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A Decision-support Model Based on Agro-environmental Data for the Economic Chemotherapy of Leaf Rust on Winter Wheat in Mississippi

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Abstract

Environmental data recorded by a weather station installed in experimental wheat plots established during 1991-93 were used to develop leaf rust predictive model for economic fungicide application. Natural inoculum was relied upon for infection. Five fungicides were evaluated on five varieties during the spring of 1992 and 1993 in 15 treatments based on mode of active ingredient, crop growth stage (GS), initial appearance of leaf rust symptoms and environmental conditions. Fungicide treatments suppressing disease severity and enhancing the yield of rust tolerant varieties were subjected to economical analysis. Weekly maximum air temperature (23°C), minimum air temperature (12°C), and average air temperature (17°C), soil temperature (29°C), rainfall (0.88 cm), relative humidity (86 percent), wind movement (12 km h^{-1}), solar radiation (26 mj/m^2) and dew point (17°C) resulted in greater leaf rust severity at Starkville, in 1992. Weekly maximum air temperature (25°C), minimum air temperature (22°C), and average air temperature (21°C), soil temperature (27°C), rainfall (3.77 cm), relative humidity (90 percent), wind movement (28 km h^{-1}) solar radiation (19 mj/m^2) and dew point (16°C) resulted in lower leaf rust development in 1993. Application of flusilozle alone, or flusilazole or propoconazole at GS-9 followed by mancozeb at GS-10.5 was recommended for maximizing profitable yield from Coker 9323 and Pioneer 2555.

Key words: Leaf rust, *Puccinia recondita* f. sp. *tritici*, Mississippi, air temperature, rainfall, relative humidity, wind movement, solar radiation, dew point, fungicide, regression, wheat

Introduction

Wheat (*Triticum aestivum* L.) Leaf rust caused by *Puccinia recondita* Roberge ex Desmaz f. sp. *tritici* is a devestating foliar disease in Mississippi. The survival of viable urediniospores and dormant mycelia serve as the inoculum sources that contribute to the establishment and development of leaf rust epidemics (Burleigh *et al.*, 1969; Eversmeyer *et al.*, 1984; Kolmer, 1992; Leonard *et al.*, 1992). Different methods to manage leaf rust on winter wheat include the use of varieties with partial resistance and application of fungicides. The use of fungicides on moderately resistant to moderately susceptible wheat varieties, has potential value to combat leaf rust and positive effects on yield (Trevathan, 1990). Control of leaf rust by seed and foliar applied fungicides has been described by several authors (Christ and Frank, 1989; Rakotondradona and Line, 1984; Trevathan, 1990). The extensive use of fungicides, however, is neither economical for wheat procedures nor beneficial for the environment. The risk of pathogen resistance to fungicides, the effects of fungicides on nontarget organisms, and the cost of fungicides can be applications. Objective of this study was to develop a desicion-support model for economic chemotheraphy of leaf rust on winter what in Mississippi. This model could be employed in a future decision-support system run on a state wide basis to issue recommendation to wheat procedures for economic fungicide application.

Materials and Methods

Environmental data consisting of air and soil temperatures, rainfall, relative humidity, solar radiation, wind movement and dewpoint during 1991-93 recorded by a weather station were used to determine the environmental conditions conductive for high epidemic or low epidemic severity in two seasons. Flusilazole, propiconazole, fenbuconazole, mancozeb and triadimefon were tested two season at Starville. Plots of Cokar 93223, Coker 9733, Coker 9835, Pioneer 2548, and Pioneer 2555, established in a randomized complete block design received foliar fungicide application at Feekes' growth stage 9 or 10.5 or at 1 percent area of flag leaf covered by rust pustules. Disease rating based on a leaf rust severity scale (James, 1971) were recorded weekly yield from each plot was obtained and increase over untreated control was determined. Fungicides treatment suppressing disease severity and increasing wheat yield significantly compared to untreated control were subjected to economical analysis. A multidisciplinary approach involving researchers and extension personal from the Mississippi Agriculture Statistics Service, the National Agricultural Statistics Service and the U. S. Department of Agriculture, was used to determine production practices and input quantities, and to estimate costs and return for wach enterprise. The data from each survey conducted once every three years on a rotating basis in different locations, was used as the basis

Table 1: Yield cost-benefit ratios and profits fron Coker 9323 and Pioneer 2555 treated with fungicides against leaf rust during two seasons at Starkbille, Mississippi

	Ciker 9323				Pioneer 2555			
Treatments	Yield (Kg h^{-1})	Percent increase over control	Cost benefit ratio	Profit ($/ha)	Yield (kg h^{-1}a)	Percent increase over control	Cost benefit ratio	Profit ($/ha)
Treatment 1992								
1. Flusilazole (0.14 kg ai/ha) applied at GS-8	5322	10	0.48	35.76	6197*	28	0.41	139.44
2. Flusilazole + Flusilazole (0.07 kg ai/ha) applied at GS-9 and 10.5	5052	4	0.51	3.36	5726*	18	0.51	84.36
3. Mancozeb (1.7 kg ai/ha) + triadimefon (0.07 kg ai/ha) applied at GS-9	5321	10	0.48	33.52	5726*	18	0.45	82.12
4. Mancozeb (1.7 kg ai/ha) + triadimefon (0.07 kg ai/ha) applied at GS-10.5	5321	10	0.48	33.52	5793*	19	0.44	88.61
5. Prppiconazole (0.12 kg ai/ha) applied at GS-9 followed by mancozeb (1.7 kg ai/ha) at GS-10.5	5052	4	0.51	00.00	6130*	26	0.42	129.72
6. Triadimefon (0.07 kg ai/ha) applied at the appearance of rust pustules below flag leaf followed by mancozeb (1.7 kg ai/ha) at GS-9	5322	10	0.48	33.52	5658*	17	0.45	72.41
7. Untreated control	4550	-----	0.51	-------	4850	0.51	-----	
LSD = (p = 0.05)	1078				606			
Treatments 1993								
1. Flusilazole (0.14 kg ai/ha) applied at GS-9	4378*	23	0.58	74.64	4042*	50	0.63	139.40
2. Flusilazole (0.07 kg ai/ha) applied at GS-9 followed by mancozeb (1.7 kg ai/ha) at GS-10.5	4109*	15	0.62	43.24	4109*	52	0.62	146.92
3. Mancozeb (1.7 kg ai/ha) applied at GS-9	4042*	13	0.62	36.71	39.07*	45	0.71	82.06
4. Mancozeb (1.7 kg ai/ha) applied at GS-9 followed by mancozeb (1.7 kg ai/ha) at GS-10.5	3974*	11	0.64	31.28	3503*	30	0.75	63.68
5. Propiconzaole (0.12 kg ai/ha) applied at GS-8 followed by mancozeb (1.7 kg ai/ha) at GS-10.5	4042*	13	0.63	32.05	3435*	27	0.66	119.98
6. Untreated control	3570	---	0.66	------	2694		0.88	------
LSD = (p = 0.05)	337				606			

GS- Feekes' growth stage, *Indicates significant difference compared to untreated control at p = 0.05

for selecting the practices included in each budget (Spurlock and Laughlin, 1992). The Mississippi Agricultural Statistics Service conducted an annual survey of farm machinery dealers and determined the prices by size of the equipment from the most common sales in each category as reported by the machinery dealers in the survey (Anonymous, 1992). Estimates of direct costs included costs of repairs for all machinery and included fuel costs for powered machinery. All these estimates were calculated on an hourly basis using cited studies (Annonymous, 1993; Cooke *et al*., 1972, 1975; Spurlock and Laughlin, 1992) and converted to a per acre/ha basis using the performance rate for the particular operation. To estimate returns, yields obtained from fungicides treated and untreated plots were multiplied by average price of wheat, based on last 10 years market prices (Anonymous, 1993). Cost-benefit ratios were determined by dividing the input costs with returns. The profit from fungicide treatment was determined by the formula: Profit = (yield increase × grain price) - (treatment cost). Environmental data, fungicide treatments and inputs (expenditure as direct or indirect cost on fertilizer, herbicides, fungicides, machinery, repair, labor etc) represented as exogenous variables while, varieties and time (year, months, weeks) represented as endogenous variables. All data were integrated to develop a decision-support model.

Results and Discussion

Weekly (March-May) environmental conditions explained 99 and 91 percent of the variability in leaf rust development at Starkville during 1992 and 1993, respectively. Regression function of the epidemic containing all the environmental parameters was significantly different in 1992 compared to 1993. Parameter estimates of each of the environmental variables had a significant influence on leaf rust development during 1992. None of parameter estimates of environmental variables had significant influence on leaf rust development, during 1993. Thus environmental conditions from March to May were more conductive for leaf rust

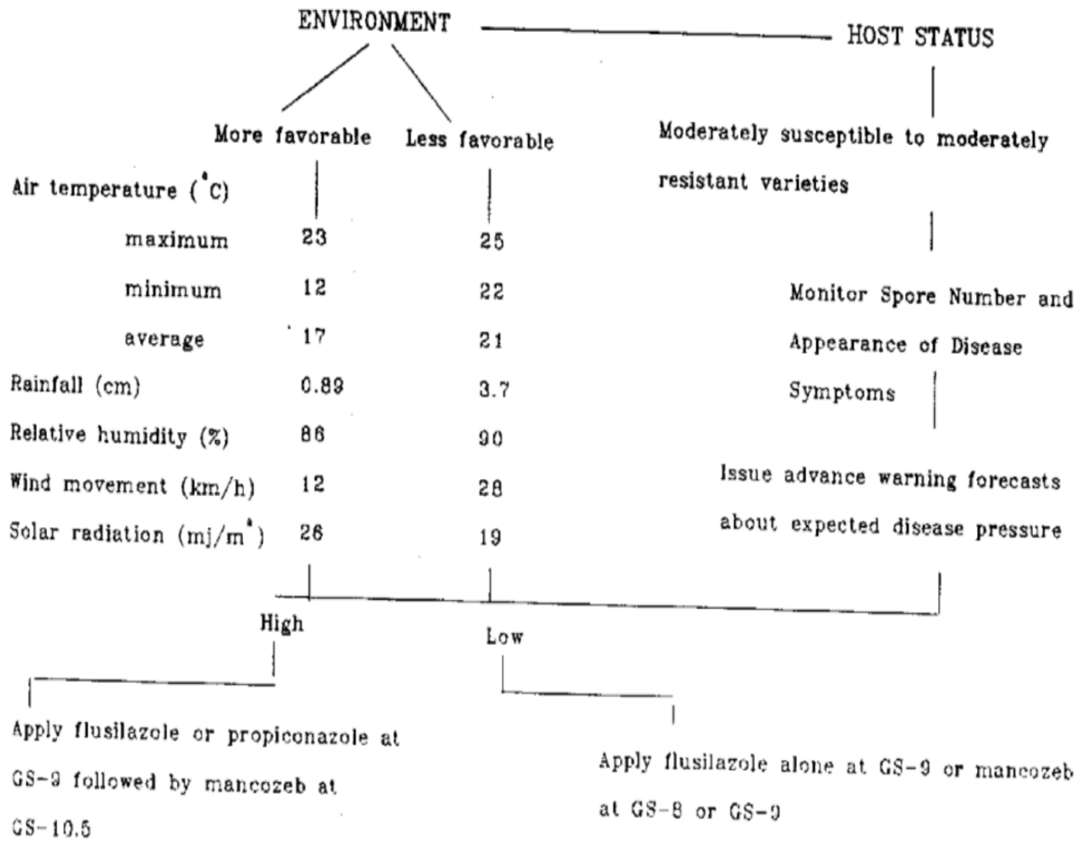

Fig. 1: A decision-support model (flow chart) for the economic chemotherapy of leaf rust on winter wheat in Mississippi

development during 1992 than 1993. Slopes of mean disease severity for the effect of weekly air temperature (min/ave), soil temperature, rainfall, solar radiation and dew point during 1992 was significantly different compared to the same parameters in 1993. However, regression of daily environmental parameters versus leaf rust severity resulted in lower R-square values compared to weekly environmental parameters. This may be due to disease severity ratings taken on weekly basis. The relationship of daily environmental variables with daily leaf rust severity may give better R-square values.

Wheat varieties responded differently to fungicides. Coker 9323 and Pioneer 2555 gave positive yield responses to fungicide application under high or low disease severity (Table 1). However, cost-benefit ratios were low under high disease severity compared to high cost-benefit ratios under low disease severity. Flusilazole (0.07 kg ai/ha) applied at GS-9 followed by mancozeb (1.7 kg ai/ha) at GS-10.5 resulted in maximum profit ($146.92) from Pioneer 2555 Flusilazole (0.14 kg ai/ha) applied at GS-8 or GS-9 resulted in a profit of $139.44. During both seasons application of propiconazole (0.12 kg ai/ha) at GS-8 or 9 followed by mancozeb (1.7 kg ai/ha) at GS-10.5 resulted in a profit of $120 or above from Pioneer 2555. The response of fungicide treatment was more evident in terms of high yield in Pioneer 2555 compared to Coker 9323. Both varieties are medium statured and rust tolerant and their genetic potential was greatly exploited by fungicide application (Table 1). Serve leaf rust epidemics on winter wheat in Mississippi occur generally after every five years. During the intervening years leaf rust severity varies from negligible to moderate intensity. Early initiation of leaf rust epidemics may depend upon winter survival of inoculum and viability of urediniospores. Availability of sufficient inoculum and conductive environmental conditions from March to May could be critical for leaf rust development. Burleigh *et al.*, (1972) used fungal growth and infection function to predict leaf rust development. Weekly averages of temperatures (max/min/ave) and rainfall in our studies explained 95 and 65 percent of the variability in disease development during 1992 and 1993, respectively. Temperature affects not only survival, latent period, infectious period, sporulation of the leaf rust fungus (Eversmeyer *et al.*, 1973; Hyde, 1982; Pretorius *et al.*, 1988; Tomerlin *et al.*, 1984) but also the expression of resistance in the host (Hyde, 1982). Wind velocity, speed and direction affects the spore dislodge, dispersal, dissemination and landing. During two seasons negative correlation of rainfall and relative humidity with leaf rust severity suggest a inverse relationship of these variables with disease development. Eversmeyer *et al.*, (1973) found hour of free moisture to be the most accurate measure of moisture available for leaf rust development rather than days of precipitation. Higher solar radiation, low wind movement and less rainfall could create conditions of high humidity thus leading to high disease severity. Prevalence of these types of environmental conditions during March-April can be a warning of expected high disease severity and recommend fungicide application (Fig. 1). We did not include urediniospore number data because disease predictive model based on measures of disease severity and weekly urediniospore numbers gave low R^2 (Eversmeyer *et al.*, 1973). Uredinidpore quantitative data carries little value unless virulence frequency, virulence association and distribution of *Puccinia recondita* f. sp. *tritici* is determined in a certain region (Khan and Ilyas, 1997). Air temperatures (max/min/ave), rainfall and relative humidity, have already been reported to influence leaf rust development (Eversmeyer *et al.*, 1988; Hyde, 1982; Pretorius *et al.*, 1988; Tomerlin *et al.*, 1984). In these studies inclusion of eleven environmental variables resulted in increased explanation of variability in leaf rust development. Moreover, economical analysis provided an estimate of returns and profits. We developed this prototype decision-support model (Fig. 1) with a heuristic approach to seek a solution of a unstructured problem (Turban, 1992). Evaluation and validation of this model in future is expected to be useful for its employment in a state wide decision-support system regarding economic fungicide application.

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