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Economics of foliar fungicides for hard red winter wheat in the USA southern Great Plains

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ABSTRACT

Grain yields of winter wheat (*Triticum aestivum* L.) in the southern Great Plains are often reduced by the presence of foliar diseases. This study was conducted to determine whether the application of foliar fungicides is an economically optimal management strategy. The effects of fungicide treatment on commercially available hard red winter wheat varieties with differing levels of genetic resistance (i.e., resistant, intermediate, and susceptible) to foliar diseases were investigated at two locations, Apache and Lahoma, OK, USA, for the harvest years 2005–2012. Two fungicides were rotated between the two locations and applied at approximately Feekes growth stage 9–10.5. When averaged across years, plots to which fungicide was applied generated greater average net returns than plots that did not receive fungicide for susceptible varieties at Apache, and for resistant, intermediate, and susceptible varieties at Lahoma. However, foliar fungicide application was not economical in every year at either location suggesting fungicide use should be reassessed each year given that profitability depends on year specific yield potential, prices, and foliar disease conditions. At both locations high disease incidence occurred in all but one site-year when the average March through May relative humidity exceeded 65%. Additional research would be required to determine the relationship between weather, including relative humidity, and disease incidence, and to develop an economic threshold for treatment decision aid.

1. Introduction

Foliar diseases such as leaf rust (*Puccinia triticina* Erikss.), stripe rust (*Puccinia striiformis* Westend. f. sp. *tritici* Erikss.), and powdery mildew [*Blumeria graminis* (DC.) Speer f. sp. *tritici* emend. É.J. Marchal] often reduce the grain yield of winter wheat in the USA southern Great Plains. Yield losses from leaf rust alone have averaged over 3% per year from 1980 to 2011 in Oklahoma, with some individual year losses in excess of 10% (USDA ARS, 2012). Historically, control of these diseases through foliar fungicide applications has not been economical for U.S. producers (Milus, 1994). As a result, management of foliar diseases has largely relied on genetic resistance and other cultural practices such as crop rotations (Roelfs et al., 1992). However, in recent years there has been a growing interest in reevaluating fungicide treatments as part of an economically optimal foliar disease management plan.

Fungicides may be applied to protect yield potential that is present at the time of application by increasing the activity of plant antioxidants and slowing chlorophyll and leaf protein degradation (Zhang et al., 2010; Hunger and Edwards, 2012). By delaying leaf senescence, fungicides allow plants to keep their leaves longer, and thus use more nutrients during late developmental stages (Morris et al., 1989; Dimmock and Gooding, 2002). Nevertheless, De Wolf et al. (2012) describe the yield response of winter wheat to foliar fungicides as "highly variable." This is primarily due to the large number of factors influencing this response, including the incidence and severity of specific foliar diseases, cultivar disease resistance, yield potential, timing of fungicide application, and environmental conditions (Kelley, 2001; De Wolf et al., 2012).

Some researchers have found that the potential for positive economic returns to fungicide treatment exists for winter wheat grown in Europe (Mercer and Ruddock, 2005; Wiik and Rosenqvist,

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2010), as well as the northern (Ransom and McMullen, 2008), central (Wegulo et al., 2011), and southern (Edwards et al., 2012a) Great Plains of the United States. However, economic benefits are highly variable. Positive returns to fungicide treatment are most likely to be realized in years when disease incidence and severity are high. In years when disease levels are low, negative returns to fungicide treatment may occur (Ransom and McMullen, 2008; Wiik and Rosenqvist, 2010; Wegulo et al., 2011; Edwards et al., 2012a). In addition, wheat cultivars that are susceptible to common foliar diseases are more likely to generate positive returns when treated with fungicide (Mercer and Ruddock, 2005; Ransom and McMullen, 2008; Edwards et al., 2012a). Ransom and McMullen (2008) suggest that foliar fungicides always be applied to susceptible winter wheat varieties. However, varieties with genetic resistance to common foliar diseases have also been shown to generate positive economic returns to fungicide treatment in years of high disease severity (Ransom and McMullen, 2008; Edwards et al., 2012a).

Returns to fungicide treatment are also influenced by treatment cost and wheat price. If wheat price is high relative to fungicide treatment cost, positive returns are more likely. However, a high cost to benefit ratio (either from high cost of treatment or low wheat price or both) may negate the profitability of fungicide application, even in years when disease pressure is high (Wiik and Rosenqvist, 2010; Wegulo et al., 2011). Additionally, producers must consider the methods by which foliar fungicides are applied. If fungicides are applied using a ground rig, wheel tracks and/or tram lines may reduce yield. If applied aerially, the cost consequence of applying at a sufficient water volume to achieve adequate plant leaf coverage is critical.

Previous literature has evaluated only the expected returns to fungicide treatment as part of a disease management strategy, and ignored the risk or variability associated with these alternatives. While expected net returns are important when evaluating alternative production strategies, it is also important to recognize that the distributions of net returns reflect different amounts of risk. Stochastic dominance analysis has been previously used to evaluate agricultural production decisions such as irrigation (Boggess and Ritchie, 1988), tillage practices (Williams et al., 1990; Epplin et al., 1993), and cropping systems (DeVuyst and Halvorson, 2004). Second degree stochastic dominance (SSD) is an alternative approach to techniques such as mean-variance (EV) analysis and allows for the elimination of strategies that are dominated by others when assuming risk-averse decision makers. Where EV analysis imposes strict assumptions on the utility function of decision makers, SSD only requires risk aversion (i.e., an upward sloping, concave utility function). The objective of this research is to determine the expected net returns to fungicide treatment of hard red winter wheat cultivars with differing levels of genetic resistance to foliar diseases in the southern Great Plains, and to determine if fungicide treatment is an economically optimal management strategy. The knowledge of expected net returns and variability associated with these disease management alternatives may allow producers growing hard red winter wheat in the southern Great Plains to increase profitability and/or reduce risk associated with foliar diseases.

This study uses seven years of data from field experiments conducted at two locations in Oklahoma to estimate grain yield response of hard red winter wheat to foliar fungicide treatment. Least-squares mean grain yields and partial budgeting analysis are used to determine the foliar disease management strategy that generates the greatest expected net returns. Subsequently, stochastic dominance is used to determine a foliar disease management strategy for both locations that would be appropriate for risk-averse producers who prefer to use the same strategy every year.

2. Materials and methods

2.1. Wheat grain yield

Hard red winter wheat grain yield data were produced in field experiments conducted during harvest years 2005–2012 at two locations, the Oklahoma State University North Central Research Station near Lahoma, OK, USA (36.38, −98.10) and an on-farm research site near Apache, OK (34.89, −98.39). Plots were lost at Apache in 2009 due to drought, and at Apache and Lahoma in 2007 due to excessive rainfall during harvest. Soil series was a Grant silt loam (fine-silty, mixed, superactive, thermic Udic Argiustoll) at Lahoma and a Port silt loam (fine-silty, mixed, superactive, thermic Cumulic Haplustolls) at Apache. Experimental design was a randomized complete block, split-plot with four replications. Whole plots were wheat cultivar and sub-plots were fungicide treatment.

Plots were sown in mid-October at a seeding rate of 67 kg ha^{-1}. Plots were prepared using conventional tillage methods in all years except for 2010 at the Apache location, where plots were planted using no-tillage practices following full season soybean [*Glycine max* (L.) Merr.]. Conventional till plots were eight 15-cm rows wide by 6.7 m long and were sown using a Hege 500 small-plot, conventional drill (Wintersteiger, Salt Lake City, UT). No-till plots were seven 19-cm rows wide by 6.7 m long and were sown using a Great Plains no-till drill modified for small plot research (Kincaid Manufacturing, Haven, KS). Conventional and no-till plots received in-furrow applications of 56 kg ha^{-1} diammonium phosphate (18-46-0) and 65 kg ha^{-1} of ammonium polyphosphate (10-34-0) at planting, respectively. Additional nitrogen application rates and timing varied by location and year, but were sufficient at Feekes growth stage 6 (Large, 1954) to produce at least 3360 kg ha^{-1} grain yield according to Oklahoma State University Extension recommendations (Zhang et al., 2009). Weeds and insects were controlled using commercially available pesticides as needed.

Cultivars tested varied by location and year with 15–24 commercially released cultivars per year. Varietal resistance for each wheat cultivar was determined based on average disease resistance rating to leaf rust, stripe rust, and powdery mildew using variety resistance ratings published in the previous year's Oklahoma State University Extension variety comparison (Edwards et al., 2012b). These publications rate varieties on a scale of one to four, where one indicates high genetic resistance and four indicates high susceptibility to a particular disease. Varieties with average disease resistance ratings between 1.0 and 1.9 were considered resistant, 2.0–2.9 were intermediate, and greater than or equal to 3.0 were classified as susceptible to common foliar diseases. One-half of each plot was randomly selected to be treated with fungicide at approximately Feekes growth stage 9–10.5 using 140 L ha^{-1} of water carrier delivered through a bicycle-wheel, small-plot sprayer set 0.38 m above the plant canopy. Two foliar fungicides, Quilt (0.12 kg L^{-1} propiconazole and 0.75 kg L^{-1} azoxystrobin) and Stratego (0.12 kg L^{-1} propiconazole and 0.12 kg Ll^{-1} trifloxystrobin), were rotated between the two locations each year. Fungicides were applied at recommended rates of 1.02 kg ha^{-1} for Quilt and 0.73 kg ha^{-1} for Stratego, and were assumed to provide similar disease control based on the results of previous Oklahoma State University research studies (Hunger and Edwards, 2012).

Plots were harvested using a small plot combine (Hege 140, Winterstieger, Salt Lake City, UT) when grain moisture content of all varieties was less than 12%. Wheel tracks between plots were included in the plot area for grain yield calculations, resulting in an overall plot width of 1.5 m. A 1.5 m alley was cut between fungicide treated and not treated sub-plots resulting in a final plot length of 5.2 m.