AN EVALUATION OF THE SOURCES, ACCURACY, AND AVAILABILITY OF THE INPUT DATA REQUIRED TO RUN FEYERHERM'S WINTER WHEAT MODEL AND PRELIMINARY TESTING PERFORMED BY DR. FEYERHERM

Working Paper

This Working Paper was prepared as part of the AgRISTARS Yield Model Development (YMD) Project. It is part of Subtask 2 in Task 3 of Major Project Element Number 1 as identified in the Project Implementation Plan for Fiscal Years 1981 and 1982.

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INTRODUCTION

As part of Research Agreement No. 58-319T-0-0337X, Dr. Arlin M. Feyerherm has supplied us with the input data needed to run his Winter Wheat Model for Indiana, Kansas, Montana and Ohio. The input data which Dr. Feyerherm supplied have been reviewed in this paper for accuracy and availability. This is the beginning process in evaluating his model as part of the AgRISTARS model evaluation program. The data were checked using independent sources where possible. Data generating programs WRVPGM'82 and DYAPGM'82 were run. We also conducted a review of the predicted yields for the bootstrap test years provided by Dr. Feyerherm. This paper summarizes the results of this review process.

Each of the variables (or group of variables) shown below is described in this paper:

AVNI	WRV's
EEF	ET, XPR, TEMP, WX
AVE_DYA	
YIELD	

A list of the data sources is included in an appendix. There is also an appendix for each variable (or group of variables) listed above which shows the comparisons between Feyerherm's values and our values (YES). In some cases comparisons are not shown because the values were identical.

AVNI

AVNI = Average amount of nitrogen applied (lbs/acre)

= (Rate/acre receiving N) * (% of acres receiving N)

Our Sources:

1971-1979 - Fertilizer Situation report, published annually by the Economic Research Service (ERS). These data are published as "All Wheat," originating from sample fields of the Objective Yield Surveys of the Statistical Reporting Service (SRS). Kansas, Indiana, and Ohio are winter wheat states only and, therefore, these data are directly applicable. But Montana carries out the objective yield survey for winter, other spring and durum wheat. So it is not entirely clear that these data are directly applicable. The number of sample fields for 1982 in Montana are winter - 55, other spring - 70, and durum - 40. In order to make these data applicable, we must assume the fertilizer is applied to all 3 types of wheat at the same rate.

1964-1970 - Cropping Practices report, published June 1971 by SRS. These data also originate from the Objective Yield Surveys of SRS and are directly applicable for all states with the exception of Montana (reasons stated above).

1959 - Commercial Fertilizer Used on Crops and Pasture in the United States, Statistical Bulletin #348, published by ERS and ARS (Agricultural Research Service). These data are for all wheat acreage and originate from the 1959 Census of Agriculture.

1954 - Fertilizer Used on Crops and Pastures in the United States, Statistical Bulletin #216, published by ARS. These data are for all wheat acreage and originated from the 1954 Census of Agriculture. A problem arises with the 1954 data in that rate/acre receiving N is not given as a column as it is in 1964. What is available is percent of harvested acreage fertilized. If all three nutrients are applied to the same percentage of harvested acreage, then AVNI can be calculated. A look at the 1964 data shows that this is the case for Indiana and Ohio, but not for Kansas and Montana. In order to use what is available, then it must be assumed that in 1954 all 3 nutrients were applied to the same percentage of harvested acreage.

Check-Edit of Feyerherm Data: All AVNI values were checked with our sources with the results shown in Appendix for AVNI. No nitrogen data were available for years 1955-1958 and 1960-1963. Feyerherm interpolated for these years, as did YES, and one error was found. AVNI for 1959 in Kansas had been miscalculated causing the interpolations between 1955-1958 and 1960-1963 to be slightly off. The only significant difference was for 1979 in Montana. Other small differences due to rounding were encountered. Values are shown in the appendix for AVNI.

EEF - (RUST LOSS)

EEF = Percent loss in yield due to stem and leaf rust.

Sources:

1955-1976 - Estimated Losses Caused by Rust in the Small Grain Cereals in the United States - 1918-1976, March 1978, published by USDA/ARS as Miscellaneous Publication 1363.

1977-1979 - Yearly reports of Preliminary Estimated Losses from Rust in 1977, 1978, 1979, respectively, produced by USDA Cereal Rust Laboratory, St. Paul, Minnesota.

All years were checked with no errors found. Values are shown in the appendix for EEF.

AVE_DYA (AVERAGE DIFFERENTIAL YIELDING ABILITY)

Weighted state-wide averages of DYA values in bushels/acre for a given year are calculated by:

$$AVE\_DYA = \sum_{k=1}^{N} q_k * DYA_k \Big/ \sum_{k=1}^{N} q_k$$

where q_k = percent of acres planted to variety k in the specified years,

and DYA = the differential yielding ability of variety k, and

N = number of varieties.

The DYA value for a specific variety (V) is the average difference in yield between variety V and a base variety (O). The formula is:

$$DYA = \frac{1}{n} \sum_{i=1}^{n} (Y_{vi} - Y_{oi})$$

where n = number of location-years with both variety (V) and variety (O) present in a performance trial, and

Y_{vi}, Y_{oi} = yields in the ith performance trial.

Intermediate standards were used when n was too small for an acceptable variance for the mean difference, or when a direct comparison could not be made. Values of AVE_DYA were obtained by interpolation for the years q values were not available.

Feyerherm's sources were as follows:

Reitz, L. P., L. W. Briggle, 1960. Distribution of the varieties and classes of wheat in the United States in 1959. USDA Statistical Bulletin 272.

Reitz, L. P., K. L. Lebsock, G. D. Hasenmyer, 1972. Distribution of the varieties and classes of wheat in the United States in 1969. USDA Statistical Bulletin 475.

Reitz, L. P., W. G. Hamblin, 1978. Distribution of the varieties and classes of wheat in the United States in 1974. USDA Bulletin 604.

Our Sources:

Dr. Feyerherm provided us with a tape containing varietal performance trial data and the DYA program on cards. This is the same data that he used. Since Dr. Feyerherm contacted most of the experiment stations in these four states (and some surrounding states), no independent source exists for this data. The data come from published reports of the experiment stations. Yearly updates can be obtained by contacting the people listed in Section VII.C of the Data Base Documentation for Test Data for KSU Winter Wheat Model. Check-data for percentages of acres planted to the different varieties came from the Annual Crop and Livestock Statistical Bulletins from each of the four states.

For 1970-1979, Dr. Feyerherm used the same sources that we did, namely bulletins from the SSO's (State Statistical Offices), to obtain q values (varietal percentages). Montana, Kansas and Indiana have varietal percentage figures available for 1970-1979, but Ohio only had data for 1974 and 1979 during the test period.

The authors (of Statistical Bulletin 475) state that their procedures for calculating the varietal percentages differ somewhat from those used in the SSO's. The base acreages used for crop reporting districts were preliminary figures and are therefore subject to revision. These factors account for the differences discovered in the planted percentages when SSO bulletins were used to compare q values for the early years. Therefore, the percentage to use depends on the source selected, and no "best" set of data exists.

Comparison of DYA values

Feyerherm used all trial data through 1969 to compute DYA values for 1954, 1959, 1964, and 1969. After 1969, DYAPGM'82 was run for each subsequent year using data up to and including that year.

Location of performance trials:

1. Montana - all experiment stations in Montana, North Dakota, and South Dakota
2. Kansas - all experiment stations in Kansas
3. Indiana and Ohio - all experiment stations in Missouri, Illinois, Indiana, and Ohio.

The way in which Feyerherm ran DYAPGM'82 on his data was duplicated in order to check the DYA values in Table 1 of the Data Base Documentation for Test Data for KSU Winter Wheat Model. The following differences were encountered:

State	Year	Variety	F DYA	YES DYA	Caused change in AVE_DYA ?
Montana	1970	Lancer	.2	.3	no
Kansas	1972	Chanute	1.4	1.5	no
Indiana	1964	Redcoat	7.2	7.3	no
Indiana	1964	Redcoat	6.4	6.7	no
Indiana	1969	Redcoat	7.2	7.3	no
Indiana	1969	Reed	6.4	6.7	no
Indiana	1969	Riley	2.5	2.6	no
Indiana	1975	Oasis	12.5	12.6	no
Indiana	1977	Oasis	12.8	12.9	yes
Indiana	1978	Arthur 71	14.0	13.9	no
Ohio	1964	Lucas	5.3	5.5	no
Ohio	1969	Redcoat	7.2	7.3	no
Ohio	1969	Reed	6.4	6.7	no
Ohio	1974	Reed	7.7	7.9	no

Most of these differences are not very great. The miscalculation on Reed was carried for several years. It should also be noted that although these differences were found, they did not often lead to a change in the AVE_DYA for that year (only 1 out of 14).

The following is a list of the AVE_DYA values which YES calculated to be different from Feyerherm's figures:

State	Year	Feyerherm's AVE_DYA	YES AVE_DYA	Difference
Montana	1971	-0.5	-0.6	0.1
Kansas	1972	3.2	3.1	0.1
Indiana	1977	12.6	12.7	-0.1
Ohio	1964	3.8	3.9	-0.1
Ohio	1979	13.4	13.9	-0.5

These differences are not very great except for Ohio in 1979. Values of AVE_DYA are shown in the appendix.

YIELD

Yield = USDA estimate of state-wide yield per harvested acre.

Yields in the test data set were compared with the data which YES maintains in a data base on the NOAA computer system. Only three discrepancies were found, and they were verified with the individual SSO's. They are as follows:

State	Year	Yield	
		Feyerherm	YES
Indiana	1974	36.0	37.5
Indiana	1975	43.0	44.0
Ohio	1979	45.0	48.0

Values are shown in the appendix for yield.

OBTAINING WRV'S (WEATHER RELATED VARIABLES)

WRVPGM'82 is a system of subroutines which uses daily weather data as input, and computes WRV's. The WRV's are averages/sums of temperatures, precipitation, plant available moisture, evapotranspiration amounts, potential evapotranspiration amounts, and excessive moisture amounts which correspond to the stages in the life of a plant. These WRV's are then used to develop the WX values (weather index). Dr. Feyerherm had previously provided us with the subroutines, in the form of cards, for use in evaluating his spring wheat model. For this project we were provided with updated versions of several of the subroutines. WRVPGM'82 is an updated version of WRVPGM'80. We were also provided with documentation on the implementation of the WRV program, and also the values of the WRV's for each of the weather stations.

As an exercise to check these WRV's and to become more familiar with the program, we chose the Goodland, Kansas station for testing purposes, using daily weather data supplied by NOAA. Feyerherm obtained his weather data from the National Climatic Center located at Asheville, North Carolina. WRVPGM'82 outputs over 80 weather related variables (described in Appendix WRV). The WRV's are then combined to form three main components of the WX (weather index). These components are discussed in the next section.

ET, XPR, TEMP, and WX

ET: Evapotranspiration effects

XPR: Excessive precipitation effects

TEMP: Temperature effects

WX: 72.6 + ET + XPR + TEMP

These components are in units of bushels per acre. The comparison of Feyerherm components and the YES computed components for Goodland, Kansas are shown in the appendix for WX. Minor differences occurred for all components and the WX. Two major differences occurred with the XPR component in 1975 and 1979; in 1975 Feyerherm's value was -4.02, YES value was -2.80 and in 1979 Feyerherm's value was -3.75 and YES value was -2.84. These discrepancies did not cause drastic differences in the WX variable. In general, the two sets of figures were quite close.

The weather stations used by Dr. Feyerherm are as follows:

No.	Montana	Kansas	Indiana	Ohio
1	Cutbank	Goodland	South Bend	Toledo
2	Great Falls	Garden City	Fort Wayne	Findlay
3	Havre	Dodge City	Indianapolis	Cleveland
4	Glasgow	Concordia	W. Lafayette	Akron
5	Miles City	Salina	Evansville	Mansfield
6	Lewiston	Russell		Columbus
7	Helena	Wichita		Youngstown
8	Billings	Topeka		Cambridge
9		Chanute		Dayton
10				Cincinnati

A description of each WRV calculated is given in the appendix for WRV.

BOOTSTRAP TESTING

Model testing was accomplished under four situations. To begin with, yield was defined in two different ways. One was to use USDA reported yield per harvested acre. The other was to adjust this yield for stem and leaf rust. The adjusted yield was

$$ADTYIELD = YIELD + LOSS$$

where $LOSS = EEF/(100-EEF) * YIELD$ and

EEF is defined as stated earlier in this paper. There were also two ways to estimate the "trend" component. One was to extrapolate, Trend = (Test year - 55). The second was to let Trend = (Test year - 1 - 55) and add on the increase in technology attributed to improved varieties (AVE_DYA) plus that due to nitrogen (.11 * AV_NI). So,

$$\Delta TECH = (TECH)_{\text{test year}} - (TECH)_{\text{previous year}}$$

where the value of TECH is

$$TECH = AVE\_DYA + .11 * AV\_NI.$$

Combining the two ways of defining yield and the two methods of estimating trend, the model can be tested under four different situations:

Model	Rust Losses	Estimating Trend
1	unknown	extrapolation
2	unknown	use of ΔTECH
3	known	extrapolation
4	known	use of ΔTECH

The following test results were obtained and compared to Feyerherm's values for the test years 1970-1979. Some minor differences occurred but are probably due to rounding.

	Model 1		Model 2		Model 3		Model 4	
	FEY	YES	FEY	YES	FEY	YES	FEY	YES
Montana								
Bias	1.0	1.1	.8	.9	1.1	1.2	1.0	1.0
RMSE	2.8	2.8	2.7	2.7	2.9	2.9	2.8	2.8
Kansas								
Bias	-0.3	-0.3	-0.5	-0.5	-0.6	-0.6	-0.8	-0.8
RMSE	3.7	3.6	3.5	3.5	3.4	3.5	3.3	3.4
Indiana								
Bias	0.8	0.8	1.1	1.2	1.0	1.1	1.3	1.4
RMSE	5.3	5.2	4.7	4.6	5.3	5.4	4.6	4.7
Ohio								
Bias	0.6	0.5	0.9	0.8	0.2	0.3	0.6	0.6
RMSE	4.1	4.1	3.7	3.7	4.0	4.0	3.6	3.6

CONCLUSION

The main focus of this working paper has been to check the input data for Dr. Feyerherm's winter wheat model for accuracy and availability, and also to become familiar with the WRV program and the DYA program. Overall, relatively few discrepancies were found and most of these can be attributed to rounding. To run this model on a "real time" basis, daily weather values for input into WRVPGM'82 are needed. These values are available through NOAA-CEAS. The Climatic Analysis Center (part of National Weather Service) transmits daily met data for first order stations to the NOAA computer installation at Suitland, Maryland. NOAA-CEAS in Columbia, Missouri has access to this data with approximately a two day delay; i.e., if you want daily met data for Monday, it will be available by Wednesday. The contact at NOAA-CEAS is Sharon LeDuc.

The remaining data needed to run the model are only available on a "yearly" basis. Therefore, values for a current year would have to be projected based on current trends.

APPENDIX

The following is a list of the sources where one could obtain the data which appear in this report or, in some cases, were used as input to generate some of the values. They are listed by the variable.

AVNI

1971 - 1979 - Fertilizer Situation, published annually by ERS.

1964 - 1970 - Cropping Practices, published June 1971 by SRS.

1959 - Commercial Fertilizer Used on Crops and Pasture in the United States, Statistical Bulletin #348, published by ERS and ARS.

1954 - Fertilizer Used on Crops and Pasture in the United States, Statistical Bulletin #216, published by ARS.

The fertilizer values published in Fertilizer Situation each December are obtained from Objective Yield Survey samples and are for the crop harvested in the same year. These samples are not statistically appropriate for making estimates at the CRD or county level. Some states publish sales data at the CRD level, but these data are not crop specific.

EEF (rust loss)

1955 - 1976 - Estimated Losses Caused by Rust in the Small Grain Cereals in the United States, 1918-1976, March 1978, published by USDA/ARS as Miscellaneous Publication 1363.

1977 - 1979 - Yearly Reports of Preliminary Estimated Losses from Rust in 1977, 1978, 1979, respectively, produced by USDA Cereal Rust Laboratory, University of Minnesota, St. Paul, MN.

These data are published at the state level only.

AVE_DYA

Varietal Planted Percentages

Reitz, L. P., L. W. Briggle, 1960. Distribution of the Varieties and Classes of Wheat in the United States in 1959. USDA Stat. Bulletin 272.

Reitz, L. P., K. L. Lebsock, G. D. Hasenmyer, 1972. Distribution of the Varieties and Classes of Wheat in the United States in 1969. USDA Stat. Bulletin 475.

Reitz, L. P., W. G. Hamblin, 1978. Distribution of the Varieties and Classes of Wheat in the United States in 1974. USDA Stat. Bulletin 604.

To obtain values in between the five-year intervals, contact the Crop and Livestock Reporting Service. These figures can usually be found in the annual bulletins. These data are only published at the state level. DYA values are obtained by running DYAPGM'82 on varietal performance trial data. These data are published yearly and can be obtained from the following sources:

Winter Wheat Performance Trial Data are produced yearly. Dr. Feyerherm obtained his data from the following sources:

State	Address	Ask for	Present Contact
Montana	Plant & Soil Science Department Montana State Univ. Bozeman, MT 59717	Yields from "Intra-State Winter Wheat Nurseries"	Dr. F.H. McNeal
Kansas	Dept. of Agronomy Kansas State Univ. Manhattan, KS 66506	Performance tests with winter wheat varieties	Ted L. Walter
Indiana	Dept. of Agronomy Agric. Experiment Sta. Purdue University West Lafayette, IN 47907	Bulletin entitled "Performance and Adaptation of Small Grains in Indiana"	none
Illinois	Dept. of Agronomy Univ. of Illinois Urbana, IL 61801	Wheat yield results of winter wheat trials	none

Locations of experiment station plots:

Montana	Kansas	Indiana and Ohio	
Havre, MT	Colby	Urbana, IL	Sikeston, MO
Sidney, MT	Belleville	Brownstown, IL	Custar, OH
Moccasin, MT	Mankato	Wanatah, IN	Vickery, OH
Huntley, MT	Manhattan	Lafayette, IN	Canfield, OH
Minot, ND	Powhattan	Farmland, IN	Wooster, OH
Williston, ND	Tribune	Vincennes, IN	Springfield, OH
Dickinson, ND	Hays	Bethany, MO	Columbus, OH
Brookings, SD	Ottawa	Columbia, MO	Ripley, OH
Presho, SD	Garden City	Pierce City, MO	Carpenter, OH
Beresford, SD	Minneola	Portageville, MO	
	Hutchinson		
	Newton		
	St. John		
	Columbus		

Yield

USDA/YES maintains a data base which was built from data provided by the SSO's. Data Services Branch of SRS maintains a county estimates file for all crops and cropping practices covering 1972-present for all states. Yield data are available for each of the four states in this report by CRD's beginning in 1931. County level data are available beginning in 1931 for Ohio, Montana, and Indiana and in 1948 for Kansas.

WRV's

The WRV's (weather related variables) are obtained by running the WRVPGM'82 using as input daily values of the minimum temperatures, maximum temperature, precipitation, snow depth and windspeed. The last two were not used to calculate WRV's for testing in this report.

Source of Input: Weather tapes supplied by the National Climatic Center (NCC) at Ashville, N.C. Weather data are also available from NOAA-CEAS at Columbia, Missouri.

Appendix AVNI
Comparison of AVNI - Feyerherm vs. YES Average
Amount of Nitrogen Applied (lbs/acre)

Year	Indiana		Kansas		Montana		Ohio	
	Fey	YES	Fey	YES	Fey	YES	Fey	YES
1954	23	23	3	3	0	0	15	15
1955	24	24	4	4	0	0	16	16
1956	25	25	5	4*	0	0	16	16
1957	27	27	6	5*	0	0	17	17
1958	28	28	7	5*	0	0	17	17
1959	29	29	8	6*	0	0	18	18
1960	31	31	8	7*	0	0	19	19
1961	32	32	9	8*	0	0	21	21
1962	34	34	9	8*	0	0	22	22
1963	35	35	10	9*	0	0	24	24
1964	37	37	10	10	0	0	25	25
1965	39	39	11	11	2	2	34	34
1966	44	44	17	17	2	2	34	33*
1967	44	44	18	18	2	2	42	42
1968	48	48	25	25	3	3	37	37
1969	40	40	25	25	2	2	36	36
1970	43	43	24	24	3	3	36	36
1971	52	51*	22	22	6	5*	43	42*
1972	51	51	31	31	6	6	42	42
1973	57	57	35	35	5	5	41	40*
1974	53	53	33	33	5	5	39	39
1975	59	59	32	32	5	5	49	49
1976	60	60	38	38	8	8	55	55
1977	61	61	35	35	10	10	60	60
1978	49	49	32	32	11	11	44	44
1979	61	61	35	35	16	10†	55	55

* Minor difference
† Significant difference

Appendix AVE_DYA
Comparison of AVE_DYA - Feyerherm vs. YES Weighted
State-wide Averages of DYA Values in Bushels/Acre

Harvest	Indiana		Kansas		Montana		Ohio	
Year	Fey	YES	Fey	YES	Fey	YES	Fey	YES
1954	0.3	0.3	0.1	0.1	-2.4	-2.4	2.4	2.4
1955	0.8	0.8	0.1	0.1	-2.2	-2.2	2.5	2.5
1956	1.3	1.3	0.1	0.1	-1.9	-1.9	2.6	2.6
1957	1.9	1.9	0.2	0.2	-1.7	-1.7	2.8	2.8
1958	2.4	2.4	0.2	0.2	-1.4	-1.4	2.9	2.9
1959	2.9	2.9	0.2	0.2	-1.2	-1.2	3.0	3.0
1960	3.3	3.3	0.4	0.4	-1.0	-1.0	3.2	3.2
1961	3.7	3.7	0.5	0.5	-0.8	-0.8	3.3	3.4*
1962	4.0	4.0	0.7	0.7	-0.6	-0.6	3.5	3.5
1963	4.4	4.4	0.8	0.8	-0.4	-0.4	3.6	3.7*
1964	4.8	4.8	1.0	1.0	-0.2	-0.2	3.8	3.9*
1965	4.8	4.8	1.4	1.4	-0.2	-0.2	4.1	4.1
1966	4.8	4.8	1.7	1.7	-0.3	-0.3	4.3	4.4*
1967	4.8	4.8	2.1	2.1	-0.3	-0.3	4.6	4.6
1968	4.8	4.8	2.4	2.4	-0.4	-0.4	4.8	4.9*
1969	4.8	4.8	2.8	2.8	-0.4	-0.4	5.1	5.1
1970	7.0	7.0	2.9	2.9	-0.6	-0.6	6.3	6.3
1971	10.5	10.5	2.8	2.8	-0.5	-0.6*	7.6	7.6
1972	12.0	12.0	3.2	3.1*	-0.5	-0.5	8.8	8.8
1973	11.4	11.4	3.6	3.6	-0.7	-0.7	10.1	10.1
1974	11.8	11.8	3.9	3.9	-0.6	-0.6	11.3	11.3
1975	12.6	12.6	4.1	4.1	-0.6	-0.6	11.7	11.8*
1976	12.5	12.5	4.6	4.6	-0.3	-0.3	12.1	12.3*
1977	12.6	12.7*	4.9	4.9	-0.1	-0.1	12.6	12.9*
1978	12.6	12.6	5.1	5.1	-0.2	-0.2	13.0	13.4*
1979	12.4	12.4	5.3	5.3	0.0	0.0	13.4	13.9*

* Minor differences

Appendix YIELD
Comparison of Yield Values - Feyerherm vs. YES
USDA Estimate of Yield per Harvested Acre

Harvest Year	Indiana		Kansas		Montana		Ohio	
	Fey	YES	Fey	YES	Fey	YES	Fey	YES
1955	29.0	29.0	15.0	15.0	27.0	27.0	29.0	29.0
1956	30.5	30.5	15.5	15.5	20.5	20.5	26.0	26.0
1957	25.5	25.5	19.0	19.0	25.0	25.0	22.0	22.0
1958	32.0	32.0	27.5	27.5	27.5	27.5	31.0	31.0
1959	26.0	26.0	20.0	20.0	25.5	25.5	24.5	24.5
1960	33.0	33.0	28.0	28.0	23.0	23.0	35.0	35.0
1961	34.0	34.0	26.5	26.5	19.0	19.0	31.0	31.0
1962	34.0	34.0	23.5	23.5	22.0	22.0	32.0	32.0
1963	40.0	40.0	21.5	21.5	26.0	26.0	38.0	38.0
1964	34.0	34.0	22.5	22.5	28.5	28.5	32.0	32.0
1965	32.5	32.5	24.0	24.0	29.0	29.0	32.0	32.0
1966	44.0	44.0	19.5	19.5	30.0	30.0	39.0	39.0
1967	37.0	37.0	20.0	20.0	30.0	30.0	34.0	34.0
1968	35.0	35.0	25.0	25.0	31.5	31.5	37.5	37.5
1969	40.0	40.0	31.0	31.0	26.0	26.0	38.0	38.0
1970	38.5	38.5	33.0	33.0	27.0	27.0	38.0	38.0
1971	46.0	46.0	34.5	34.5	30.0	30.0	44.0	44.0
1972	48.0	48.0	33.5	33.5	27.0	27.0	45.0	45.0
1973	35.0	35.0	37.0	37.0	26.5	26.5	32.0	32.0
1974	36.0	37.5*	27.5	27.5	29.5	29.5	41.0	41.0
1975	43.0	44.0*	29.0	29.0	35.0	35.0	42.0	42.0
1976	36.0	36.0	30.0	30.0	32.0	32.0	40.0	40.0
1977	45.0	45.0	28.5	28.5	29.0	29.0	47.0	47.0
1978	39.0	39.0	30.0	30.0	31.0	31.0	39.0	39.0
1979	47.0	47.0	38.0	38.0	25.5	25.5	45.0	48.0*

* Differences encountered

Appendix EEF
EEF (Rust Loss) Values Supplied†
Percent Loss in Yield Due to Stem and Leaf Rust

Harvest Year	Indiana	Kansas	Montana	Ohio
1955	4	4	0	3
1956	0	0	0	3
1957	3	13	0	3
1958	0	0	0	1
1959	0	10	0	2
1960	0	3	0	0
1961	0	8	0	1
1962	0	4	5	0
1963	0	0	0	0
1964	1	1	0	0
1965	0	4	5	0
1966	0	0	0	0
1967	0	0	0	0
1968	5	8	0	0
1969	3	0	0	0
1970	1	1	0	0
1971	2	2	0	0
1972	0	1	0	0
1973	0	8	0	0
1974	0	16	0	0
1975	0	8	1	0
1976	0	0	0	0
1977	0	1	0	0
1978	1	2	0	0
1979	1	2	0	0

† No differences between Feyerherm and YES values

Appendix WRV
Comparison of WRV's - Feyerherm vs. YES
Weather Related Variables

The letters following the underline in the WRV name denote crop stages. They are P = planting, W = winter, S = spring, J = jointing, F = flag leaf, H = heading, M = milk, D = dough. There are eight phenological periods: PW, WS, SJ, JF, FH, HM, MD, DR. The following is a description of each WRV.

WRV Name	Definition
PR_PW through PR_DR	Total precipitation in each phenological period starting with the period PW and ending with the period DR
TN_PW through TN_DR	Average daily minimum temperature during each of the 8 phenological periods
TX_PW through TX_DR	Average daily maximum temperature during each of the 8 phenological periods
T50_JF	Average number of degree-days by which daily minimum temperatures exceeded 50° F during period JF
T50_FH	Same as preceding except period is FH
T56_HM	Average number of degree-days by which daily minimum temperatures exceeded 56° F during period HM
T56_MD	Same as preceding except period is MD
T77_ab	Average number of degree-days by which daily maximum temperatures exceeded 77° F during period (ab) where (ab) = FH, HM, MD, DR, respectively
CN_P through CN_R	Contents (plant-available water) of all six zones in the Baier-Robertson soil moisture budget at the specified stage of development for the 9 stages P through R
CPR_P through CPR_R	Cumulative precipitation from planting (P) up to the specified stage of development for the 9 stages P through R
AE_PW through AE_DR	"Actual" evapotranspiration during the specified phenological period, as computed in the Baier-Robertson VSMB for the 8 periods from PW to DR
PE_PW through PE_DR	"Potential" evapotranspiration during a specified phenological period, as computed in the Baier-Robertson VSMB for the 8 periods from PW to DR

Appendix WX

Comparison of WX and Its Components -- Feyerherm vs. YES for the Goodland, Kansas Weather Station-Unit is Bushels per Acre

Harvest Year	ET		XPR		TEMP		WX	
	Fey	YES	Fey	YES	Fey	YES	Fey	YES
1955	11.3	11.3	0	0	-62.3	-63.0	21.5	20.9
1956	4.5	4.4	0	0	-71.3	-71.3	5.8	5.7
1957	21.9	21.9	0	-0.06	-61.2	-61.1	33.3	33.3
1958	17.1	17.4	0	0	-60.5	-60.5	29.2	29.5
1959	10.8	11.2	0	0	-69.1	-69.7	14.3	14.1
1960	23.9	23.9	0	0	-62.8	-63.0	33.7	33.5
1961	20.6	20.8	-0.05	-0.21	-62.7	-62.8	30.4	30.4
1962	16.6	16.7	-6.05	-6.26	-63.1	-63.4	20.0	19.6
1963	18.5	18.7	0	0	-69.0	-69.2	22.2	22.0
1964	14.4	14.4	-0.19	-0.19	-64.9	-65.1	21.9	21.7
1965	8.8	9.9	0	0	-63.9	-64.4	17.6	18.1
1966	18.0	18.0	0	0	-64.2	-64.4	26.4	26.2
1967	12.7	13.4	0	0	-62.8	-62.6	22.5	23.3
1968	15.9	15.8	-0.89	-0.89	-68.0	-67.8	19.7	19.7
1969	20.8	20.7	0	0	-61.7	-62.1	31.6	31.2
1970	21.0	21.0	0	0	-58.8	-59.5	34.8	34.1
1971	22.5	22.3	0	0	-62.0	-62.7	33.1	32.1
1972	19.6	19.5	-0.39	-0.39	-64.2	-64.1	27.6	27.6
1973	18.7	18.7	0	0	-57.0	-57.7	34.2	33.6
1974	19.7	19.2	-1.17	-1.17	-61.6	-61.8	29.5	28.8
1975	15.6	15.4	-4.02	-2.80*	-60.2	-60.4	23.9	24.7
1976	12.9	12.8	0	0	-67.6	-67.5	17.9	17.9
1977	22.1	22.1	0	0	-67.8	-68.4	26.9	26.2
1978	18.1	18.5	0	0	-61.1	-61.7	29.6	29.5
1979	22.5	22.1	-3.75	-2.84*	-62.4	-62.1	28.9	29.7

* Significant difference