Grains Industry Research Scholarship - Ms Jodie White - Pathotypes, epidemiology and economic importance of sorghum rust in Australia

Summary
This project had three aims. The first was to quantify the potential yield loss in grain sorghum due to infection by rust, caused by *Puccinia purpurea*. Yield losses of up to 13% occurred when grain hybrids were planted late in the planting window (February). The second aim was to identify the environmental conditions which are conducive to rust infection. Infection occurred at 16-25°C and when there was a leaf wetness period of more than six hours, conditions which occur in late March-April. The third aim was to determine if there were pathogenic strains (pathotypes) of the sorghum rust pathogen. Four pathotypes were identified, indicating considerable variation in Australian *P. purpurea* populations.

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Conclusions

1. There are at least four pathotypes of *P. purpurea* in Australia, and it is highly likely that if additional isolates are screened against the differential set, more pathotypes will be identified. The members of the differential set have not been defined with respect to their rust resistance genes. It is possible that some may possess the same gene, or that individual lines may possess more than one gene. Consequently, even more diversity in the pathogenic population may be found if the resistance genes in the differential set members are characterised.

2. Breeding lines in field trials may be exposed to different suites of pathotypes, depending on the structure of the rust pathogen population at each location. The implications from these differences are that if ad hoc screening for rust resistance relies on data collected from the same locality over several years, or from only a few localities, a false impression of a particular breeding line resistant to *P. purpurea* will be obtained.

3. The source of the pathotypic variation in *P. purpurea* is probably from exposure of the population to both commercial hybrids with different resistance genes, and to alternative weed *Sorghum* species such as *S. halepense* (Johnson grass). Almost nothing is known of the genes for rust resistance in commercial hybrids, and it is evident from field observations that even within a single population of *S. halepense*, there is considerable variation in rust susceptibility between individuals.

4. The dynamics of rust epidemics on *S. bicolor* varies from year to year, being influenced by the availability of inoculum early in the season, and by environmental conditions throughout the season. In the Gatton district at least, the length of high leaf wetness periods and the range of temperatures experienced between February and May are sufficient for rust infection to occur. The lack of rainfall apparently does not inhibit infection, but rainfall during the crop's growth will influence the rate of disease development and ultimately the level of infection at maturity.

5. Rust has the potential to significantly reduce grain yields, particularly if infection occurs early in the crop's development. In these trials, a significant reduction in yield occurred in one of the three trials, when there was a relatively high level of rust infection during the early grain-filling period (80 days after sowing). From controlled environment cabinet trials, it was evident that young plants (2-6 fully expanded leaf stage) were more susceptible to infection by *P. purpurea* than older plants. At first this appears to contradict field observations that rust is most evident during the later grain filling periods, but it is likely that either there is often insufficient inoculum present at the start of the growing season, and/or that the environmental conditions are unsuitable for infection in crops which are sown before February in southern Queensland (QLD).

Recommendations
1. Further work on pathotyping of Australian isolates of *P. purpurea* be undertaken to gain a more comprehensive understanding of the composition, geographic distribution, and host preferences, if any, of populations in Australia. This project forms the basis of such studies, by developing protocols for the collection, purification and inoculation of isolates of the rust pathogen. This work could be conducted as a postgraduate degree project.

2. An understanding of the genes for resistance to *P. purpurea* in commercial Australian hybrids, elite breeding lines, and genotypes in the differential set be improved through genetic studies. Such information would not only clarify the pathotyping of *P. purpurea* isolates, but would also provide a sound basis for targeted breeding for resistance to this pathogen. This research could be conducted as a project associated with the Department of Primary Industries and Fisheries (DPI&F) sorghum breeding projects.

3. The reaction of current commercial grain and forage varieties to the pathotypes identified during this study be ascertained. This would provide valuable information for the Australian sorghum industry. Similarly, the reactions of elite breeding lines and experimental hybrids would provide important information to public and private breeders before commercial release. This information would be particularly important for forage sorghums, which are exposed to rust for a much longer period of time than grain sorghums, and for germplasm targeted for more humid production areas where the potential for rust development is high. This research could be conducted as a project associated with the DPI&F sorghum breeding program, and private industry programs.

4. The sources of, and processes responsible for, variation within the *P. purpurea* populations be investigated. A thorough knowledge of the genes for resistance in germplasm as outlined in point 2 above, and of the variation in Johnson grass populations and its influence on pathotypic variation in the rust pathogen would also assist in targeted breeding pursuits. This work could be conducted as a postgraduate degree project.

5. Additional yield loss trials be conducted on a greater number of commercial hybrids, planted at different times during the growing season, and at different locations. The results from these trials would improve knowledge of the potential yield losses likely to occur throughout the sorghum growing regions of Australia in different seasons. This work could be conducted as a postgraduate degree project.

**Outcomes**

**Economic benefits**

Although this project has had no direct economic benefits to the Australian grains industry to date, there is potential for a significant impact in the future. The management of rust on sorghum is restricted to breeding for improved resistance, because fungicide application is not an economic reality for commercial grain and forage producers, and agronomic practices such as control of alternative weed hosts are impractical. The knowledge that rust has the potential to cause significant yield losses in some years, and that several pathotypes of the pathogen are present in Australia has considerable significance for public and private sorghum breeders in Australia. The effort on selection of breeding lines and elite germplasm in a range of diverse environments for resistance to *P. purpurea* needs to be increased. The release of grain and forage hybrids and/or inbred lines which have improved rust resistance will reduce the long-term impact of rust on yield, leading to improved profit margin and industry sustainability. High levels of rust infection are also known to place stress on sorghum plants, which can lead to high levels of stalk rot and lodging; reducing the rust susceptibility of commercial varieties will also have a significant impact on these indirect influences.

**Social benefits**

This project has contributed to the Australian grains industry by providing the opportunity for Ms White to gain training and experience in plant pathology concepts and knowledge, thereby increasing the capacity base of practical plant pathology in Australia. The project was designed for Ms White to gain experience which could be applied to other pathogen-host situations with the minimum of adjustment.

**Achievements/Benefits**

**Background**

Yield loss potential. Rust caused by *P. purpurea* Cooke is considered to be a relatively minor disease of sorghum in Australia, causing limited yield loss because epidemics occur late in the season towards the end of grain filling (Queensland Department of Primary Industries and Fisheries (QDPIF) 2003b). However, in later plantings under cooler, moister conditions...
more favourable to the pathogen, infection can be more severe earlier in the vegetative stage of crop development, potentially causing significant yield losses (Ryley, Persley et al. 2002). Rust also contributes to lodging by reducing leaf area and increasing plant stress (Ryley, Persley et al. 2002). In order to gain a better knowledge of the potential yield losses in grain sorghum varieties, field trials were conducted over three seasons, in which two hybrids (Pride and TX610) planted in mid February (after the end of the recommended planting window for southern QLD) were either sprayed regularly with the fungicide oxycarboxin to minimise rust infection, or left unsprayed. Natural infection occurred from spreader rows, which had been planted 2-5 weeks earlier than the trial plots. All trial plots were sprayed with a fungicide and an insecticide from flowering onwards to control sorghum ergot and sorghum midge, respectively. Rust severity was rated regularly and at maturity all plots were harvested, the grain weighed, and the yield loss determined.

Environmental conditions favourable for infection. Despite observations that sorghum rust is usually more severe late in the season as the temperature drops, there is very little information on the critical drivers of rust infection (particularly temperature and leaf wetness period). During this project, the influence of, and interactions between, temperature, leaf wetness period, light/dark period, inoculum concentration and plant growth stage on rust severity were studied in controlled environmental cabinets. Data on temperature, relative humidity (RH) and leaf wetness were also collected during the yield loss trials, and were compared with the results from controlled studies.

Pathotypes. Many rust pathogens of crops exist as populations containing individuals with different pathogenic capacities. Some of these individuals (isolates) can attack particular host varieties but not others. Isolates can be classified into pathotypes, based on their reaction on a set of host varieties, each of which contains a different gene for resistance. A knowledge of the pathotypic structure of a rust population is vital if the deployment of host resistant genes is to be effective. Only one such study has been conducted for P. purpurea - in Hawaii, Berquist et al., (1971) identified two pathotypes, using a differential set of only three varieties. Ninety isolates of P. purpurea were collected from grain sorghum (S. bicolor, forage sorghum (S. sudanense) and the weed, Johnson grass (S. halepense), during this study, of which 29 were inoculated onto a differential set of 10 S. bicolor genotypes.

Achievements

Yield loss potential. There were no significant hybrid x treatment interactions in any of the three trials, so only pooled data are discussed here. Yield losses of 3%, 8% and 13% were recorded in 2003, 2004 and 2005, respectively, and only in the last trial was the difference between the yields of sprayed and unsprayed plots significantly different (P<0.05) (Attachment 1, Table 1). The differences in yield loss between years can be related to the dynamics of rust development. In the oxycarboxin-sprayed plots, rust severity increased in a more or less linear fashion, reaching a value of <1% at maturity in all trials. In 2003, rust severity increased slowly (0.2% leaf area infected at 80 days after sowing (DAS)), then increasing exponentially (final mean severity of 2.7% for Tx610 and 4.6% for Pride). In 2004, the rust severity was 1.9% at 80 DAS, thereafter increasing linearly to 2.8% and 3.6% for Tx610 and Pride, respectively. The rust severity at 80 DAS in 2005 was 2.7%, with the final rust severities for both hybrids being less than in the other years (Attachment 1, Figure 1). It is possible that the yield losses measured in these trials are underestimated, because trial plots treated with oxycarboxin had measurable rust infection levels (0.45-0.77% leaf area infected) at maturity.

Environmental conditions favourable for infection. Controlled environment cabinet experiments indicate that rust infection can occur between 16°C and 28°C (the limits of the experiment cabinets), with an optimum temperature of 20°C. A minimum leaf wetness period of two hours was established for infection of leaves of a susceptible genotype by urediniospores of P. purpurea, with maximum infection occurring after 20 hours of continuous leaf wetness. A low level of rust infection occurred in continuous light, but severity increased up to a maximum at 16 hours darkness, after which rust severity decreased. Rust severity was also influenced by spore density and plant growth stage - the highest levels of infection occurred as spore density increased, and between the 2-6 fully expanded leaf stages. The results from these experiments were used to develop protocols for pathotype studies.

In the yield loss field trials, rust infection and disease development occurred in all three years (2002-2005) when most days had a mean daily temperature of 17-26°C and leaf wetness periods of >or = 5 hours. The rainfall totals recorded between February and April in all three years were well below the long-term mean totals, with that recorded in 2005 being less than both of the previous years. The results of the field and controlled environment cabinet trials suggest that, at least in the Catton region of southern QLD, conditions (particularly temperature and leaf wetness) between February and May are suitable for infection of S. bicolor by urediniospores of P. purpurea. They also suggest that initial inoculum levels, and early rust infection play a major role in the dynamics of rust development.
Pathotypes. Four pathotypes were identified from the 29 Australian isolates which were tested (see Attachment 1, Table 3). Pathotype 1 was the most prevalent (13 isolates) and was found in central and southeast QLD and in New South Wales (NSW) but not in north QLD. Pathotype 3 was the second most common pathotype (12 isolates), followed by pathotype 2 (3 isolates) and pathotype 4 (1 isolate). The first of these was found in north, central and southern QLD and the only isolate of pathotype 4 was found in southern QLD. *S. bicolor*, *S. sudanense* and *S. halepense* were hosts to pathotypes 1, 2 and 3, while pathotype 4 was found on *S. bicolor*.

**Benefits to industry**

This study examined, for the first time in Australia, the potential yield loss associated with rust, the optimal environmental conditions for rust development and the existence of pathotypes of *P. purpurea*. Significant losses (up to 13%) due to rust were identified in some late-planted grain sorghum hybrids, suggesting that the Australian sorghum industry should be aware of its potential to have a deleterious effect on grain yield. Although these studies were undertaken on only two hybrids, and little is known of the resistance of the suite of current commercial grain sorghum varieties to the rust pathogen, the potential impact should not be underestimated.

These studies also identified a wide range of environmental conditions that would allow infection of *P. purpurea* on sorghum under field conditions. This research highlighted the ability of the sorghum rust pathogen to cause significant yield losses at low infection levels (<5% leaf area infected) even in years when there is lower than normal rainfall. The exposure of a sorghum crop to high levels of inoculum in the early crop development stages appears to have a significant effect on the development of rust, and to its final yield loss potential. These results should raise the profile of sorghum rust and the role that it can play in the loss of yield - early season infections are the most threatening.

The discovery of four pathotypes of *P. purpurea* indicates that there is considerable pathogenic variation in the Australian populations. Public and private sorghum breeding programs in Australia currently rate breeding lines for their rust resistance in the field on an opportunistic basis. Consequently, these breeding lines would be exposed to different populations, each with its own suite of pathotypes. An inaccurate measure of a particular breeding line's rust resistance will be obtained if field conditions are not conducive to rust development or if assessments are made at only one or two locations. This study has proved that pathotypes of *P. purpurea* exist in the sorghum growing regions of Australia. Sorghum breeders in Australia need to ensure that if they continue to assess rust resistance of sorghum breeding material based on field trial results only, adequate provision for pathotypic variation in different geographic populations of the pathogen needs to be considered.

Improved resistance of commercial varieties of grain and forage sorghum to *P. purpurea* will lead to a reduction in direct and indirect (increased stress leading to lodging) yield losses, further leading to increased productivity and profitability.

**Other research**

Other research opportunities are outlined in the recommendations section.

**Intellectual property summary**

The intellectual property (IP) generated from the project will be a PhD thesis and associated scientific publications, which will be protected by the copyright provisions of the University of Queensland (UQ), DPI&F, and the relevant scientific journals in which the papers are published.

**Additional information**

Publications