Research Updates

A Model for Dry Bean Yield Loss Due to Rust

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Summary. **Severity of rust *(Uromyces appendiculatus)* and yield of dry edible beans *(Phaseolus vulgaris* L.) were recorded for 9 years in west-central Nebraska in fungicidal efficacy trials. A weighted analysis of covariance was used to estimate yield loss due to rust. The model fit the data well (R^2= 0.94), and the slope over all years had a 19 kg·ha^{-1} decrease in yield for each 1% increase in severity of rust. Yield response within years occurred only through reduction of rust for most fungicide treatments.**

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Rust, caused by *Uromyces appendiculatus*(Pers. Unger), on dry beans (*Phaseolus vulgaris* L.)is a production constraint worldwide. Bean yield reductions from rust have been documented to be 18% to 100% (Mullins and Hilty, 1985; Stavely and Pastor- Corralos, 1989; Valez-Martinez et al., 1989). In humid tropical and subtropical regions, rust can be severe annually, while in humid temperate, and semi-and regions severe disease epidemics are less frequent, but still can cause significant yield reductions. Local weather conditions also play a significant part in determining rust severity and can result in site-to-site and year-to-year variation (Stavely and Pastor-Corrales, 1989). The prediction of yield losses in dry beans caused by rust is difficult, because differences between years in weather conditions, races of rust, cultivars, types of resistance, crop management, and field location can influence not only the amount of rust but also bean yields in general (Castaño et al., 1986; Mmbaga and Steadman, 1992; Stavely and Pastor-Corrales, 1989).

Uromyces appendiculatum is one of the most variable plant pathogens; therefore, stable plant resistance has been difficult to achieve (Stavely and Pastor- Corrales, 1989). Chemical control is effective, but it increases production and environmental costs. With the need to be competitive, bean growers must have information to manage their crop effectively for maximum yield and minimum financial input. Understanding the relationship of yield with the severity of rust is useful for determining disease management strategies and predicting yield loss potential.

Regression models, used to study and predict yield losses due to disease, require a database of different disease intensities and corresponding crop yields (MeronuckandTeng, 1984; Meronuck, 1987; Shane and Teng, 1987; Teng, 1987). Experiments conducted over several locations and years are essential to obtain a sufficient number of values so that an analysis of covariance (ANCOVA) model with disease intensity as a covariable can be used to predict yield losses (Madden, 1983).

The use of fungicides to develop a range of disease severities is common in plant disease loss studies (Sah and Mackenzie, 1987). There are several precautions that should be considered when using ANCOVA to develop a disease-yield loss model based on combined data from different fungicide trials. Fungicides might provide a positive or negative effect on yield in addition to their direct control of a single disease (Stavely and Pastor-Corrales, 1989). Also, confounding effects with other diseases or other interactions may occur (Sah and Mackenzie, 1987). However, Shane and Teng (1987) state that the main purpose for obtaining pest–yield data is to have an estimate of yield at different levels of pest infestation, not to compare treatments with a control.

The objectives of this study were to 1) use data obtained from fungicidal efficacy trials to develop and evaluate a model to predict yield loss in pinto dry beans due to rust and 2) evaluate the usefulness of this model as it applies to field management decisions.

Materials and methods

Severity of rust and seed yield of the rust-susceptible bean 'Pinto UI 114' were collected from fungicidal efficacy trials planted the first week of June at North Platte, Neb., for 9 years (1981-87, 1989, and 1990). 'UI 114' is a medium-maturity cultivar (90+ days) that has been grown on the High Plains for the past 25 years. It has been a standard cultivar used in comparing adaptability of newer cultivars and as the susceptible check to compare reaction to rust. Severity of rust was recorded once, 72–75 days after planting, as percent of leaf area visibly covered by sporulating pustules or chlorotic halos surrounding these pustules. The pictorial key published by Stavely (1985) was used as a guide, and defoliation was not a factor in the assessment method. Plots consisted of three rows, six m long, with the center row assessed for disease and harvested for

yield (expressed as kg·ha^{-1}).

Plots were separated by one spreader row of 'UI114' and sprinkler-irrigated as needed. If no rust pustules were visible by 15 July (just beforeflowering), spreader rows were inoculated with local races of rust and reinoculated at 7-day intervals for 3 weeks. The rust was diluted with 99% talc and applied as a dust. Plots were sprinkler-irrigated intermittently for brief periods following inoculation. Even with inoculation, severe rust epidemics did not always develop.

Variousfungicideswere tested for rust control efficacy, and nontreated (nonprotected) checks were included for each year. The experimental design each year was a randomized complete block with either four or five replications. Treatments (consisting of fungicide products, timing, number of fungicide applications, and fungicide rates) varied from year to year.

Severity of rust and seed yields were averaged over replicates for each treatment in each year to develop a rust–yield loss model. A weighted analysis of covariance (ANCOVA) on yield with year as the classification factor and rust as the covariate was used. Weights were the number of replicates used for each of the 88 yield means (total of all treatments over years). ANCOVA was used to determine the appropriate shape of the regression lines and if the regression lines differed from year to year. The fit of the model was evaluated with R^2.

Treatments with high fungicide application rates and the same timing werecomparedwithinthesameyearfor 4yearsusingANOVA.Aprotected LSD was used to determine if treatments affected yield through their influence onseverityof rust only and not because of other factors (e.g., micronutrient content, phytotoxicity) relating to fungicideproduct or rate. The assumption wasthatanydifferencein yields among high-ratefungicidetreatments applied at the same time would be due to factors other than rust inhibition.

Results

The data used for the ANCOVA model are summarized in Table 1. A linear model to describe the yield responseto severity of rust was adequate because a quadratic response to rust was not significant ($P > 0.05$). Slopes didnotdiffersignificantlyamongyears ($P > 0.05$). A slope of-18.9 that differed from 0 ($P < 0.05$) was adequate for all years (Fig. 1). There was about a 19kg·ha^{-1}decreaseinyield for each 1% increaseinseverityofrust,measured 72 to 75 days after planting. The fit of the model was quite good ($R^2 = 0.94$).

The intercept for each year was the estimated yield when rust was not present.Yieldintercepts for years were different ($P < 0.05$), varying from lowest in 1984 to highest in 1987. The different intercepts were due to year differences in precipitation, humidity, temperature, wind conditions, and other pests that influence yield.

Fungicide effects on yield other than by control of rust were determined by comparisons of high-rate fungicide treatments with the same application times in 1982, 1985, 1986, and 1987. Only in 1986 were there significant differences in yield between two of the treatments [Mancozeb (=2798) vs. Myclobutanil (60 DF) (=2329)]. These twotreatmentswereappliedatthesame time and in similar amounts, and resultedinsimilarrustseveritybasedon a protectedLSD(0.05)foreachyear(Table 2). None of the other high-rate treatments differed significantly in yield.

Rust severity was relatively high in 1981, 1982, 1984, and 1985, and relatively low in 1983, 1986, 1987, 1989, and 1990 (Table 1). In 1983, a low rust year, no measurable precipitationwasrecorded in July and August at North Platte, Neb. In the higher rust years (198 1 and 1982), measurable precipitation occurred on 24 days (out of 62 days) in the months of July and August for both years. The other years were intermediate for precipitation. However,monthlymeantemperatures varied considerably among years.

Discussion

The finding that a 1% increase in severity of rust, measured 72–75 days after planting, reduced yield by about 19kg·ha^{-1}irrespectiveoftheyear,yield level,orrust severity, was unexpected. Thisfindingisbasedon the observation that the yield-rust regression lines are linear and parallel for all years. In addition, this finding can be interpreted to mean that bean yield is linearly related to the amount of healthy foliage since the yield–rust relationship is linear.

Several cautions should be considered with this model. At lower levels of rust, yield probably is not reduced until a certain threshold of rust is reached. Ablett and Schaafsma (1990) and Woodbury and LeBaron (1959) showed that beans can tolerate a certain amount of photosynthetic leaf area reduction and defoliation before measurable seed yield loss is recorded. Also, at high rust severity, plants defoliate and make it impossible

Table 1. *Summary of severity of rust* (Uromyces appendiculatus) *and yield of dry beans* (Phaseolus vulgaris *L.) for each of 9 years at North Platte, Neb.*

Year	No. treatments	Seed yield (kg·ha^{-1}) Mean	Seed yield (kg·ha^{-1}) Range	Rust severity[z] (%)s (all treatments) Mean	Rust severity[z] (%)s (all treatments) Range
1981	7	2167	1694–2468	16.6	6.3–46.3
1982	11	2026	1649–2346	24.0	7.0–45.0
1983	14	1752	1229–2129	7.2	2.2–16.4
1984	19	1317	1011–1733	16.8	4.3–43.8
1985	12	1076	426–2365	53.1	14.5–75.0
1986	7	2377	1842–2798	14.1	6.4–23.0
1987	8	3380	3172–3689	4.2	0.5–16.0
1989	5	2991	2749–3293	11.4	4.0–23.0
1990	5	1541	1411–1739	13.8	7.0–22.0

[z]*Last number in column also represents rust severity of unprotected treatments.*

Table 2. *Dry bean* (Phaseolus vulgaris *L.) yields and severity of rust* (Uromyces appendiculatus) *for four fungicide treatments at North Platte, Neb., in 1986.*

Year	Fungicide	Application rate (kg·ha^{-1})	Application timing	Yield[z] (kg·ha^{-1})	Mean rust severity (%)
1986	Mancozeb	1.80	7/28, 8/11	2798 a	8.8
1986	Myclobutanil (40 W)	0.07	7/28, 8/11	2601 ab	6.0
1986	Myclobutanil (40 W)	0.14	7/28, 8/11	2508 ab	5.8
1986	Myclobutanil (60 DF)	0.07	7/28, 8/11	2329 b	6.4

[z]*Mean yields of treatments were compared for each year and application timing separately using a protected LSD(0.05).*

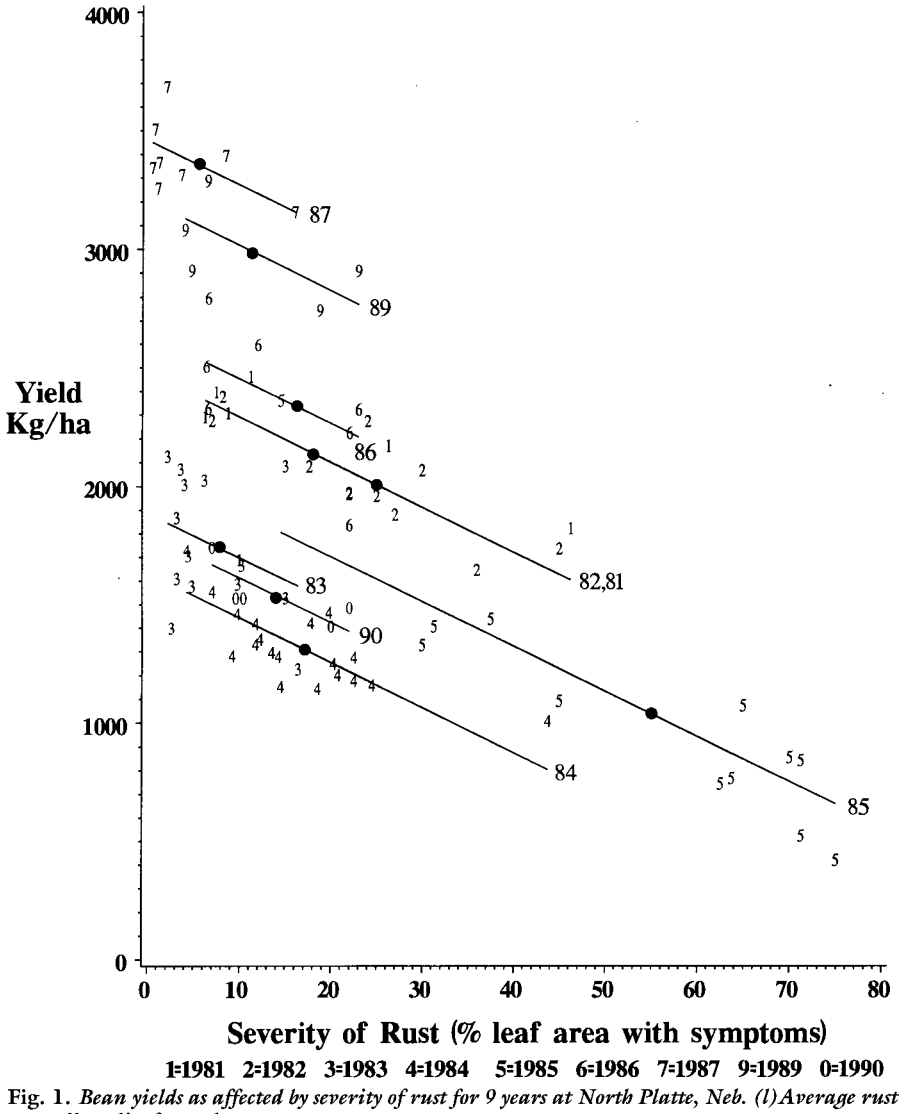

Fig. 1. *Bean yields as affected by severity of rust for 9 years at North Platte, Neb. (1)Average rust over all studies for each year.*

to approximate severity of rust based on percent of leaf area diseased. Even with moderate amounts of rust, small differences between treatments cannot always be detected accurately. In addition, the yield increase or decrease due to factors other than disease control could compromise the usefulness of a disease intensity-yield loss ANCOVA model based on disease trials conducted in different environments. Violation of the assumption that treatments affect yield by control of rust severity only would likely cause the slope coefficient and the intercepts for each environment to be biased.

In this study, appropriate comparisons of fungicide treatments were used to show that fungicides influenced yield mainly through the control of rust, although an exception did occur in comparisons between the sterol-inhibiting Myclobutanil (60 DF) and Mancozeb. The difference may be the result of the micronutrientsmanganeseand zinc, contained in Mancozeb, on bean growth and productivity. The other treatments in this study appeared to affect yield only through the reduction in severity of rust.

Although this study presents an average loss figure for one rust-susceptible pinto bean cultivar (UI 114) in west-central Nebraska, the data will be useful for the development of other models and to predict dry bean losses due to rust. Data on different cultivars and other locations should be collected to make accurate yield-loss assessments. The model also can be used to estimate rust-induced yield losses in kg·ha^{-1} for a year by multiplying by 19 the rust severity at 72 days. This model is a tool that can be used in combination with other procedures in making recommendations on management of rust even though it can have limitations.

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