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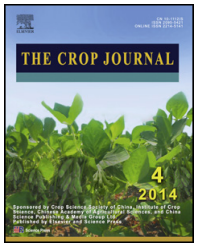

Effect of stripe rust on the yield response of wheat to nitrogen

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ABSTRACT

Nitrogen (N) is the most important fertiliser element determining the productivity of wheat. N nutrition is known to affect the level of stripe rust infection, with higher N associated with increased disease severity. Stripe rust, caused by *Puccinia striiformis* f. sp. *tritici*, is a major yield-limiting disease of wheat in Australia. This paper describes experiments designed to investigate the agronomic response to the interaction of various levels of N application and stripe rust severity in wheat varieties differing in response. Experimental plots were established in crop seasons 2006 and 2007 on the Liverpool Plains of northern NSW, Australia. Yield, biomass, grain protein content (GPC) and harvest index (HI) data were recorded. Increased rates of N increased the severity of stripe rust during grain filling. N application also increased yield and GPC in all varieties in both years. Stripe rust reduced the yield of the rust-susceptible wheat varieties, and GPC and proportion of added N recovered in the grain were also reduced in one year but not the other. It was evident from our experiment that stripe rust caused yield loss accompanied by either no change or reduction in GPC, indicating that the total amount of N entering the grain was reduced by stripe rust. The effects of stripe rust on N yield are most likely associated with reduced uptake of N during grain filling.

1. Introduction

Of the three main rusts affecting wheat, stripe rust, caused by *Puccinia striiformis* f. sp. *tritici* (Pst), is the one that has proved the most difficult to manage in Australia. There are a limited number of resistance genes available in adapted varieties, and new pathotypes that overcome the most widely deployed genes have arisen at frequent intervals. Outbreaks of all three wheat rusts are highly dependent on weather conditions, with management relying on a combination of plant resistance,

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reducing "environmental risk" factors and the tactical application of fungicides if required. One important aspect of environmental risk is that associated with nitrogen management.

Nitrogen (N) nutrition is known to affect the level of stripe rust infection, with higher N associated with increased disease severity [1,2]. Different mechanisms have been suggested to be involved in this response. Some studies suggest that increased crop density and canopy density associated with N fertilisation creates a more favourable microclimate for stripe rust development [2,3]. Other studies suggest that the effect of N on stripe rust is mediated via increased N content of the host tissue acting as a substrate for pathogen growth, rather than via changes in canopy microclimate [4,5].

Diseases can also affect the way in which the crop uses nitrogen [6]. In general, controlling rusts with fungicides increases the protein content of wheat grains. The mechanisms for this are uncertain, but it has been suggested that rusts have a greater proportional effect on nitrogen mobilisation into the grain than on the supply of photosynthate [6].

Adding nitrogen to a wheat crop in the presence of stripe rust could thus increase the severity of the disease, and the disease itself could then reduce the amount of nitrogen exported in the grain. Understanding the interaction of these factors is important in assessing the productivity impacts of rust management, namely, yield and quality (protein).

This paper describes replicated plot experiments designed to investigate the agronomic response (grain yield and quality) resulting from the interaction of various levels of N application and stripe rust severity in wheat varieties of differing levels of response.

2. Materials and methods

2.1. Experimental plot design

Field experiments were conducted over two consecutive seasons at the Breeza Research Station (New South Wales Department of Primary Industries) located on the Liverpool Plains of northern New South Wales (NSW), Australia (150°25′ 31″ E and 31°10′54″ S). Plots were sown with varieties Baxter, Ellison and Hybrid Mercury (HM) in 2006. In 2007, varieties Ellison and H45 were grown. Among these varieties, HM and H45 were considered highly susceptible, Baxter moderately resistant and Ellison resistant to pathotype (134 E16 A+), which was the dominant pathotype in eastern Australia during the years in which the experiments were conducted. In both years wheat was grown in experimental plots of 10 m length and 1.8 m width. Spacing between rows was 40 cm and sowing rate was adjusted based on grain weight and germination of the various wheat varieties so as to attain a target plant population of 100 plants m^{-2}. In both years, N rates of 0, 50, 100, 200 or 300 kg ha^{-1} were established by application of granular urea prior to sowing. The trial areas in both years deliberately followed a long fallow from a previous sorghum crop to ensure low starting soil N reserves. Soil N levels were measured to 1.2 m prior to sowing in each year with a total of 64 kg ha^{-1} nitrate N available in 2006 and 42 kg ha^{-1} nitrate N in 2007.

All plots were inoculated with *Pst* spores prior to a rain event during tillering in each season to supplement natural inoculation with wind-blown spores from neighbouring fields. Low-disease plots were then established in each trial by treatment of seed with fluquinconazole (Jockey-Bayer Crop Science at 450 mL 100 kg^{-1} seed) prior to sowing and foliar applications of tebuconazole (Folicur-Bayer Crop Science at 290 mL ha^{-1}) at the start of booting (GS32) and full flag leaf emergence (GS39). In 2006 the fungicide treatment was applied to all varieties, but in 2007 it was applied only to the susceptible variety H45 because Ellison was highly resistant to the dominant pathotype at the time of the trial.

The experimental design in 2006 was a split-plot design with fungicide treatment as the main plot factor, and variety and nitrogen as the subplot factors. In 2007 a randomised complete block design was used. There were four replicates in both years.

2.2. Disease assessment

Disease severity (percentage of leaf area covered in pustules) was visually estimated using a standard scale from the Australian Cereal Rust Laboratory, University of Sydney [7]. This scale measures the severity of stripe rust using scores ranging from one (no symptoms) to nine (abundant sporulation across the whole leaf area with no evidence of individual stripes). Scores for each plot were recorded as the average of responses for the two uppermost leaves of all plants in a plot at each assessment time. Visual assessments of infection were made 116 days after sowing (DAS) in 2006 and 113 DAS in 2007, corresponding approximately to early milk development (GS 75) in each season. For analysis, the scores were converted to percentages using the midpoint of each category on the scale and arcsin $\sqrt{x}$ transformed for analysis of variance (ANOVA).

2.3. Yield and biomass parameters

In both years, a 1.5 m segment of each row was randomly cut at ground level from each plot just prior to harvest. These samples were used to determine biomass, after drying at 50 °C for 48 h, and grain yield. Final grain yield was also obtained at maturity by harvesting each 10.0 m × 1.8 m plot with a Kew experimental plot header. Grain protein concentration was determined by NIR reflectance. The trial was harvested 145 DAS in 2006 and 154 DAS in 2007. Data were analysed by ANOVA.

The amount of N harvested in the grain protein was calculated from yield and grain protein content, using a conversion factor of protein content of 5.61 times amino acid N content [8]. N in protein was used rather than total grain N (which is about 1.05 times higher) because commercial prices are based on protein content. The Mitscherlich diminishing returns function,

$$Y = \alpha(1-\beta\rho^{N})$$

where Y represents grain protein N yield and N represents nitrogen application rate, was fitted to response curves for the susceptible varieties in each year using nonlinear regression in PASW Statistics version 18. This function was shown to give good fits to the response of yield and protein content of wheat