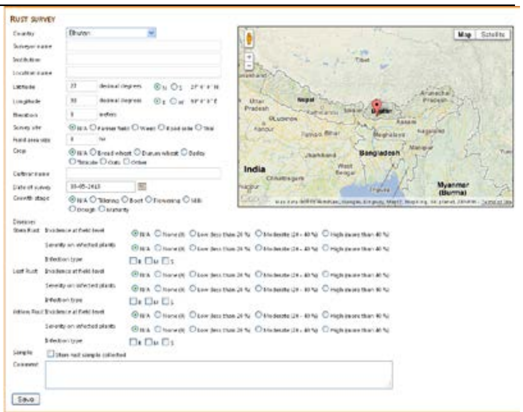
The rust survey database currently holds more than 12.500 geo-referenced, standardized, field survey data on all three rusts and covering 34 countries, 2007 to 2013. Both the survey General table and the isolate General table include the key variables Host ID, Pathogen ID, Year, country and location. The link between the survey data and the isolate data is sample ID table. This enables survey data collection without sampling of isolates, analysis and storage of isolate data not associated with a specific survey and surveys including sampling of isolates for further analysis. When isolates have been sampled they might be analysed with several different methods in different labs in the network. The database is built to "Track and trace" isolates sampled, and the different analysing methods applied to it by different labs (Figure 2).
Expansion beyond the current core databases is currently in development with planned inclusion of a Barberry Database (the alternate host for *Pgt* and *Pst*), Trap Nursery Database and a Molecular Diagnostics Database. Barberry plants (*Berberis* spp.) act as

alternate host for several wheat rust species and to find out what type of rust attack Barberry in Central and West Asia, samples of rust are analysed using DNA sequence analysis that is compared with existing known sequences stored in gene banks.

2.2 Tools

After login different user groups have access to different tools and features. The GCRMS manager can create new users, quality control and publicise data, Figure 3 (1 and 3). Surveyors can enter data via a dedicated data entry web form, Figure 3 (2), they can edit own data uploaded before publishing and they can analyse own data via the "My rust" tools and features (not shown). After data have been uploaded and made public, several tools are updated "on the fly" i.e. the Survey data overview table Figure 3 (4) the Survey mapper, Figure 3 (5) and the Google map showing the relative importance of the three rust types by year, Figure 3 (6).
The upload of data via the web based report form secure the quality of data because the user can only select predefined options, enter dates via a calendar button etc. The step of quality control by the GCRMS management group is yet another control before release of data. Upload of data via smartphones and tablets is now under development. Slow or no Internet connection is still a barrier in many developing countries, but this is expected to improve considerably in Africa and Asia.
Figure 3 (5) is an example of the interactive Survey mapper. Selected is the year 2012, countries in the Himalayan region, yellow (stripe) rust, all crop growth stages and all disease levels. The colours indicate the level of disease: red is high, orange is medium, yellow is low disease severity and green is no disease The map shows that Stripe rust was widespread in the mountain regions but not at lower altitudes in the region selected. This corresponds well with the fact that *Puccinia striiformis* causing Stripe rust is not well adapted to very high temperatures. The relative importance of the three rusts is given in Figure 3 (6). Data are from 2012. The three bar colours indicate Stem (black) rust, Leaf (brown) rust and Stripe (yellow) rust. The height of the bars indicates the frequency of fields in the survey recorded with rust (>0) from zero to 100 % that specific year. This information shows that Stem rust is a problem mainly in East Africa and Yemen whereas leaf and yellow rust is relative more important in central and West Asia.
Similar tools are available for isolate information showing frequencies of isolate pathotypes (what resistance genes the isolate can overcome) and their distribution in the region. Several molecular tools are now available for the fast and reliable identification of genotypes. This facilitates the comparison of populations and how they evolve and spread in the region. The ultimate goal is to produce an information system that facilitates the forecasting of wheat rust epidemics, to prepare appropriate management strategies. Secondly to introduce resistant cultivars in areas with high disease risk and finally to identify and understand the evolution of new aggressive strains of pathogens helping the breeders proactively to develop new resistant cultivars dedicated to specific countries and environments.

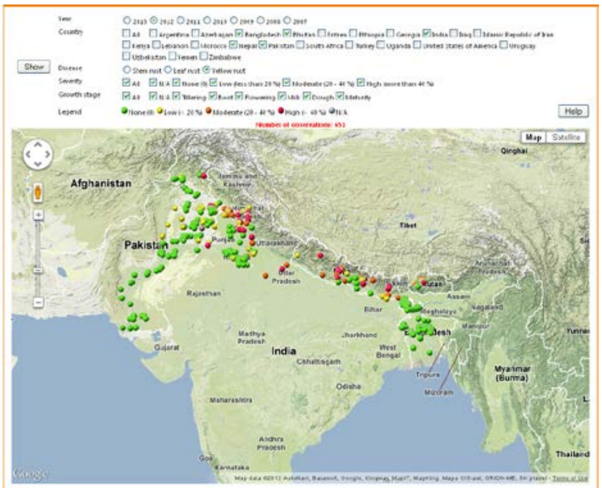
1 - User Management



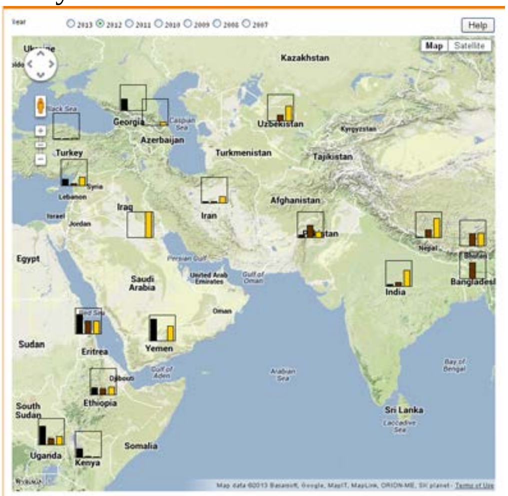
2 - Data entry web form

3 - Survey data management and quality control

4 - Survey data Overview by country and year



5 - Survey mapper



6 - Relative importance of the three rusts

Figure 3. Web tools for User management, data upload, quality control and display of disease surveillance data.

3. USER MANAGEMENT AND FEATURES

The Wheat Rust Toolbox includes a comprehensive User Management system that permits controlled access to specific tools and functionality. Registered users have country-specific access to an on-line data entry system and a suite of country-specific data visualization options for their own data. The current system permits secure on-line survey data entry, storage in a structured database, data editing, data visualization and data export (via XML/Excel) of country-specific data. Data visualization options include: a tabular data summary, an interactive graphical display of all rust data by year, a raw data analysis tool, and an interactive map of the country survey data. These options combined with the advantage of having the data analysed in a global or regional context will be a major motivation for using the system in the future. Only when country data has been checked and approved for publication by the data owner does it enter into the public domain, global data dissemination tools.

4. DISSEMINATION – INTEGRATED INFORMATION RESOURCES

The principal portal for dissemination for the rust surveillance and monitoring data is RustTracker.org (http://rusttracker.cimmyt.org). This site was developed by CIMMYT and partners as a component of the Durable Rust Resistance in Wheat (DRRW) project and is an integral part of the Borlaug Global Rust Initiative (BGRI). The aim of RustTracker.org is to provide a comprehensive set of information about global rust surveillance and monitoring. The site is directly integrated with the Wheat Rust Toolbox and includes implementations of all the data dissemination tools generated by the data management platform. Other key features of RustTracker include a comprehensive set of situation updates regarding current rust status and an extensive set of country-specific pages and tools covering approximately 40 countries. Stem rust, and the “Ug99 race group" in particular, has been an initial focus of RustTracker.org, but information and content is being expanded to include both stripe rust and leaf rust. Ultimately, RustTracker.org aims to be the most comprehensive source of information for all rust surveillance and monitoring related content.

The Wheat Rust Toolbox is now an integrated part of the Global Rust Reference Centre (GRRC), hosted by Aarhus University. The GRRC website, www.wheatrust.org, holds information about all activities at the centre, but also data on yellow rust in Europe and beyond, and managed by the Wheat Rust Toolbox. GRRC links to RustTracker and the two portals integrate and coordinate all of its activities. It is envisaged that over time, additional country-based websites hosted by national partners will provide outlets for a selected set of Wheat Rust Toolbox data outputs.

Whilst the Wheat Rust Toolbox and the Global Wheat Rust Monitoring System in general has a focus on the pathogen it is essential that linkages exist to the host, so that surveillance and monitoring information can be used to guide control and mitigation efforts. Progress has also been made on this more holistic and integrated approach by integrating data from the CIMMYT Wheat Atlas and the Genetic Resources Information System (GRIS).

5. REFERENCES

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