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COST-BENEFIT AND STATISTICAL ANALYSIS OF FUNGICIDES FOR SUPPRESSION OF FUSARIUM HEAD BLIGHT (SCAB) IN HARD RED SPRING WHEAT IN 1997

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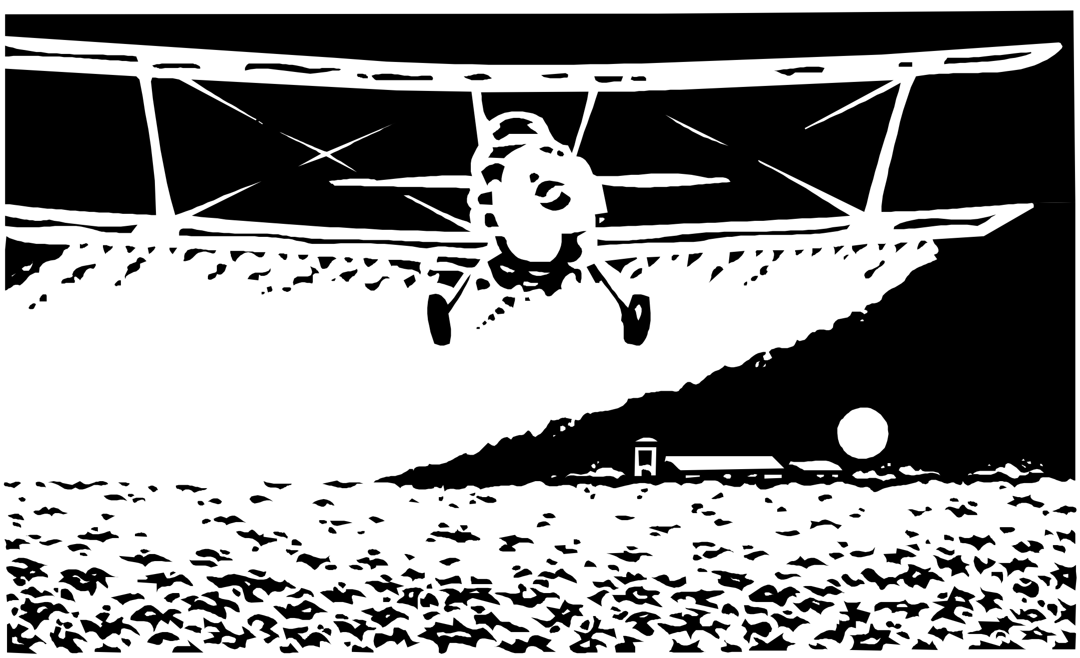

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Abstract

A cost-benefit and statistical analysis of fungicides for suppression of fusarium head blight (scab) in hard red spring wheat was completed on data from physical experiments done in Fargo and Carrington, North Dakota in 1997. Various fungicide data were analyzed by applying revenues and costs to the experiment yields to determine net revenue. The net revenues were analyzed statistically using a one-way ANOVA (analysis of variance). No statistical difference was found between the control and other treatment with the Fargo data. There was a statistical difference between the control and other treatments with the Carrington data. The data sets were combined and analyzed; location proved to be a significant factor.

Key Words: fusarium head blight, scab, fungicides, hard red spring wheat, cost-benefit, statistical, North Dakota

COST-BENEFIT AND STATISTICAL ANALYSIS OF FUNGICIDES FOR SUPPRESSION OF FUSARIUM HEAD BLIGHT (SCAB) IN HARD RED SPRING WHEAT IN 1997

Ronald H. Haugen and Dwight G. Aakre*

The Situation

Due to wet weather for several years (1993-1997) in North Dakota, the incidence of fusarium head blight (scab) in hard red spring wheat has had a negative economic affect on farmers and the state's economy. North Dakota has had cumulative losses of $458 million due to scab (Johnson et al., 1998). Scab affects yield and grain quality, and thus affects gross returns per acre. Foliar applied fungicides are available for scab suppression. This study looks at various registered and non-registered fungicides applied in experimental tests and interjects a statistical analysis and a cost-benefit analysis to the physical data. Data from experiments during 1997 at Fargo and Carrington, North Dakota were studied.

It should be noted that at the time of the experiments some fungicides used in this study may not have been registered for use by the Environmental Protection Agency or the North Dakota Department of Agriculture. It is illegal to use these fungicides until they are registered.

Background

Fusarium head blight (scab) attacks the kernel within the head. Wet and humid conditions at flowering are conditions that increase scab incidence. It reduces wheat yield and quality (Bowden et al., 1995). The blight produces a toxin called vomitoxin (scientific name: deoxynivalenol or DON). Vomitoxin may cause sickness in animals and humans (Johnson et al., 1995). Some varieties of wheat are less susceptible than others but to date no wheat is resistant to the disease. Yield losses are due to sterile flowers and formation of light test weight kernels sometimes called "tombstone" kernels. (McMullen and Stack, 1994). Wet preharvest conditions, similar to what occurred in North Dakota in the past five years, can lead to the growth of the mold in wheat.

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Objectives

This study had two main objectives:

1) To provide producers information concerning the management decision of whether to apply fungicides for suppression of scab.

2) To develop a model that can be used with scab data, so economic impacts can be determined.

Economic Model

A cost-benefit model was developed for this study. The model was not intended to forecast prices or costs, but to determine the economics of applying various fungicides. Both absolute and marginal costs were analyzed. Yield and prices were used for gross revenues. Additional costs were included from the fungicide application and interest on the application. The model integrated the experimental data with economic input and output prices to determine the economic returns for each fungicide. The same model was used for both the Fargo and Carrington data.

The economic model equation is:

Net Revenue = (Yield x Price) - Direct Costs - Fungicide Product Cost
- Fungicide Application Cost - Fungicide Application Operating Interest Cost.

Direct spring wheat production costs of $55.83 are subtracted from gross revenue (Swenson and Aakre, 1996). These direct costs are shown in Table 1. Indirect fixed costs such as depreciation and investment charges are not included for purposes of this study.

A fungicide application rate of $3.50 per acre is used (Aakre, 1996). This represents the most frequent reported custom rate. This rate is used for each product application in multiple application treatments. An interest charge of 10 percent for 6 months was used on the product and application cost (Swenson and Aakre, 1996).

The wheat price of $3.95 was used. This was the harvest price on August 29, 1997 at the Hunter Grain Company, Hunter, ND (Hunter Grain Company, 1998). This was the base price on 60 pound test weight and 14 percent protein. The prices are adjusted based on U.S. grading requirements, test weight and damage. Discounts are applied at the time of pricing. The U.S. grade requirements relevant for this study are test weight and total damage and are shown in Table 2 (U.S. Department of Agriculture, 1998). U.S. Sample grade is any grade that does not meet U.S. No. 1, 2, 3, 4 or 5. A test weight discount is also applied (Harvest States Cooperatives, 1998) as shown in Table 3. In addition, a damage discount is added (Hunter Grain Company, 1998). The damage discount scale is shown in Table 4.

Table 1. Direct Costs for Hard Red Spring Wheat Production.

Direct Costs	Dollars Per Acre
Seed	8.00
Herbicides	8.71
Fungicides	1.50
Insecticides	0.00
Fertilizer	14.13
Crop Insurance	3.60
Fuel & Lubrication	6.63
Repairs	9.60
Drying	0.00
Miscellaneous	1.00
Operating Interest	2.66
TOTAL	55.83

SOURCE: Swenson and Aakre, 1996.

Table 2. U.S. Grade Requirements for Hard Red Spring Wheat.

	Minimum limit of:	Maximum limit of:	
Grade	Test weight per bushel (lb.)	Total damaged kernels (%)	Discount per bushel ($)
U.S. No. 1	58.0	2.0	0.00
U.S. No. 2	57.0	4.0	0.10
U.S. No. 3	55.0	7.0	0.20
U.S. No. 4	53.0	10.0	0.30
U.S. No. 5	50.0	15.0	0.40
Sample Grade*	NA	NA	0.50

*Sample grade does not meet any requirements for U.S. No. 1, 2, 3, 4 or 5.
SOURCE: U.S. Department of Agriculture, 1988 and Hunter Grain Company, 1998.

Table 3. Spring Wheat Test Weight Discounts.

Test Weight in Pounds (discounted under 58 pounds)	Discount per bushel ($)
57.5 to 57.9	0.01
57.0 to 57.4	0.02
56.5 to 56.9	0.05
56.0 to 56.4	0.08
55.5 to 55.9	0.11
55.0 to 55.4	0.14
54.5 to 54.9	0.18
54.0 to 54.4	0.22

SOURCE: Harvest States Cooperatives, 1998.

Table 4. Damage Discounts.

Percent Damage	Discount per bushel ($)
1.0	0.02
2.0	0.04
3.0	0.06
4.0	0.08
5.0	0.10
6.0	0.13
7.0	0.16
8.0	0.19
9.0	0.22
6.0	0.25
11.0	0.30
12.0	0.35
13.0	0.40
14.0	0.45
15.0	0.50

SOURCE: Hunter Grain Company, 1998.

Total damage is used in grading wheat. There is a relationship between visible vomitoxin (DON) and total damage. Stack (1998) determined a relationship between vomitoxin parts per million and percent total damage. For the Fargo study, a factor of 1.4134275 was used to convert vomitoxin to percent damage. For the Carrington study, a factor of 0.7936507 was used to convert vomitoxin to percent damage. These conversion factors are based on historical data for each location.

Statistical Model

Statistics are applied to the calculated net revenues of each fungicide treatment. The net revenue is used because it is the residual after costs are subtracted from income. Test weight and quality discounts because of any scab damage are factors in determining net revenue. Fungicide application costs are also factored into the net revenue calculation.

Statistics was used to determine if the fungicide applications were significant. The null and alternative hypothesis are shown below.

null hypothesis:

$H_o: \mu_1 = \mu_2 = ... = \mu_k$

alternative hypothesis:

$H_a: \mu_i \neq \mu_j$ for i = 1 ,..., k and j = 1,..., k

where μ = the mean of the net revenues for each treatment.

The model is run with five scenarios. The base analysis used the $3.95 wheat price. A second analysis used a 10 percent higher wheat price of $4.35, all other variables were held constant. A third analysis used a 10 percent lower wheat price of $3.55, all other variables were held constant. A fourth analysis used a 20 percent higher fungicide price, all other variables were held constant. A fifth analysis used a 20 percent lower fungicide price, all other variables were held constant.

The model was run using SAS (SAS Institute Inc., 1998) software. A one-way ANOVA (analysis of variance), with an alpha of 0.05 was used. This would be at the 95 percent significance level.

Fargo Experiment

Data were from an experimental trial conducted at Fargo, North Dakota, by the NDSU Extension Service in the 1997 crop growing season. Various fungicides were applied on hard red spring wheat. The design of the experiment was to test various registered and non-registered fungicides to fusarium head blight (scab) suppression when applied only once, at early flowering period, at the recommended label rate.

Table 5 shows the information for the Fargo experiment. Six fungicide treatments were compared to the untreated check. The table shows the fungicide, code, number of applications, growth stage of application, application rate, cost per product unit and product cost per acre. Experimental fungicides are noted with an "E". Folicur has a "SE" code for a special exemption for North Dakota for 1997. A non-registered "NR" code is for a fungicide that was registered for use on other crops but not wheat. A registered "R" code is for fungicides registered for wheat at present. All fungicides were applied at the Feekes growth stage of 10.51. The cost per unit of the product was the cost at the time of the application. For experimental fungicides, the price of the highest priced competitive product was used.

Table 5. Fargo Fungicide Evaluations for Suppression of Fusarium Head Blight.

No	Code	Fungicide Treatment	No. Applic	Growth Stage at Application	Application Rate/Acre Product	Cost Per Unit ($)	Product Cost/Acre ($)
1	NA	Untreated	NA	NA	NA	NA	NA
2	SE	Folicur	1	10.51	4 fl oz	2.13	8.50
3	R	Tilt	1	10.51	4 fl oz	2.88	11.50
4	E	Opus	1	10.51	13.5 oz	0.85	11.50
5	E	Prochloraz	1	10.51	0.35 lbs ai	32.86	11.50
6	R	Benlate + Mancozeb	1	10.51	0.5 lb + 1.0 lb	16.50 + 3.25	11.50
7	NR	Bravo Weather Stik	1	10.51	1.5 pts	6.66	10.00

E = Experimental SE = Special ND exemption for 1997 (priced)
R = Registered for wheat (priced) NR = Not registered for wheat (priced) NA = Not applicable

Physical Results

The physical results from the Fargo experiment are shown in Table 6. It should be noted that yield and test weight differences were not significant at the 95 percent significance level. Vomitoxin percentage differences were significant at the 95 percent significance level.

Table 6. Physical Results of Fargo Experiment.

Fungicide Treatment	Yield (bushels per acre)	Test Weight (pounds per bushel)	DON (vomitoxin) (parts per million)
Untreated	26.1	59.4	4.5
Folicur	33.6	60.6	1.8
Tilt	33.0	59.4	2.4
Opus	33.3	60.2	2.5
Prochloraz	32.9	60.1	2.4
Benlate + Mancozeb	30.2	60.0	1.9
Bravo Weather Stik	30.9	60.0	2.1
LSD (0.05)	NS	NS	1.8

Statistical Results

The statistical results of the Fargo experiment are shown in Table 7.

Table 7. Statistical Results of Fargo Experiment.

Treatment	Observ-ations	Base Run Mean ($)	High Wheat Price ($)	Low Wheat Price ($)	High Fungicide Price ($)	Low Fungicide Price ($)
		Wheat price = $3.95 Fungicide prices = base price	Wheat price = $4.35 Fungicide prices = base price	Wheat price = $3.55 Fungicide prices = base price	Wheat price = $3.95 Fungicide prices = 20% higher	Wheat price = $3.95 Fungicide prices = 20% lower
Folicur	3	53.45	66.27	40.63	51.66	55.23
Prochloraz	3	49.01	61.75	36.26	46.59	51.42
Opus	3	48.70	61.40	36.01	46.29	51.12
Untreated	3	47.94	59.22	36.65	47.94	47.94
Tilt	3	47.66	60.26	35.05	45.24	50.07
Bravo WS	3	42.12	53.93	30.31	40.02	44.22
Benlate+ Mancozeb	3	38.40	49.96	26.86	35.99	40.82
P-values (95%)		0.6553	0.6695	0.6281	0.6030	0.6774

Table 7 shows the order from highest to lowest net revenues for each treatment for the base run. The order for the most part did not vary for each run. Only the magnitude of the net revenues varied. There were three exceptions. The Tilt treatment did have higher net revenue than the untreated treatment for the high wheat price run. The untreated treatment came in second to Folicur in the low wheat price and the high fungicide price analysis. P-values indicate there was not a significant difference between the untreated and treated plots. The means are reported and discussed but no conclusions should be made because they were not significantly different.

Carrington Experiment

Data were from an experimental trial conducted at Carrington, North Dakota, by the NDSU Agricultural Experiment Station in the 1997 crop growing season. Various fungicides were applied on hard red spring wheat. The design of the experiment was to test various registered and non-registered fungicides for fusarium head blight (scab) suppression when applied at various growth rates at various application rates. Three valid repetitions of each treatment were used for this study.

Table 8 shows the information for the Carrington experiment. Nineteen fungicide treatments were evaluated. The table shows the fungicide, code, number of applications, growth stage of application, application rate, cost per product unit and product cost per acre. Experimental fungicides are noted with an "E". Folicur has a "SE" code for a special exemption for North Dakota for 1997. A non-registered "NR" code is for a fungicide that was registered for use on other crops but not wheat. A registered "R" code is for fungicides registered for wheat at present. The table shows the number of applications and the various Feekes growth stages for each application. The cost per unit of the product is the cost at the time of the application. For experimental fungicides, the price of the highest priced competitive product was used.

Physical Results

Physical results for the Carrington experiment are shown in Table 9. Yield, test weight and vomitoxin results were significant at the 95 percent level.

Table 8. Carrington Fungicide Evaluations for Suppression of Fusarium Head Blight.

No	Code	Fungicide Treatment	No. Applic	Growth Stage at Application	Application Rate/Acre Product	Cost Per Unit ($)	Product Cost/Acre ($)
1	NR	Bravo Ultrex	1	10.5	1.4 lb	5.50	7.70
2	NR	Bravo Ultrex	2	8.0 + 10.5	1.4 + 1.4 lb	5.50	15.40
3	NR	Bravo Ultrex	3	8.0 + 10.1 + 10.5	0.9 + 1.4 + 1.4 lb	5.50	20.35
4	NR	Bravo Weather Stik	3	8.0 + 10.1 + 10.5	1.0 + 1.5 + 1.5 pt	6.66	26.64
5	E	Quadris + COC	3	10.5	0.4793 pt + 22.4 oz (1.0%v/v)	21.53 + 0.0527	11.50
6	E	Quadris + COC	1	10.5	0.7669 pt + 22.4 oz (1.0%v/v)	21.53 + 0.0527	17.69
7	E	Quadris + Benlate + COC	1	10.5	0.4793 pt + 0.5 lb + 22.4 oz (1.0%v/v)	21.53 + 16.50 + 0.0527	19.75
8	E	Quadris + Benlate + COC	1	10.5	0.7669 pt + 0.5 lb + 22.4 oz (1.0%v/v)	21.53 + 16.50 + 0.0527	25.94
9	R	Benlate	1	10.5	0.5 lb	16.50	8.25
10	SE	Folicur + NIS	1	10.3	4.0 fl oz + 5.6 fl oz (0.25%v/v)	2.13 + 0.1773	9.50
11	E	Opus	1	10.5	10.0 oz	0.85	8.50
12	E	Opus	1	10.5	20.0 oz	0.85	17.00
13	E	Opus	2	10.1 + 10.5	10.0 + 10.0 oz	0.85	17.00
14	R	Benlate + Mancozeb	1	10.5	0.5 + 1.0 lb	16.50 + 3.25	11.50
15	R	Benlate + Mancozeb	2	10.5.1 + 10.5.3	0.5 + 1.0 lb	16.50 + 3.25	23.00
16	R	Benlate + Mancozeb	2	10.5.1 + 10.5.3	0.25 + 0.5 lb	16.50 + 3.25	11.52
17	R	Tilt	1	10.5	4.0 fl oz	2.88	11.50
18	E	Prochloraz	1	10.5	0.35 lbs ai	32.86	11.50
19	NA	Untreated	NA	NA	NA	NA	NA

E = Experimental (no price estimate)   SE = Special ND exemption for 1997 (priced)
R = Registered for wheat (priced)   NR = Not registered for wheat (priced)   NA = Not applicable

Table 9. Physical Results of Carrington Experiment.

Fungicide Treatment	No. Applic	Application Rate/Acre Product	Yield (bushels per acre)	Test Weight (pounds per bushel)	DON (vomitoxin) (parts per million)
Bravo Ultrex	1	1.4 lb	42.6	57.0	7.3
Bravo Ultrex	2	1.4 + 1.4 lb	42.3	57.3	7.8
Bravo Ultrex	3	0.9 + 1.4 + 1.4 lb	38.1	55.3	5.8
Bravo Weather Stik	3	1.0 + 1.5 + 1.5 pt	38.9	55.8	6.1
Quadris + COC	3	0.4793 pt + 22.4 oz (1.0%v/v)	47.1	58.3	9.0
Quadris + COC	1	0.7669 pt + 22.4 oz (1.0%v/v)	47.3	58.3	12.2
Quadris + Benlate + COC	1	0.4793 pt + 0.5 lb + 22.4 oz (1.0%v/v)	49.3	59.0	5.9
Quadris + Benlate + COC	1	0.7669 pt + 0.5 lb + 22.4 oz (1.0%v/v)	50.0	58.8	6.0
Benlate	1	0.5 lb	47.5	59.0	4.5
Folicur + NIS	1	4.0 fl oz + 5.6 fl oz (0.25%v/v)	49.6	58.8	5.8
Opus	1	10.0 oz	49.2	59.3	6.9
Opus	1	20.0 oz	45.1	58.0	7.7
Opus	2	10.0 + 10.0 oz	47.8	58.3	9.1
Benlate + Mancozeb	1	0.5 + 1.0 lb	49.8	59.5	3.3
Benlate + Mancozeb	2	0.5 + 1.0 lb	50.9	59.5	3.2
Benlate + Mancozeb	2	0.25 + 0.5 lb	48.1	58.8	4.6
Tilt	1	4.0 fl oz	46.5	58.3	8.7
Prochloraz	1	0.35 lbs ai	50.5	58.8	6.8
Untreated	NA	NA	40.2	57.5	9.5
LSD (0.05)	NA	NA	3.2	1.0	1.93

Statistical Results

The statistical results of the Carrington experiment are shown in Tables 10, 11, 12, 13 and 14. There was a significant difference between the treatments. Fungicide treatments were grouped by the degree of variability of mean net revenues. Table 10 shows the base run, Table 11 shows the high wheat price run, Table 12 shows the low wheat price run, Table 13 shows the high fungicide run and Table 14 shows the low fungicide run. The P-values for all of these runs were 0.0001.

Treatments within the same group do not have statistically significant differences. Only treatments in separate groups (not over lapping) have significantly different means.

The base run results are shown in Table 10, there are ten groupings of significance (from A to J). Only groups that are not overlapping are significantly different. Group A includes treatments from Benlate+Mancozeb, with the highest mean net revenue of $118.54, to Benlate+Mancozeb (two applications), with a net revenue of $101.64. Benlate+Mancozeb, Folicur+NIS, Prochloraz, Benlate, Opus and Quadris+Benlate+COC are significantly different than the untreated check. Also, in Group I and J, Bravo Ultrex and Bravo Weather Stick, both with three applications, have significantly lower mean net revenues than the untreated check.

Table 11 shows results using the higher wheat price of $4.35. There is an overall higher magnitude of mean net revenues. It should be noted that Opus (with two 10 ounce treatments) had a slightly higher mean net revenue than the untreated control. The base run showed Opus with slightly lower mean net revenue than the untreated control.

Table 12 shows results using a lower wheat price of $3.55. There is an overall lower magnitude of mean net revenues. The groupings of significance changed compared to the base run. Group A still includes Benlate+Mancozeb (single application). Group A does not include the Benlate+Mancozeb with multiple treatments.

Table 13 shows results using 20 percent higher fungicide prices. The magnitude of mean net revenues decreased. Benlate+Mancozeb (single treatment) is in Group A. Group A includes Benlate+Mancozeb (split application with low rates) but not Benlate+Mancozeb (split application with high rates).

Table 14 shows results using 20 percent lower fungicide prices. The magnitude of mean net revenues increased. The groupings of significance basically did not change. One exception is that the untreated control had a lower mean net revenue than the Opus (two 10 ounce applications) and Quadris+COC (high rate) treatments.

Generally, multiple applications had lower net revenues with the exception of Opus. Opus with two 10 ounce applications had consistently higher net revenue than Opus with one 20 ounce treatment. Benlate+Mancozeb with one application at 0.5 and 1.0 pounds per acre respectively had higher net revenues in all scenarios.

In the high wheat price scenario, mean net revenues for treatments were higher than the base scenario. In the low wheat price scenario, mean net revenues for treatments were lower than the base scenario. In the high fungicide price scenario, mean net revenues for treatments were lower than the base scenario. In the low fungicide price scenario, mean net revenues for treatments were higher than the base scenario.

Table 10. Base Results of Carrington Experiment.

Fungicide Treatment	No. Applic	Application Rate/Acre Product	Mean Net Revenue ($)	Grouping									
Benlate + Mancozeb	1	0.5 + 1.0 lb	118.54	A									
Folicur + NIS	1	4.0 fl oz + 5.6 fl oz (0.25%v/v)	115.61	A	B								
Prochloraz	1	0.35 lbs ai	115.39	A	B								
Benlate	1	0.5 lb	112.79	A	B	C							
Opus	1	10.0 oz	109.35	A	B	C							
Quadris + Benlate + COC	1	0.4793 pt + 0.5 lb + 22.4 oz (1.0%v/v)	104.83	A	B	C							
Benlate + Mancozeb	2	0.5 + 1.0 lb	103.17	A	B	C	D						
Benlate + Mancozeb	2	0.25 + 0.5 lb	101.64	A	B	C	D	E					
Tilt	1	4.0 fl oz	100.09		B	C	D	E	F				
Quadris + Benlate + COC	1	0.7669 pt + 0.5 lb + 22.4 oz (1.0%v/v)	98.30			C	D	E	F	G			
Quadris + COC	1	0.4793 pt + 22.4 oz (1.0%v/v)	95.84			C	D	E	F	G			
Untreated	NA	NA	87.09				D	E	F	G	H		
Opus	2	10.0 + 10.0 oz	85.83					E	F	G	H		
Quadris + COC	1	0.7669 pt + 22.4 oz (1.0%v/v)	83.53						F	G	H		
Bravo Ultrex	1	1.4 lb	83.37						F	G	H		
Opus	1	20.0 oz	82.06							G	H		
Bravo Ultrex	2	1.4 + 1.4 lb	75.24								H	I	
Bravo Ultrex	3	0.9 + 1.4 + 1.4 lb	59.16									I	J
Bravo Weather Stik	3	1.0 + 1.5 + 1.5 pt	47.01										J

*Wheat price = $3.95, fungicide prices = base price.

Table 11. High Wheat Price Results of Carrington Experiment.

Fungicide Treatment	No. Applic	Application Rate/Acre Product	Mean Net Revenue ($)	Grouping									
Benlate + Mancozeb	1	0.5 + 1.0 lb	138.32	A									
Prochloraz	1	0.35 lbs ai	135.89	A	B								
Folicur + NIS	1	4.0 fl oz + 5.6 fl oz (0.25%v/v)	135.48	A	B								
Benlate	1	0.5 lb	131.89	A	B	C							
Opus	1	10.0 oz	128.85	A	B	C							
Quadris + Benlate + COC	1	0.4793 pt + 0.5 lb + 22.4 oz (1.0%v/v)	124.82	A	B	C							
Benlate + Mancozeb	2	0.5 + 1.0 lb	123.17	A	B	C	D						
Benlate + Mancozeb	2	0.25 + 0.5 lb	120.52	A	B	C	D	E					
Tilt	1	4.0 fl oz	119.29		B	C	D	E					
Quadris + Benlate + COC	1	0.7669 pt + 0.5 lb + 22.4 oz (1.0%v/v)	118.50		B	C	D	E	F				
Quadris + COC	1	0.4793 pt + 22.4 oz (1.0%v/v)	114.81			C	D	E	F	G			
Opus	2	10.0 + 10.0 oz	104.76				D	E	F	G	H		
Untreated	NA	NA	103.61					E	F	G	H		
Quadris + COC	1	0.7669 pt + 22.4 oz (1.0%v/v)	102.69					E	F	G	H		
Bravo Ultrex	1	1.4 lb	100.26						F	G	H		
Opus	1	20.0 oz	99.86							G	H		
Bravo Ultrex	2	1.4 + 1.4 lb	92.53								H	I	
Bravo Ultrex	3	0.9 + 1.4 + 1.4 lb	75.78									I	J
Bravo Weather Stik	3	1.0 + 1.5 + 1.5 pt	67.28										J

*Wheat price = $4.35, fungicide prices = base price.

Table 12. Low Wheat Price Results of Carrington Experiment.

Fungicide Treatment	No. Applic	Application Rate/Acre Product	Mean Net Revenue ($)	Grouping							
Benlate + Mancozeb	1	0.5 + 1.0 lb	98.76	A							
Folicur + NIS	1	4.0 fl oz + 5.6 fl oz (0.25%v/v)	95.75	A	B						
Prochloraz	1	0.35 lbs ai	94.90	A	B						
Benlate	1	0.5 lb	93.70	A	B						
Opus	1	10.0 oz	89.85	A	B	C					
Quadris + Benlate + COC	1	0.4793 pt + 0.5 lb + 22.4 oz (1.0%v/v)	84.84	A	B	C	D				
Benlate + Mancozeb	2	0.5 + 1.0 lb	83.17		B	C	D				
Benlate + Mancozeb	2	0.25 + 0.5 lb	82.77		B	C	D	E			
Tilt	1	4.0 fl oz	80.86		B	C	D	E			
Quadris + Benlate + COC	1	0.7669 pt + 0.5 lb + 22.4 oz (1.0%v/v)	78.09			C	D	E	F		
Quadris + COC	1	0.4793 pt + 22.4 oz (1.0%v/v)	76.88			C	D	E	F		
Untreated	NA	NA	70.58				D	E	F	G	
Opus	2	10.0 + 10.0 oz	66.90					E	F	G	
Bravo Ultrex	1	1.4 lb	66.48					E	F	G	
Quadris + COC	1	0.7669 pt + 22.4 oz (1.0%v/v)	64.38						F	G	
Opus	1	20.0 oz	64.26						F	G	
Bravo Ultrex	2	1.4 + 1.4 lb	57.95							G	
Bravo Ultrex	3	0.9 + 1.4 + 1.4 lb	42.55								H
Bravo Weather Stik	3	1.0 + 1.5 + 1.5 pt	30.75								H

*Wheat price = $3.55, fungicide prices = base price.

Table 13. High Fungicide Price Results of Carrington Experiment.

Fungicide Treatment	No. Applic	Application Rate/Acre Product	Mean Net Revenue ($)	Grouping								
Benlate + Mancozeb	1	0.5 + 1.0 lb	116.13	A								
Folicur + NIS	1	4.0 fl oz + 5.6 fl oz (0.25%v/v)	113.62	A	B							
Prochloraz	1	0.35 lbs ai	112.98	A	B							
Benlate	1	0.5 lb	111.06	A	B							
Opus	1	10.0 oz	107.56	A	B	C						
Quadris + Benlate + COC	1	0.4793 pt + 0.5 lb + 22.4 oz (1.0%v/v)	100.68	A	B	C	D					
Benlate + Mancozeb	2	0.25 + 0.5 lb	99.23	A	B	C	D	E				
Benlate + Mancozeb	2	0.5 + 1.0 lb	98.34		B	C	D	E	F			
Tilt	1	4.0 fl oz	97.67		B	C	D	E	F			
Quadris + COC	1	0.4793 pt + 22.4 oz (1.0%v/v)	93.43			C	D	E	F	G		
Quadris + Benlate + COC	1	0.7669 pt + 0.5 lb + 22.4 oz (1.0%v/v)	92.85			C	D	E	F	G		
Untreated	NA	NA	87.09				D	E	F	G	H	
Opus	2	10.0 + 10.0 oz	82.26					E	F	G	H	
Bravo Ultrex	1	1.4 lb	81.75						F	G	H	
Quadris + COC	1	0.7669 pt + 22.4 oz (1.0%v/v)	79.82							G	H	
Opus	1	20.0 oz	78.49							G	H	
Bravo Ultrex	2	1.4 + 1.4 lb	72.01								H	
Bravo Ultrex	3	0.9 + 1.4 + 1.4 lb	54.89									I
Bravo Weather Stik	3	1.0 + 1.5 + 1.5 pt	41.41									I

*Wheat price = $3.95, fungicide prices = 20% higher.

Table 14. Low Fungicide Price Results of Carrington Experiment.

Fungicide Treatment	No. Applic	Application Rate/Acre Product	Mean Net Revenue ($)	Grouping								
Benlate + Mancozeb	1	0.5 + 1.0 lb	120.96	A								
Prochloraz	1	0.35 lbs ai	117.81	A	B							
Folicur + NIS	1	4.0 fl oz + 5.6 fl oz (0.25%v/v)	117.61	A	B							
Benlate	1	0.5 lb	114.53	A	B	C						
Opus	1	10.0 oz	111.13	A	B	C						
Quadris + Benlate + COC	1	0.4793 pt + 0.5 lb + 22.4 oz (1.0%v/v)	108.98	A	B	C						
Benlate + Mancozeb	2	0.5 + 1.0 lb	108.00	A	B	C						
Benlate + Mancozeb	2	0.25 + 0.5 lb	104.06	A	B	C	D					
Quadris + Benlate + COC	1	0.7669 pt + 0.5 lb + 22.4 oz (1.0%v/v)	103.75		B	C	D					
Tilt	1	4.0 fl oz	102.50		B	C	D	E				
Quadris + COC	1	0.4793 pt + 22.4 oz (1.0%v/v)	98.26			C	D	E	F			
Opus	2	10.0 + 10.0 oz	89.40				D	E	F	G		
Quadris + COC	1	0.7669 pt + 22.4 oz (1.0%v/v)	87.25				D	E	F	G		
Untreated	NA	NA	87.09				D	E	F	G		
Opus	1	20.0 oz	85.63					E	F	G		
Bravo Ultrex	1	1.4 lb	84.98						F	G		
Bravo Ultrex	2	1.4 + 1.4 lb	78.47							G	H	
Bravo Ultrex	3	0.9 + 1.4 + 1.4 lb	63.44								H	I
Bravo Weather Stik	3	1.0 + 1.5 + 1.5 pt	52.61									I

*Wheat price = $3.95, fungicide prices = 20% lower.

Combination of Experiments

The data for the Fargo and Carrington experiments were combined into one statistical run. Only the chemicals common for each experiment were used in this analysis. A "RCBD" or Randomized complete block design was used. This test was done to determine if there was any significant difference between treatments as a result of location. The results indicated that there was no significant difference in treatments (P-value = 0.1577); however, there was significant differences in the "blocks" or locations (P-value = 0.0001). Location affected net revenue. The statistical results are shown in Table 15. It should be noted that the Carrington control plot showed significantly low net revenue.

Table 15. Results of Combined Experiments.

Fungicide Treatment	Number of Observations	Mean Net Revenue	Standard Deviation
Benlate + Mancozeb	6	78.47	44.7204
Untreated	6	67.52	25.6933
Folicur	6	84.53	35.3495
Prochloraz	6	82.20	37.3735
Tilt	6	73.87	28.9062

Conclusions

The conclusions based on the Fargo experiment indicate there is no significant difference in net revenue by applying fungicides versus not applying. In comparing the return over variable costs, there is no statistically significant difference. The means vary, but the variances about the means are too large. In comparing one fungicide to another, it is not statistically proper to compare the means when they are not significantly different.

Results at Carrington indicated that some treatments consistently provided significantly higher economic returns than when left untreated. This was true at alternative prices for wheat and fungicides. Disease was more severe at the Carrington site, as indicated by the high vomitoxin levels and the lower test weights. Response to fungicide application was more positive than in Fargo. Thus, variation in environmental conditions that affect disease development and yield potential will affect results from fungicide application.

The first objective of this study was accomplished in regards to the Fargo and Carrington experiments. Data were analyzed and can be made available to producers. The second objective was achieved. We now have a model and procedure that can be used to analyze other fungicide experiments.

The study may be limiting because in any cost-benefit analysis, the conclusions are based on the inputs and prices used on the date of the analysis. An effort was made to use inputs and prices to be as representative as possible.

This study proved to be a model for future statistical studies. Economics applied to the physical results may yield different results. This model should be used in the future with NDSU and other data.

There is a need for further study in this area. This analysis was based on only one year's data. More data points (observations) would be helpful in determining significance differences. Biological data does have great variability based on many factors such as rainfall, temperature, soil nutrients, insects, weeds, and disease. The more observations studied the greater the chance of factoring out the variability.

Further study is needed to verify the differences in fungicide products and conditions of application. One needs to look at the physical results as well as the economic results.

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