THE EFFECT OF SELECTED WEATHER VARIABLES ON THE AMOUNT OF STEM RUST DAMAGE TO WHEAT IN NEBRASKA

by

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THE EFFECT OF SELECTED WEATHER VARIABLES ON THE AMOUNT OF STEM RUST DAMAGE TO WHEAT IN NEBRASKA

ABSTRACT: Researchers have long tried to correlate weather factors with plant disease occurrences. However, inconclusive results have usually been obtained because most plant diseases have biologic as well as climatic optimums.

In this study, thirty weather variables were correlated, by the stepwise regression method in a computer, to the amount of wheat lost to stem rust in Nebraska over a period of fifty-two years. The amount of May precipitation was found to be significant at the one per cent confidence level.

INTRODUCTION

Stem rust (*Puccinia graminis tritici*) can be a destructive force to a field of wheat. Some years, up to eighty per cent of a wheat crop may be taken by this species of fungi. In other years, almost no damage is done.

According to Dr. Robert Powelson, a phytopathologist at Oregon State University, there appear to be three main variables which determine the amount of damage that will be done by *Puccinia*. These variables are: (1) the amount of virulent fungus available to reproduce and spread, (2) the acreage planted to a susceptable crop, and (3) the weather.[1.]

Each variable (of the three) has a complex of elements. It would be of value if a way were found to predict when infestations are likely to occur. The challenge of this complex problem was the stimulation for the research reported in this paper.

STATEMENT OF PROBLEM

The object of this research is to discover: (1) if certain weather elements have an effect on the percentage of the Nebraska wheat crop lost to stem rust, and (2) if so, whether predictions of future damage can be made.

REVIEW OF LITERATURE

In the past fifty years there has been a significant amount of work published correlating crop plant disease damage to weather factors. The finding of this research has not been entirely conclusive.

Beauverie, for example, reported that stem rust was essentially a wet season disease.[2.] Since urediospores require moisture on the plants for a few hours in order to germinate, he believed that rust epidemics must be associated with wet weather. Carleton found that lack of moisture tended to be a limiting factor in rust development.[3.]

Lambert, however, found no correlation between a high number of rainy days during the growing season and severity of stem rust infection in the Upper Mississippi Valley in the period 1904 to 1925.[4.] He calculated that the odds were six to one that stem rust epiphytotics would occur during hot growing seasons.[5.]

Peltier found in his analysis of weather-rust data for the period 1921 to 1930 that: (1) stem rust did not become epiphytotic during years of early heading and ripening of winter wheat in eastern Nebraska, (2) while low temperature was the limiting factor in primary infection, moisture limited secondary infection, and (3) rust epiphytotics were promoted by having a large amount of spores available when conditions for maximum infection prevailed.[6.]

In a biometrical study carried out by Levine, mean temperature and total precipitation in the last two months of the growing season were found to be correlated with the intensity of stem rust infection on susceptible varieties of wheat.[7.] However, Levine pointed out that these were not the sole determinants in predicting an epiphytotic. Wallin found that the greater the March precipitation in Texas, Oklahoma, and Kansas, the greater the likelihood of a summer epiphytotic of stem rust in Kansas, North Dakota, South Dakota, and Minnesota.[8.] In another study Wallin found that there was a correlation between precipitation, temperature, and the occurrence of stem rust outbreaks in the Dakotas, Nebraska, and Minnesota.[9.] However, Wallin did make clear that long term temperature and rainfall lines were not always precise in separating "rust years" from "non-rust years."[10.]

A tendency toward stem rust epidemics is exhibited, in the Mississippi Valley, according to Hamilton and Stakman, if rust spores arrive earlier than they do in a normal year.[11.] They found that June 5th was the average date of the first Puccinia spore appearance in eastern Nebraska.[12.] Rowell found, in his dew chamber experiments with Puccinia graminis, that rapid drying of the spores after a heavy dew resulted in a great loss in infectivity.[13.]

Most of the variables used in this study were either those suggested in the literature, or alterations thereof.

HYPOTHESIS

Because factors other than weather influence the amount of stem rust damage to wheat in a particular year, a 100 per cent correlation is not to be expected between the forementioned variables considered in this research. Nevertheless, it is believed that some useful correlations will be obtained through the employment of the common null hypothesis. The amount of stem rust damage will equal Y. The equation to be tested is:

$$Y = \underbrace{(\beta_0 + \beta_1 X_1 + \beta_2 X_2 \ldots + \beta_{30} X_{30})}_{\text{selected climatic influences}} + \underbrace{(\quad ? \quad)}_{\text{biological influences}} + \underbrace{(\quad ? \quad)}_{\text{amount of susceptible host available}}$$

Ho: $\beta i = 0$

Hi: some $\beta \neq 0$

THE STUDY AREA AND DATA SOURCES

A major difficulty encountered in this problem was that of getting data on stem rust damage to wheat. The data used were obtained from the Cooperative Rust Laboratory of the University of Minnesota for the fifty-two year period 1916-67. Whe weather data were obtained from the Nebraska sector of the publication, Climatological Data by Section (E. S. S. A.) for the years 1916-67.

Nebraska was chosen for the place of study because: it is a major wheat producing state, and the essential data were available. A study unit about the size of a county would have been more suitable for this type of work, but no extended period of stem rust damage data of this type could be found. Another suitable study area would be a state with little variation in climate and significant production of a particular variety of wheat. North Dakota comes quite close to being this ideal type, as it is of moderate size, relatively smooth in topography, and has a specialty crop of Durum wheat. No long term damage to only Durum wheat, however, could be found for this or any other state.

Out of all the states for which data was available, Nebraska came closest to being a satisfactory study unit. Although there is a decrease in precipitation as one travels from east to west in this state, winter wheat is the dominant crop in most parts.

Since the data on stem rust damage were a state average of the percentage of the crop lost, the weather data were analyzed in the same manner. A state average for each of the variables was obtained by averaging these weather stations: Chadron, North Platte, and Lincoln. In a few cases a station had some missing data for a short period. In these instances data for a nearby station was substituted. For the "percentage of possible sunlight," "average wind velocity," and "relative humidity" categories, data were only available for Lincoln and North Platte. During this fifty-two year time span, the form of presentation of humidity data changed from a monghly average to a monthly average at various times of the day. In the latter case, the 6 a.m. average and the 6 p.m. average were averaged in order to get comparable data.

It should be noted that the selected representative weather stations show a lack of representation from the northeastern and north central parts of the state. This is an intentional bias, because comparatively little of the state's wheat production comes from these two areas.[14.]

ANALYSIS

A stepwise multiple regression was done by computer comparing stem rust damage to the thirty weather variables. (See table 1 for complete list of variables and data.) This seemed to be the best available method for segregating the most significant variables and forming a usable prediction equation.

No data was transformed, even though the stem rust data was not normally distributed. This was because more than half of that data either showed no damage at all or only a one tenth of a per cent of crop loss. Since the data range was from zero to thirty per cent crop loss, quite an irregular pattern was formed when graphed. (see figure 1) No transformation was able to make the pattern more regular.[15.] It must then be assumed, then, that the "Student's T test" and the "Table of five per cent and one per cent points for r and R" are valid indicators of the reliability of the computed results.

The results of the first regression test were quite interesting. Simple correlations revealed the following variables to be correlated at the one per cent confidence level with stem rust losses:

A total May precipitation, with a .43348 correlation coefficient, B precipitation from May 21-31 with a .41103 correlation coefficient,

C (total May precipitation) · (percentage of possible May sunlight) with a .42858 correlation coefficient,

D (total May precipitation) · (May mean temperature) with a correlation coefficient of .47196,

E (percentage of possible June sunlight) · (average June relative humidity) with a correlation coefficient of .45620, and

F (total May precipitation)^2 with a .46531 correlation coefficient.

The multiple correlation was also significant at the one per cent confidence level, having an R-square of .51272 for the six variables which were deemed significant at the five per cent confidence level by the Student's T test. Variable twenty-three, (May 1-31 precipitation) · (May mean temperature) was the most significant member in the equation, accounting for approximately 22.3 per cent of the variations in stem rust damage.[16.]

This prediction equation comes from the first multiple regression.

$$Y_{\text{stem rust}} = -.10416 - .1936 X_3 + .0285 X_4 + .0024 X_3 \cdot X_5$$

X_3: May 1-31 precip.; X_4: May 21-31 precip.; $X_3 \cdot X_5$: (May precip.)·(May mean temp.)

$$+ .000118 X_2 \cdot X_8 + .00002457 X_{17} \cdot X_{18}$$

$X_2 \cdot X_8$: (last frost)·(May wind vel.); $X_{17} \cdot X_{18}$: (% poss. June sunlight)·(June relative humidity)

$$+ .0107 X_3^{\,3}$$

$X_3^{\,3}$: (May 1-31 precip.)

Approximate yearly predictions of crop loss due to the actions of Puccinia graminis were calculated by computer and compared to the actual crop losses.[17.] Most of the predictions came fairly close to the actual wheat losses. The three notable exceptions were the years 1919, 1920, and 1944. These years had ten, twelve, and twenty per cent crop losses respectively. However, the prediction equation only predicted slightly more than one, one, and five per cent losses for these same years.

But there were some notably good predictions. The years 1923, 1935, 1959, 1960, 1961, 1962, and 1965 were also "bad rust years," and were predicted so. The prediction equation made only one bad prediction after 1920. Also, all of the years with no rust damage at all were predicted at less than five tenths of one per cent damage.

A curious attribute of this prediction equation is that the precipitation from May 21-31 has a positive effect on the prediction equation, whereas the May 1-31 precipitation has a negative effect on this same equation. This occurred even though both of these variables had positive simple correlations of significance.

Since most of the significant variables in both the simple and multiple correlations were related to May precipitation in some way, it seemed that a better multiple correlation could be obtained by a more detailed examination of this variable. Thus, the effects of May 1-20 and May 21-31 precipitation were examined separately.[18.]

A stepwise multiple regression was also done on these variables. However, only a .38634 R-square was obtained on this run, with the only significant variables being May 21-31 precipitation and (May 1-31 precipitation)·(May 21-31 precipitation.[19.]

SUMMARY AND CONCLUSIONS

It seems as if certain weather elements do have an affect on the percentage of the Nebraska wheat crop lost to stem rust. The most important of these variables seems to be the amount of precipitation in May. Especially toward the end of May, when wheat "heads," does this relationship between moisture and stem rust damage seem most critical. This finding, in general, seems to be in agreement with what some other researchers have found.

Beauverie (1923), Moreland (1906), Carleton (1905), Peltier (1933), Levine (1928), and Wallin (1964b) all found some relation between moisture and damage by stem rust. But, the results obtained in this study seem to indicate that the time the moisture arrives is as important as the amount of moisture itself. This probably has to do with moisture availability at a time when the *Puccinia* spores can get an early start at germination and reproduction.

Although some researchers found relationships between temperature and stem rust damage (some of which were conflicting), no temperature correlations, as such, were found in this study.

The prediction equation computed in the first multiple regression run was fairly successful. For most of the years in this study, the predicted crop losses were reasonably close to the actual crop losses. Yet, there were a few years in which little damage was predicted, but significant losses occurred.

Although other variables, in addition to unmodified rainfall variables, correlated by computer with stem rust damage, some of these may have been "chance" correlations. Considering an original sample size of thirty and a five per cent confidence level on the Student's T test, it is quite possible that one or two of these variables is correlated only by coincidence.

It seems, then, that in order to better predict and understand the depredations of Puccinia graminis, biological - as well as physical - variables should be taken into consideration.

FOOTNOTES

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6. Peltier, George L. 1933. Relation of weather to the prevalence of wheat stem rust in Nebraska. Journal of Agricultural Research 46: page 72.
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10. _Ibid_. page 44.

11. Hamilton, Laura M. and E. C. Stakman. 1967. Time of stem rust appearance on wheat in the Western Mississippi Basin in relation to epidemics from 1921 to 1962. Phytopathology 57: page 609.

12. _Ibid_. page 604.

13. Rowell, J. B., C. R. Olien, and R. D. Wilcoxson. 1958. Effect of certain environmental conditions on infection of wheat during the growing season in the spring wheat area of the United States to the occurrence of stem rust epidemics. Phytopathology 18: page 377.

14. Nebraska. Department of Agriculture. Nebraska agricultural statistics; centennial edition 1967. Lincoln, Nebraska, pages 70, 71, and 78.

15. The cube, square, square root, log and log·log of the stem rust data were unsuccessfully tried.

16. See computer run #1, Table II B.

17. Note computer run #2, Table III B.

18. For a complete list of these variables see Table II A.

19. For more details see computer run #3, Table IV B.

APPENDIX

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TABLE I

Data

YEAR	RUST DAMAGE %	LAST FROST	MAY 1-31 PRECIP. INCHES	MAY 21-31 PRECIP.	MAY MEAN TEMP. F.	MAY MAX. TEMP.	MAY MIN. TEMP.	MAY WIND VELOCITY M.P.H.	AMT. POSSIBLE MAY SUNLIGHT %	MAY REL. HUMIDITY %
	-03	-01	-02	-02	-01	-01	-01	-01	-01	-01
16	023	290	270	028	589	731	446	087	655	625
17	020	306	409	207	517	620	412	092	555	675
18	001	350	254	139	615	752	479	108	640	625
19	100	346	250	098	586	705	467	081	645	685
20	120	283	344	134	579	674	465	085	475	720
21	001	286	238	053	606	713	494	075	550	670
22	005	200	270	222	602	718	487	095	655	650
23	040	263	318	161	577	683	466	084	650	660
24	000	147	243	152	541	669	412	094	580	600
25	001	213	164	036	595	720	470	087	705	600
26	000	230	196	060	639	761	518	102	705	588
27	001	283	215	057	591	706	477	115	620	620
28	001	237	285	045	629	756	502	075	685	560
29	001	313	229	131	577	691	596	082	600	658
30	005	323	428	053	575	683	467	086	570	680
31	001	313	281	108	580	706	437	088	755	583
32	008	280	201	140	627	751	502	096	725	415
33	000	233	269	120	579	687	471	095	585	668
34	001	216	062	021	695	840	550	102	780	505
35	140	376	530	235	528	610	447	096	345	775
36	001	203	193	047	655	767	538	090	690	427
37	060	223	167	110	618	743	505	095	715	640
38	050	223	450	126	589	696	481	085	555	710
39	001	166	249	037	659	789	501	089	750	568
40	013	303	061	010	604	739	603	088	795	553
41	001	096	167	048	663	768	532	092	700	690
42	001	226	463	040	568	680	455	097	650	740
43	001	420	291	114	557	674	441	091	525	663
44	200	263	339	100	626	749	504	095	700	625
45	001	343	318	154	554	678	431	099	600	695
46	001	413	361	151	551	665	436	091	580	690
47	.025	600	302	170	566	692	441	088	640	663
48	001	390	201	198	600	727	473	073	690	420
49	001	196	426	118	614	730	505	101	550	753
50	001	323	352	172	562	682	440	109	550	690
51	001	416	464	162	592	718	479	101	530	695
52	001	310	378	162	593	712	468	100	680	680
53	020	353	158	050	567	696	445	127	655	668
54	050	360	333	191	558	674	441	095	605	642
55	001	210	354	178	625	779	499	113	735	598
56	001	360	205	142	614	753	489	114	610	625
57	020	186	545	144	572	673	471	114	510	743
58	001	297	212	057	629	762	494	100	565	645
59	054	356	526	100	584	697	474	119	555	670
60	050	436	299	095	586	725	451	123	645	638
61	150	950	394	093	566	674	458	132	545	623
62	300	266	519	321	645	778	512	135	670	605
63	001	420	290	111	609	734	482	116	560	665
64	005	410	233	086	622	752	491	126	640	570
65	150	360	495	268	609	745	444	033	610	615
66	001	303	084	042	602	761	441	024	765	565
67	000	406	386	256	539	652	425	022	585	635

TABLE I cont.

YEAR	RUST DAMAGE	JUNE 1-30 PRECIP.	JUNE 1-10 PRECIP.	JUNE MEAN TEMP.	JUNE MAX. TEMP.	JUNE MIN. TEMP.	JUNE WIND VELOCITY	AMT. POSSIBLE JUNE SUNLIGHT	AVE. JUNE REL. HUMIDITY	JULY 1-31 PRECIP.	JULY MEAN TEMP.	JULY REL. HUMID.
	-03	-02	-02	-01	-01	-01	-01	-01	-01	-02	-01	-01
16	023	251	191	654	855	520	086	695	695	141	792	622
17	020	336	247	665	805	527	097	785	640	093	759	615
18	001	212	095	745	887	602	074	835	600	262	743	635
19	100	376	244	705	819	592	079	655	745	310	784	625
20	120	174	031	690	798	582	090	685	655	259	722	635
21	001	392	126	715	843	614	059	720	670	343	765	660
22	005	188	034	727	859	595	078	820	620	553	722	690
23	040	480	358	693	793	597	090	740	720	321	766	670
24	000	274	095	657	787	531	087	700	710	212	726	633
25	001	432	220	707	827	587	100	730	650	248	758	570
26	000	289	062	694	831	557	081	680	610	294	765	628
27	001	347	112	667	773	560	091	630	695	176	733	568
28	001	347	087	633	737	526	066	550	683	440	743	688
29	001	212	139	682	800	564	071	680	605	290	765	643
30	005	305	170	688	813	562	073	750	645	121	742	513
31	001	284	161	754	838	633	079	775	623	085	780	548
32	008	285	095	707	826	589	077	685	698	427	780	660
33	000	135	026	779	913	644	089	820	513	275	787	623
34	001	237	053	751	889	614	093	785	365	052	821	610
35	140	382	109	667	776	568	082	720	768	194	824	392
36	001	223	160	734	863	602	080	805	543	038	863	400
37	060	321	153	687	801	574	088	635	637	210	788	565
38	050	212	034	712	832	592	090	700	430	239	778	588
39	001	319	125	700	820	580	092	680	630	139	808	565
40	013	201	158	727	866	587	092	750	578	113	809	538
41	001	323	224	704	802	588	092	610	875	271	766	442
42	001	425	106	679	780	574	085	630	760	236	765	638
43	001	379	144	668	805	570	088	705	683	302	774	648
44	200	390	159	682	800	571	098	670	682	326	742	663
45	001	507	203	621	728	514	083	575	702	260	693	560
46	001	319	081	704	834	574	096	760	528	104	770	650
47	025	773	203	648	758	539	084	635	768	206	750	690
48	001	356	029	681	798	564	072	615	680	236	751	565
49	001	469	142	692	813	581	089	610	725	354	755	633
50	001	167	002	689	826	547	105	815	620	382	703	732
51	001	878	415	624	733	518	085	445	745	420	722	730
52	001	323	008	750	891	608	112	800	640	210	754	618
53	020	232	148	734	875	595	112	755	635	161	761	590
54	050	266	101	709	842	576	128	765	663	172	801	530
55	001	411	101	650	771	554	109	535	700	080	798	598
56	001	330	063	750	902	608	107	845	598	363	750	685
57	020	268	082	673	793	591	101	610	712	353	778	688
58	001	200	040	675	798	584	113	640	668	704	711	733
59	054	393	020	728	861	595	104	765	438	143	732	665
60	050	405	052	677	802	558	109	625	760	170	757	603
61	150	173	077	701	831	595	097	740	668	235	749	655
62	300	428	191	681	789	572	107	610	705	432	729	693
63	001	390	082	731	899	609	114	750	418	217	777	600
64	005	565	182	683	812	553	112	695	638	308	799	623
65	150	737	347	678	785	570	052	500	755	489	739	755
66	001	397	162	697	821	564	052	710	665	313	799	710
67	000	898	424	658	763	553	029	585	765	324	720	693

Table IIA

All of the variables used in the regression tests were used because it was thought that variations in each one of these variables would cause variations in the amount of stem rust damage to wheat in Nebraska.

The variables concerning temperature were chosen because it was believed that abnormally cold or hot weather would tend to limit the growth of the Puccinia spores. The data of the last frost seemed to be a good way to find out whether a late frost would retard the damage caused by stem rust.

Since many researchers found correlations between precipitation and rust damage, many precipitation variables were used in this study. This was done in order to see if any "critical" periods in the life cycles of either Puccinia or wheat could be discerned, and if discernible, the extent of "criticalness" of these periods. Humidity variables were used because it was believed that low relative humidities would tend to dry out the spores, making them less viable.

Wind variables were used because it was thought that higher wind speeds would mean greater spreading of spores. The percentage of sunlight variables were used because it was hypothesized that excessive light would render Puccinia spores inviable. Variables were squared and multiplied with one another in order to see

Table IIA cont.

if more subtle relationships could be brought out.

Table II Part A cont.

List of Variables for the First Computer Run

X1 = $(\text{May mean temperature})^2$

X2 = date of last frost, April 1 = 1

X3 = May 1-31 precipitation

X4 = May 21-31 precipitation

X5 = mean May temperature

X6 = average daily maximum temperature in May

X7 = average daily minimum temperature in May

X8 = average May wind velocity

X9 = percentage of possible May sunlight

X10 = average May relative humidity

X11 = June 1-30 precipitation

X12 = June 1-10 precipitation

X13 = mean June temperature

X14 = average daily maximum temperature in June

X15 = average daily minimum temperature in June

X16 = average June wind velocity

X17 = percentage of possible June sunlight

X18 = average June relative humidity

X19 = average July precipitation

Table II Part A cont.

X20 = mean July temperature

X21 = average July relative humidity

X22 = $(X3) \cdot (X9)$

X23 = $(X3) \cdot (X5)$

X24 = $(X3) \cdot (X11)$

X25 = $(X2) \cdot (X8)$

X26 = $(X8) \cdot (X10)$

X27 = $(X11) \cdot (X13)$

X28 = $(X17) \cdot (X18)$

X29 = $(X19) \cdot (X20)$

X30 = $(X3)^2$

Table III, Part A

List of Variables for the Second Computer Run

$X1 = (X3)^2$

X2 = (date of last frost)· (average May wind velocity)

X3 = May 1-31 precipitation

X4 = May 21-31 precipitation

X5 = (May 1-31 precipitation)· (mean May temperature)

X6 = (percent of possible June sunlight)· (June relative humidity)

Table IV, Part A

List of Variables for the Third Computer Run

X1 = May 1-20 precipitation

X2 = May 1-31 precipitation

X3 = May 21-31 precipitation

X4 = $(X1) \cdot (X2)$

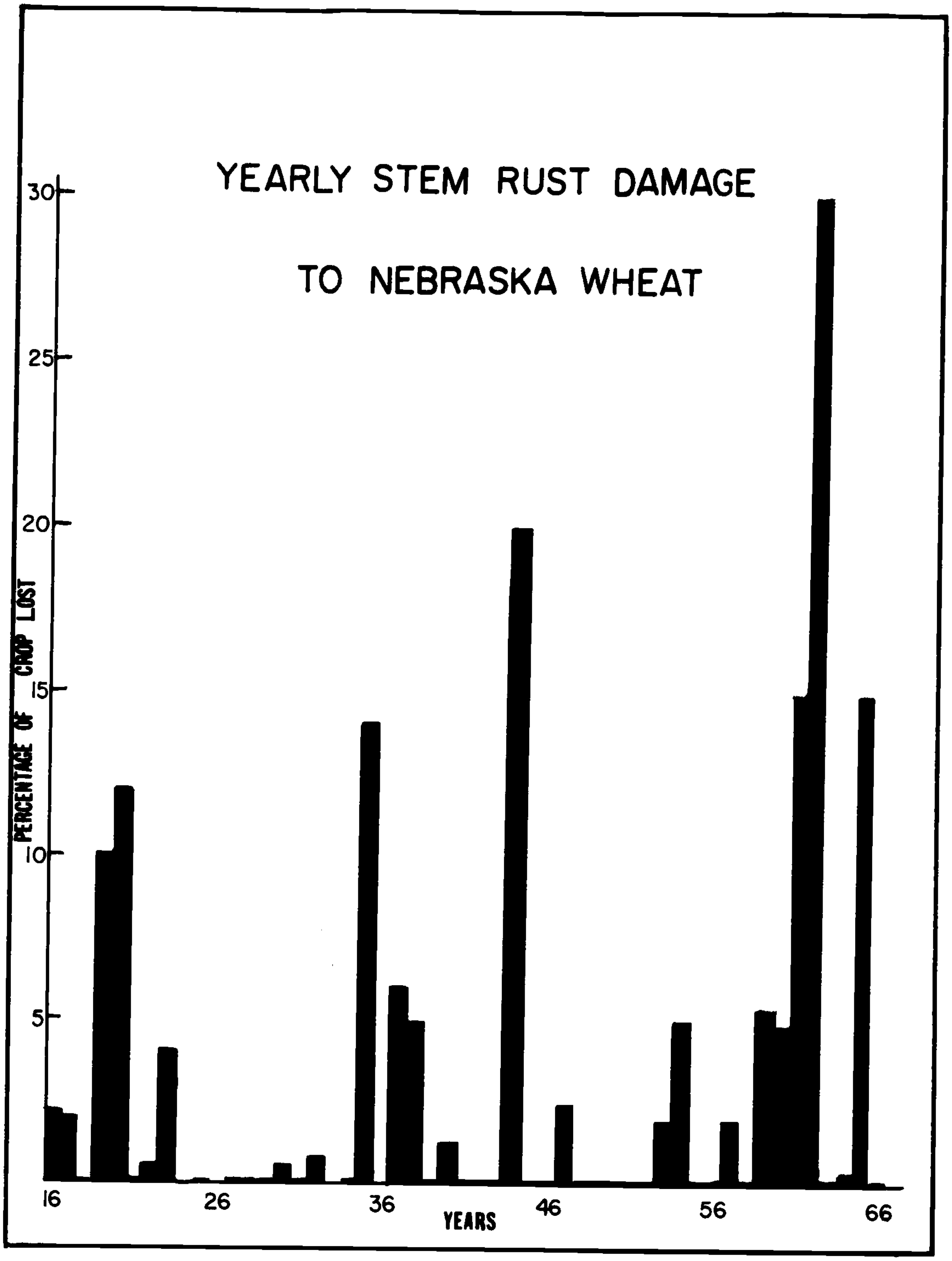
X5 = $(X1) \cdot (X3)$

X6 = $(X2) \cdot (X3)$

X7 = $(X1)^2$

X8 = $(X2)^2$

X9 = $(X3)^3$


YEARLY STEM RUST DAMAGE
TO NEBRASKA WHEAT
PERCENTAGE OF CROP LOST
30
25
20
15
10
5
16
26
36
46
56
66
YEARS

```
ACCT= 70108/01      DEPT= 197     ID= LMJ               CLASS= C
DATE= 07/15/68   TIME IN= 17/41/08  TIME OUT= 17/41/32

TIME USED
 COMP= 00/00/12.189
 CHAN= 00/00/07.433

FACILITIES REQUESTED          FACILITIES USED
  CORE=030      OUT=01000       CORE=030      OUT=00303
  SCR =003      PUN=00000       SCR =003      PUN=00000
                INP=00112


JOB,    LMJ,70108/01,197,2,1000
SCHED,CORE=30,SCR=3
STEP
```

SUBP

54265	MULREG	61462	DET	61514	LOGF	61723	Q8QERROR	62201	FIXF	62250	FLOATF
62277	ABSF	62313	SQRTF	62424	EXPF	62556	SINCOS	63067	POWRF	63437	XTOI
63667	Q1QADRI	64050	CONTROL	65732	TAPEHAND	66127	EOFCHR	66215	FORMAT	66556	BCDOUT
70240	BCDINP	71242	STEPWISE								

ENTR

61500	TIME	61462	DATE	61523	LOGF	62201	IFIX	62201	XFIXF	62250	FLOAT
62277	XABSF	62277	IABS	62277	ABSF	62313	SQRTF	62424	EXPF	62556	COSF
62564	SINF	63067	Q1QEXRR	63067	POWRF	62250	FLOATF	63437	XTOI	62201	FIXF
64012	Q1QSTRX	64000	Q1QSTRI	63767	Q1QSTXR	63732	Q1QSBXR	63706	Q1QADXR	63763	Q1QSBRX
63743	Q1QADRX	63740	Q1QDVIR	63735	Q1QMOIR	63732	Q1QSBIR	63705	Q1QADIR	63726	Q1QDVRI
63722	Q1QMORI	63716	Q1QSBRI	63667	Q1QADRI	64050	OIC	64661	BCDMGFLG	64662	BCDPN
64545	ZERO..XX	64541	ZERODIV	65032	CARDSI	65101	TPI04	64657	EXPMGFLG	64653	ARFMGFLG
64555	DVFMGFLG	64554	ARTFT	64556	DVUFT	64560	EXPFT	64202	Q8QIOTAB	64142	Q8QEXITS
64705	STATUS	65734	Q8QBACKS	66127	EOFCR	65641	PWRTBL	66657	Q8QLGOTC	64552	CREXPOVF
66215	Q8QIFRMT	66246	Q8QFORMT	64161	Q8QIOSET	64144	Q8QSENSE	64405	Q8QEDITS	61723	Q8QERROR
64573	FIOSIM	65624	ABNORMAL	65637	PWRTBCD	64260	Q8QIOERR	70335	Q8QLGINC	64125	Q8QENTRY
66026	Q8QENFIL	63767	Q1QSTIR	63437	Q1QEXRI	66664	Q8QLGOTR	70347	Q8QLGINR	64222	Q8QARRAY
67327	Q8QENGOT	66657	Q8QLGOTI	66556	Q8QINGUI	66036	Q8QREWND	70727	Q8QENGIN	70342	Q8QLGINI
70240	Q8QINGIR	56533	MULREG	62277	ABS	61514	ALOG10	62313	SQRT	62556	COS
62564	SIN	62424	EXP	61523	ALOG	61476	EXIT	66133	EOFCKF	72222	STEPWISE

COMM

11610 1

DATA

NONE

```
PROBLEM NO.    2                                                DATE  7 12 68

NO OF DATA =    52

NO OF VARIABLES =  8

NO OF CASE =  2
TRANSFORMATIONS
          2 =  2( 3) 6
          5 =  3( 3) 5
          6 =  7( 3) 8
          8 =  1( 0) 0
          1 =  3( 3) 3


INPUT FORMAT
     (3X,F4.4,F4.2,2F4.3,F4.2,8X,F4.2,/,31X,2F4.2)

INPUT VARIABLES
  2.30000000E-02  2.90000000E 01  2.70000000E 00  2.80000000E-01  5.89000000E 01  8.70000000E 00  6.95000000E 01  6.95000000E 01

VARIABLES AFTER TRANSFORMATIONS

  7.29000000E 00  2.52300000E 02  2.70000000E 00  2.80000000E-01  1.59030000E 02  4.83025000E 03  6.95000000E 01  2.30000000E-02
```

RAW SUMS OF SQUARES AND CROSS PRODUCTS

X(1) VERSUS X(1) THRU X(8)
8.77357076E 03 1.73570580E 05 2.10557422E 03 8.06597718E 02 1.22832866E 05 2.41140741E 06 3.68394537E 04 2.82147708E 01

X(2) VERSUS X(2) THRU X(8)
6.30155516E 06 4.90956450E 04 1.92498723E 04 2.87501707E 06 7.04744271E 07 1.09714336E 06 6.44615700E 02

X(3) VERSUS X(3) THRU X(8)
5.45723700E 02 2.14604800E 02 3.19433880E 04 6.98149573E 05 1.07067250E 04 6.52366000E 00

X(4) VERSUS X(4) THRU X(8)
1.01756800E 02 1.25586492E 04 2.85382227E 05 4.34195000E 03 2.86847000E 00

X(5) VERSUS X(5) THRU X(8)
1.87575680E 06 4.09989628E 07 6.29413925E 05 3.89162756E 02

X(6) VERSUS X(6) THRU X(8)
1.05711182E 09 1.61825920E 07 7.38245860E 03

X(7) VERSUS X(7) THRU X(8)
2.53393000E 05 1.08366000E 02

X(8) VERSUS X(8) THRU X(8)
2.37303000E-01

RESIDUAL SUMS OF SQUARES AND CROSS PRODUCTS

X(1) VERSUS X(1) THRU X(8)
3.04637160E 03 9.04076157E 03 4.60951894E 02 1.41864273E 02 2.59957699E 04 -2.72345002E 04 -9.51912474E 02 1.10769477E 01

X(2) VERSUS X(2) THRU X(8)
1.57497583E 06 1.84926765E 03 1.53544422E 02 9.31005640E 04 4.17615703E 05 1.14806450E 04 1.52283786E 02

X(3) VERSUS X(3) THRU X(8)
7.34540058E 01 2.37199654E 01 4.13565055E 03 -2.13076076E 03 -1.45442499E 02 1.60236327E 00

X(4) VERSUS X(4) THRU X(8)
2.46038077E 01 1.31914895E 03 2.33866734E 03 -4.43450001E 01 8.79350385E-01

X(5) VERSUS X(5) THRU X(8)
2.38407909E 05 -2.34281449E 05 -9.57313750E 03 9.93916166E 01

X(6) VERSUS X(6) THRU X(8)
1.87378755E 07 9.10249004E 04 8.51719924E 01

X(7) VERSUS X(7) THRU X(8)
4.02375000E 03 -4.71925000E 00

X(8) VERSUS X(8) THRU X(8)
1.86020519E-01

SIMPLE CORRELATION COEFFICIENTS

X(1) VERSUS X(1) THRU X(8)
1.00000000E 00 1.30519869E-01 9.74442960E-01 5.18179748E-01 9.64608125E-01 -1.13990274E-01 -2.71888028E-01 4.65316272E-01

X(2) VERSUS X(2) THRU X(8)
1.00000000E 00 1.71931354E-01 2.46658414E-02 1.51934022E-01 7.68740388E-02 1.44216132E-01 2.81343116E-01

X(3) VERSUS X(3) THRU X(8)
1.00000000E 00 5.57962673E-01 9.88270343E-01 -5.74336970E-02 -2.67527291E-01 4.33483741E-01

X(4) VERSUS X(4) THRU X(8)
1.00000000E 00 5.44668607E-01 1.08919870E-01 -1.40937967E-01 4.11036482E-01

X(5) VERSUS X(5) THRU X(8)
1.00000000E 00 -1.10845329E-01 -3.09085386E-01 4.71964136E-01

X(6) VERSUS X(6) THRU X(8)
1.00000000E 00 3.31500771E-01 4.56200972E-02

X(7) VERSUS X(7) THRU X(8)
1.00000000E 00 -1.72495219E-01

X(8) VERSUS X(8) THRU X(8)
1.00000000E 00

VARIABLE	SUM	MEAN	STD. DEV.
1	5.45723700E 02	1.04946865E 01	7.72869823E 00
2	1.56774400E 04	3.01489231E 02	1.75732408E 02
3	1.56710000E 02	3.01365385E 00	1.20011442E 00
4	6.33400000E 01	1.21807692E 00	6.94570084E-01
5	9.22725000E 03	1.77447115E 02	6.83715211E 01
6	2.32369200E 05	4.46863846E 03	6.06142990E 02
7	3.60100000E 03	6.92500000E 01	8.88240164E 00
8	1.63300000E 00	3.14038462E-02	6.03942146E-02

TYPE 3 TAPE OUTPUT
END BASICSTATI

```
PROBLEM NO.    2

NO OF DATA =    52

NO OF VARIABLES =  8

NO OF CASE =  2

F LEVEL TO ENTER VARIABLES =       0

F LEVEL TO REMOVE VARIABLES =       0


   8 VARIABLES   ELIMINATE    7
SYY =1.86020519E-01DEG. FREE. = 5.10000000E 01
 STANDARD ERROR OF Y =  6.0394215E-02
```

STEP NO. 1
VARIABLE ENTERING 5

SSE	R-SQUARE	DEG. FREE
1.44584421E-01	2.22750146E-01	5.00000000E 01

F LEVEL 14.3294
STANDARD ERROR OF Y = 5.3774422E-02
CONSTANT -4.2573379E-02

VARIABLE	COEFFICIENT	STUDENTS T
X- 5	4.1689731E-04	3.7854165E 00

STEP NO. 2
VARIABLE ENTERING 3

SSE	R-SQUARE	DEG. FREE
1.35927494E-01	2.69287632E-01	4.90000000E 01

F LEVEL 3.1207
STANDARD ERROR OF Y = 5.2669066E-02
CONSTANT -4.7159434E-02

VARIABLE	COEFFICIENT	STUDENTS T
X- 3	-7.1087587E-02	-1.7665514E 00
X- 5	1.6500503E-03	2.3360507E 00

```
STEP NO. 3
  VARIABLE ENTERING      2

        SSE                        R-SQUARE            DEG. FREE
     1.24688812E-01      3.29703987E-01      4.80000000E 01
  F LEVEL        4.3264
  STANDARD ERROR OF Y =  5.0967476E-02
  CONSTANT -6.7975912E-02
            VARIABLE    COEFFICIENT    STUDENTS  T

             X=  2  8.6369579E-05  2.0800059E 00
             X=  3 -8.2898310E-02 -2.1065510E 00
             X=  5  1.8212022E-03  2.6453395E 00
```

```
STEP NO. 4
  VARIABLE ENTERING      4
        SSE                        R-SQUARE            DEG. FREE
     1.13647285E-01        3.89060491E-01        4.70000000E 01
  F LEVEL        4.5663
  STANDARD ERROR OF Y =  4.9173441E-02
  CONSTANT -7.6806532E-02
              VARIABLE    COEFFICIENT    STUDENTS  T

               X=  2   9.4482812E-05   2.3478885E 00
               X=  3  -9.6550270E-02  -2.5077224E 00
               X=  4   2.5678154E-02   2.1368989E 00
               X=  5   1.9127724E-03   2.8737380E 00
```

STEP NO. 5
VARIABLE ENTERING 1

SSE	R-SQUARE	DEG. FREE
1.00945111E-01	4.57344213E-01	4.60000000E 01

F LEVEL 5.7883
STANDARD ERROR OF Y = 4.6845052E-02
CONSTANT -2.8539144E-03

VARIABLE	COEFFICIENT	STUDENTS T
X- 1	9.3331367E-03	2.4058874E 00
X- 2	1.1118561E-04	2.8538622E 00
X- 3	-1.5542184E-01	-3.5249882E 00
X- 4	2.9938749E-02	2.5845522E 00
X- 5	1.8862413E-03	2.9742832E 00

STEP NO. 6
VARIABLE ENTERING 6

SSE	R-SQUARE	DEG. FREE
9.34991945E-02	4.97371608E-01	4.50000000E 01

F LEVEL 3.5836
STANDARD ERROR OF Y = 4.5582451E-02
CONSTANT -9.2233717E-02

VARIABLE	COEFFICIENT	STD ERROR OF COEF	T VALUE	STD. COEFF
X- 1	1.1064492E-02	3.8839517E-03	2.8487718E 00	1.4159323E 00
X- 2	1.0949343E-04	3.7920166E-05	2.8874724E 00	3.1859913E-01
X- 3	-1.8907153E-01	4.6439619E-02	-4.0713411E 00	-3.7571060E 00
X- 4	2.7040285E-02	1.1375032E-02	2.3771613E 00	3.1097967E-01
X- 5	2.3198042E-03	6.5822114E-04	3.5243539E 00	2.6262208E 00
X- 6	2.2316532E-05	1.1788683E-05	1.8930471E 00	2.2397857E-01

PREDICTED VS ACTUAL RESULTS

RUN NO.	ACTUAL	PREDICTED	DEVIATION
1	2.300000E-02	-1.015732E-02	3.315732E-02
2	2.000000E-02	8.997471E-03	1.100253E-02
3	1.000000E-03	6.617461E-02	-6.517461E-02
4	1.000000E-01	1.017707E-02	8.982293E-02
5	1.200000E-01	1.304366E-02	1.069563E-01
6	1.000000E-03	8.615212E-03	-7.615212E-03
7	5.000000E-03	4.955513E-02	-4.455513E-02
8	4.000000E-02	3.068563E-02	9.314372E-03
9	0	-1.423018E-02	1.423018E-02
10	1.000000E-03	-1.026879E-02	1.126879E-02
11	0	4.713310E-03	-4.713310E-03
12	1.000000E-03	-4.065424E-03	5.065424E-03
13	1.000000E-03	-9.893887E-03	1.089389E-02
14	1.000000E-03	-5.325947E-03	6.325947E-03
15	5.000000E-03	2.483042E-02	-1.983042E-02
16	1.000000E-03	9.035498E-03	-8.035498E-03
17	8.000000E-03	3.878241E-02	-3.078241E-02
18	0	-8.899086E-03	8.899086E-03
19	1.000000E-03	-1.150001E-02	1.250001E-02
20	1.400000E-01	9.213170E-02	4.786830E-02
21	1.000000E-03	7.592709E-03	-6.592709E-03
22	6.000000E-02	5.502065E-03	5.449793E-02
23	5.000000E-02	1.883917E-02	3.116083E-02
24	1.000000E-03	8.023624E-03	-7.023624E-03
25	1.300000E-02	1.066214E-02	2.337859E-03
26	1.000000E-03	2.148993E-02	-2.048993E-02
27	1.000000E-03	2.129574E-02	-2.029574E-02
28	1.000000E-03	7.405239E-03	-6.405239E-03
29	2.000000E-01	5.303525E-02	1.469648E-01
30	1.000000E-03	-4.004645E-03	5.004645E-03
31	1.000000E-03	2.379745E-03	-1.379745E-03
32	2.500000E-02	4.682592E-02	-2.182592E-02
33	1.000000E-03	3.024284E-02	-2.924284E-02
34	1.000000E-03	6.217055E-02	-6.117055E-02
35	1.000000E-03	3.606502E-02	-3.506502E-02
36	1.000000E-03	6.970578E-02	-6.870578E-02
37	1.000000E-03	6.317207E-02	-6.217207E-02
38	2.000000E-02	1.407483E-02	5.925172E-03
39	5.000000E-02	3.418528E-02	1.581472E-02
40	1.000000E-03	4.805546E-02	-4.705546E-02
41	1.000000E-03	5.476292E-02	-5.376292E-02
42	2.000000E-02	8.822547E-02	-6.822547E-02
43	1.000000E-03	9.344305E-03	-8.344305E-03
44	5.400000E-02	8.018682E-02	-2.618682E-02
45	5.000000E-02	4.062016E-02	9.379845E-03
46	1.500000E-01	1.246781E-01	2.532185E-02
47	3.000000E-01	2.231760E-01	7.682396E-02
48	1.000000E-03	1.553410E-02	-1.453410E-02
49	5.000000E-03	4.227028E-02	-3.727028E-02
50	1.500000E-01	1.120072E-01	3.799278E-02
51	1.000000E-03	-1.252044E-03	2.252044E-03
52	0	4.326389E-03	-4.326389E-03

DEVIATION MEAN, SUM OF SQUARES, ... CUBES, ... FOURTH POWERS.

```
          1.0227442824E-11    9.3499195597E-02    4.0572958229E-03    8.3067637354E-04
BETA1,BETA2,KAPPA,W1,W2
       1.04725651E 00      4.94105232E 00      1.34160933E 00      3.18995962E 00      3.48625933E 00
```

INVERSE MATRIX

ROW 1	1	2.2117456E 01	2	8.2283961E-01	3	-2.4163545E 01	4	6.7254862E-01
	5	2.1915284E 00	6	1.2397849E 00				
ROW 2	1	8.2283961E-01	2	1.0899812E 00	3	-1.8345529E 00	4	1.5642958E-01
	5	7.6545498E-01	6	-2.7551879E-02				
ROW 3	1	-2.4163545E 01	2	-1.8345529E 00	3	7.6242551E 01	4	-1.6323251E 00
	5	-5.1286832E 01	6	-3.7416012E 00				
ROW 4	1	6.7254862E-01	2	1.5642958E-01	3	-1.6323251E 00	4	1.5321885E 00
	5	8.5455211E-02	6	-1.8652529E-01				
ROW 5	1	2.1915284E 00	2	7.6545498E-01	3	-5.1286832E 01	4	8.5455211E-02
	5	4.9712883E 01	6	2.7465101E 00				
ROW 6	1	1.2397849E 00	2	-2.7551879E-02	3	-3.7416012E 00	4	-1.8652529E-01
	5	2.7465101E 00	6	1.2533016E 00				