Development of an automated smart trap for wheat pathogens

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Using automation technology for spore capture and analysis

National surveys show fungicide use on wheat continues to increase despite fluctuations in disease pressure, reaching a 30 year high in 2012 (Defra). Septoria tritici is the most significant foliar disease in UK wheat causing between £43M to £53M in yield losses annually; Yellow and brown rust are more sporadic but have caused significant losses during high disease years. In all cases control is by fungicide application costing £82M annually (GFK Kynetec 2013). Effective disease management relies on either prophylactic pesticide use or significant manual intervention and time consuming assessment of crop disease indicators by farmers and agronomists. Furthermore indications are that current levels of pesticide use could lead to increased risk of pesticide resistance, if this should occur it is estimated that wheat yields could reduce by up to 20%. To address this we have developed a prototype integrated and automated spore detection system, designed for unattended field application, to monitor and identify the presence of Septoria, brown and yellow rust. The prototype system incorporates novel cyclonic pathogen collection, on-board sample processing and isothermal DNA amplification chemistry. We present the engineering design, optimisation and evaluation of our prototype system reporting on successfully completed laboratory testing and initial field trial results.

Design

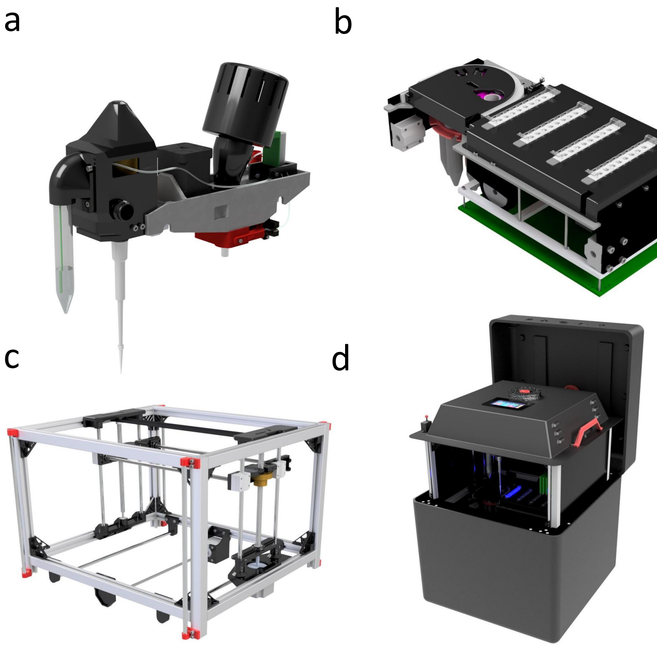

Fig. 1 – a) Top Assembly with cyclone, b) Base Assembly with LAMP units, c) Chassis Assembly, d) Packaged Assembly

Collection

- Cyclone pathogen collection.
- Sampling can be modified to collect at different time intervals autonomously.
- A rotatable cartridge supplies pipette tips (Pipetteman D10), and disposable cyclone tubes (15 ml Falcon Tubes) for 7 day autonomous sampling.
- A high flow impeller motor for driving air though the cyclone at 100 l/min.

Sample Handling

- Automated pipette for handling sample volumes.
- X, Y, Z stepper driven axis (figs 1a, 1b, 1c respectively) for fluid handling from cyclone to detection units as well as cyclone engagement.
- Physical and chemical lysis is used to release spore DNA.
- Disposable pipette tips to reduce cross-contamination and carry-over.

Detection

- Detection is carried out with Loop-mediated isothermal AMPlification (LAMP) detection unit (blue highlight, fig 1d), and the output results fed back to the user remotely.

Optimisation

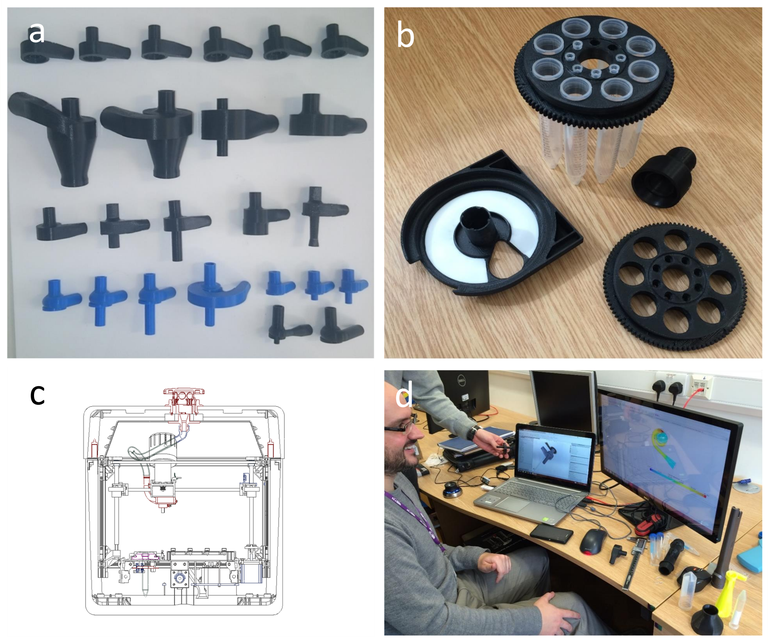

Fig. 2 – a) Cyclone evolution, b) Consumable carrier, c) Schematic of prototype, d) CFD cyclone development

Component optimisation

Component iterations were ongoing throughout the project. Examples:

- Cyclone design optimisation (figures 2a and 2d) – including vortex finder optimisation, cyclone size, and material.
- Consumable optimisation (fig 2b) – including sealing, flexible region, positioning.
- Inlet optimisation (fig 2c).
- Functional optimisation (e.g. specific pipette movement).

System optimisation

- Continuous system optimisation and modifications yielded improved performance of the prototype.
- One example is the addition of a physical agitation unit to assist with the chemical lysis of the spores.
- Another example is the use of a pipette and pipette tips rather than microtubing for sample delivery. This reduced cleaning operations and increased sample volume accuracy.
- The system chassis was adapted over several iterations to reduce it in size and mount the system in a weatherproof Peli-Case.

Evaluation

Fig. 3 – a) Field testing of prototype with battery pack, b) Lid open for access to control panel, c) Lid closed for operation.

End-to-end evaluation

- Field trials are currently ongoing with two units deployed (fig 3) at Fera Science Ltd (Sand Hutton, North Yorkshire).
- Initial results indicate the system is capable of end-to-end collection of airborne pathogens, processing them (including handling and lysis), and detection without human intervention.

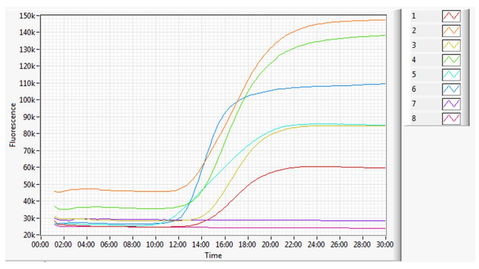

Fig. 4 – An example of a graph taken from one of the LAMP modules in the system showing the 8 chambers and fluorescence changes over time (minutes).

Next steps

This prototype will be the basis for the development of a commercially available system which, in addition to inoculum detection, will be capable of providing growers/agronomists with real-time information on inoculum moving into a crop enabling more effective timing and selection of fungicide application, and thus better control, increased yield, and improved environmental stewardship.