Tackling wheat rusts through resistance – success, challenges and preparedness

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Wheat (*Triticum aestivum* and *T. durum*), second only to rice, accounts for one-fifth of our food, providing 21% of food calories and 20% of proteins to more than 4.5 billion people in 94 developing countries[1]. It is the most important cereal that contributes to one-third of the total foodgrain production in India. During 2016–17, 97.44 million tonnes (mt) of wheat was produced from 30.72 million hectares (m ha). Wheat is an indicator of the economic health of India due to its sustainable production.

Many challenges come in the way of wheat production. Among the various biotic impediments to wheat production, rusts are the foremost. Wheat rusts are devastating pathogens worldwide. Globally wheat rusts occur in all the wheat-growing areas. Three rusts: stem/black (*Puccinia graminis* Pers. f.sp. *tritici* Eriks. & Henn.), leaf/brown (*P. triticina* Eriks.) and stripe/yellow (*P. striiformis* f.sp. *tritici* Westend.) cause varying degrees of loss worldwide[2]. Usually wheat rusts can induce 5–10% loss in normal years; however, under extreme conditions, stem and stripe rusts can incur 100% loss whereas leaf rust may inflict 50% loss[3,4]. Wheat stripe rust affects 10–12 m ha in North India, whereas stem rust affects 7–8 m ha in Peninsular, Central India and other adjoining areas. Leaf rust occurs on wheat in most of the areas, but is not a major problem in the main wheat belt of northern India, as it appears late in the season.

Considering the importance of rust pathogens in wheat production worldwide, these are one of the most widely researched plant pathogens. Systematic efforts for controlling wheat rusts are on for the last three and half centuries; however, the war persists. Among the various options available for wheat rust control, resistance is the only effective, economic and ecologically safe way to manage the pathogen. Wheat rusts are difficult to control as these pathogens frequently evolve into new virulent forms called pathotypes, which render resistant-wheat varieties susceptible. Generally, a rust-resistant wheat variety lasts for 4–5 years. Secondly, these get airborne and are able to spread over larger areas, even between continents like wildfire to cause epidemics. Wheat rusts are shifty pathogens as they get acclimatized to the changed varieties and climatic conditions. For example, some of the wheat stripe rust pathotypes are able to survive at higher temperatures than the usual required for other pathotypes. Cultivation of a single wheat genotype or cultivars having similar resistance over a large area makes the wheat crop more prone to rust outbreaks. This human-guided evolution can be avoided by cultivating wheat varieties with diversity for rust resistance in different areas.

Frequent rust epidemics on wheat have been documented worldwide[2], including India[5]. There have been global efforts to study and tackle wheat rusts by recognized centres[6]. These centres/researchers are responsible for monitoring wheat rusts and their pathotypes in their areas/countries of interest. The information thus generated provides input for undertaking anticipatory wheat breeding and varietal deployment[7].

Strategic wheat and barley rust management in India – success

Organized wheat rust research programme in India was initiated by Karam Chand Mehta from Agra College. He started wheat rust research around 1922–23 at four locations – Agra, Almora, Shimla, Murrey (now in Pakistan) and selected Flowerdale, Shimla, Himachal Pradesh as an ideal place for studying wheat rusts throughout the year. Initially Mehta met all the research expenses from his own savings; later on a grant was made available to him by the Imperial Council of Agricultural Research. Mehta studied the racial patterns of wheat rust pathogens, identified rust-resistant wheat varieties and studied the epidemiology of wheat rusts in India and Nepal. He proved beyond doubt that *Berberis* spp. were not functional and did not play any role in the epidemiology of wheat rusts in India and Nepal[8,9]. Subsequently breeding rust-resistant wheat for hills was also started by him along with Pal[10].

Initially wheat rust races were identified on classical differentials. However, with the propounding of Flor's gene hypothesis and advent of near isogenic lines (NILs) for rust resistance (*Lr*, *Sr* and *Yr*), wheat rust pathotype identification systems had changed world over. Consequently, pathotype identification system based on NILs was also introduced in India[11]. Subsequently, characterization of rust resistance genes based on gene matching technique was initiated in the country[12]. Now, it is possible to know the genetics of rust resistance and diversity of a large number of wheat lines in about a month.

Wheat rust research in India has now become a systematic, coordinated and model system of disease management. It is based mainly on the intelligent deployment of rust-resistant wheat varieties by utilizing the information of pathotype distribution in different areas. ICAR-Indian Institute of Wheat and Barley Research at Flowerdale (IIWBR), is a nodal and designated centre for wheat rust research requirements of India, Bangladesh, Bhutan and Nepal. Mandate of the centre focuses on the following aspects:

(i) Identification of new pathotypes of *Puccinia* species on wheat in initial stages and sources of resistance.

(ii) Mapping pathotype distribution of wheat rusts in India and adjoining countries and providing background information for anticipatory wheat breeding.

(iii) Identifying rust-resistant wheat lines through screening of advance varietal trial and wheat breeders' materials at seedling and adult plant stage against different pathotypes of three rusts under controlled conditions.

(iv) Identification of rust resistance genes in wheat material using gene matching technique. To counsel gene/varietal deployment of wheat based on pathotype pattern of wheat rusts in different agro-ecological zones.

(v) Maintenance of the national repository of 145 rust pathotypes of different *Puccinia* species on wheat, identified since 1931 and supply of nucleus inocula

to enable wheat rust research elsewhere in India.

(vi) Conducting contemporary studies on genetics, gene mining, molecular aspects, pyramid rust resistance genes in acceptable background using both host–pathogen interaction and molecular marker data.

(vii) To act as a team of excellence and provide technical upscaling to different centres in India and adjoining countries.

Achievements

Over the years we have successfully kept vigil on wheat rusts, identified new pathotypes in initial stages, mapped the pathotype distribution and identified genetics of rust resistance of all the wheat material till date. Information on pathotype mapping of wheat rusts and genetics of rust resistance of all the wheat accessions since 1930s is well documented. Effective gene/varietal deployment based on racial patterns of wheat rusts has been put into practice. While most of the countries in the world witnessed epidemics of either one or more rusts during the last 25 years, India harvested a record tonnage of wheat during these years. We have imparted hands-on training to four scientists from Nepal, one from Bangladesh and short-term exposure to about 45 scientists from across the globe. Rust research programme in India has remained proactive and rust epidemics not occurred on wheat over the last more than four decades. Considering even mild losses of wheat due to rusts, there has been saving of 5–7 mt every year[13]. According to our 2007 estimate, meagre 5% loss due to wheat rusts amounts to Rs 39,200 million. Wheat stripe rust is a disease of 10–12 m ha of North India, and 25% loss was valued at Rs 100,000 million in 2007 (ref. 14).

Challenges

In the words of Noble laureate Norman Borlaug, 'rust never sleeps'. Wheat rusts are dynamic, fast-evolving and are able to spread like wildfire. By gaining virulence, super races are evolving. Continued vigil is necessary for the occurrence of new pathotypes, shift in virulence patterns and development of rust resistance varieties. Novel sources of rust resistance need to be identified. Hills have been considered to be the source for recurrence of wheat rusts. However, now-a-days there is practically no wheat cultivation in the hills, and rusts appear early at few locations in the plains than in the hills. Epidemiology of wheat rusts needs to be revisited with the changed cropping patterns. Further work on contemporary and alternative approaches of rust management must be undertaken.

Preparedness

The Regional Station of ICAR-IIWBR at Flowerdale, has a proactive system in place to manage wheat rusts. The centre has identified 55 new pathotypes during the last 30 years, developed and registered 48 diverse rust-resistant genetic stocks which are being used to develop rust-resistant wheat by many wheat breeding centres. All the 145 pathotypes of wheat rusts identified since 1931 are available for screening wheat material for rust resistance. DNA fingerprints of all the wheat rust pathotypes are available. The distribution pattern of wheat rust pathotypes and genetics of rust resistance of Indian wheat material is well documented till date. The centre was also involved in the sequencing of genomes of wheat rusts[15,16]. Over the years there has been focused breeding for wheat and barley rust resistance with strategic pathological back-up, which has led to the development and deployment of rust-resistant varieties[17]. Work on gene mining is in progress and new rust resistance genes are under designation. The centre has initiated studies on molecular basis of host–pathogen interaction and transcryptomics. A new wheat rust pathotype is identified along with resistance sources in initial stages. The identified rust resistance sources are deployed much before the population of virulent pathotype could increase to epidemic proportions. Flowerdale centre has an active collaboration with all the wheat centres in India and international centres like CIMMYT, Mexico; PBI, Australia; ICARDA, HQ-Beirut, Lebanon, and Borlaug Global Rust Initiative. The centre has several glasshouses; most of them have light and temperature control facilities, six polyhouses to study adult plant rust resistance under controlled conditions, basic instruments, molecular laboratory facility and widely experienced researchers to efficiently counter the challenge of wheat rust management.

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