EFFECT OF ANNUAL PRECIPITATION AND TEMPERATURE ON THE PERFORMANCE OF WHEAT VARIETIES

By

Ali Mojtahedi

Agronomist (Ingenieur Agricole)

from

Agriculture College

Montpellier, France

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Thesis Approved:

A. M. Schlehuber

Thesis Adviser

H. Murphy

Robert MacVicar

Dean of the Graduate School

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INTRODUCTION

The most important factor in production of wheat is yield; consequently in every agricultural experiment this factor must be kept in mind. The interests of farmers and of wheat growers are related directly to yield. In order for wheat to produce good yield, it must have maximum benefit from the environment in which it grows.

Of the multiple factors that affect environment, the most important is climate. The factors of climate that most affect winter wheat are precipitation, temperature, relative humidity and wind velocity. In general, there is a relation between precipitation and temperature; usually precipitation is accompanied by low temperature.

Climate indirectly affects the yield of winter wheat in favoring or retarding the development of diseases, especially the different kinds of rusts, and also facilitating the lodging of cereals.

Temperature influences every chemical and physical process connected with plants: solubility of minerals; absorption of water, gases, and other mineral nutrients; diffusion; synthesis; as well as the vital process of growth and development. The effects of high temperatures on plants are difficult to separate from the usual accompanying factors of high light intensity and rapid transpiration. Most crops make their growth during the portion of the year when the temperature remains within certain limits; becoming dormant, maturing, or dying when the temperature falls too low or rises too high.

It is well known that in the dry countries there is a positive and significant correlation between the yield of wheat and the amount of rainfall. But in the humid countries this correlation is non-existent or negative. It seems natural that the non-existent or negative correlation is due to adverse conditions, especially that due to development of diseases and lodging. Now if we get productive varieties with resistance to diseases, would there be positive and significant correlation between yield and precipitation? In other words, do the "better" varieties benefit more from certain environmental conditions, especially from rainfall? If true, the creation of productive varieties in the humid countries can occur at a very high level.

It was the purpose of this study to verify this hypothesis.

REVIEW OF LITERATURE

Relationships between weather and wheat production have been studied all over the world. A selected bibliography of the influence of weather on crops was published by Hannay (8) in 1931.

Zink (15) studied the relation of weather factors to wheat yields on Levan Ridge, Utah, and for this purpose 120 combinations of weather factors in relation to wheat yields were studied for the 25 years, 1908-1933. About 40 of the combinations studied indicated a fair amount of correlation between yield and weather factors and about one-third of these were statistically significant at the 5% level. Partial and multiple correlations were determined for the 15 highest of these combinations. Multiple correlations from 0.71 to 0.81 were obtained for weather conditions during the spring period, especially in the period two or three weeks preceding heading. The high correlations were with evaporation, length of drought period, and rainfall.

Sando (13) found a significant negative correlation between rainfall and yields of wheat grown at the Maryland Agricultural Experiment Station. He noted that in general yields above normal were associated with subnormal rainfall for the months of March and May. No definite relation appeared to exist between yields of the varieties studied and other climatic factors such as snowfall, temperature, and sunshine.

Welton and Morris (14) studied the effect of rainfall on wheat yields in Ohio and concluded that subnormal rainfall induced higher yields of wheat. They found that April and November are the two individual months in which the subnormal rainfall appears to be the most beneficial. They concluded that the exceptionally high yields, which were occasionally obtained, represented what wheat could and probably would do every year, barring the interference of other factors, providing the rainfall were a little less.

Berce and Wilbaux (1) at Gembloux, Belgium, in a study over a 27 year period on the relationship between yields of winter wheat and meteorological factors, found a negative and significant correlation between yield of winter wheat and maximum mean temperature in June with $r = -0.514 \pm 0.095$, a significant and negative correlation of -0.507 ± 0.096 with yields and amount of rainfall in July, and $r = -0.407 \pm 0.101$ between the amount of rainfall for the bi-monthly period November-December and the yield. From these correlations they concluded there were harmful effects of rain before harvest and in winter before frost time. The temperature was less influential but high temperature in June caused scalding.

Dunham (7) studied the effect of environment on wheat, oats, and flax grown at Crookston, Minnesota, during a period of four years, 1934 to 1937. He found an apparent association between yield and precipitation for wheat, oats, and flax in 1935 and 1936, but not in 1937 and 1934 when the precipitation during the preceding year of fallow was disregarded.

In summation of a 30 year study of the influence of rainfall on wheat yields in South Australia (Victoria), Richardson (12) reported that yield of wheat is very largely determined by rainfall. Throughout the entire 30 year period the wheat growers of Victoria secured on the average 0.89 bushels of wheat for every inch of winter rainfall.

Call and Hallsted (3) reported that moisture is the limiting factor in wheat production in Western Kansas.

Kvicala (9) in 1940 in Southern Moravia found that in winter wheat the average monthly temperature in autumn substantially influences the yield and that rains in September and December have a strong negative correlation with yield of winter wheat.

Bogush (2) in New Zealand submitted six lines of wheat under field conditions to heavy and extended artificial rain and natural rainfall alternating with fair drying conditions for a period of nearly three weeks. This heavy weathering did not result in any significant losses in grain weight and yield.

In a statistical study of data covering a total of 387 crop years at 19 stations in the Great Plains, Cole (5) found that spring wheat yields were positively associated with annual rainfall. He obtained coefficients of correlation between precipitation and average yield ranging from 0.61 to 0.90 at the several stations.

Locke and Mathews (11) in a study over 33 years from 1915-1948 at Woodward, Oklahoma, found a positive and significant correlation between the yields of wheat and amount of rainfall in April.

Laude (10) reports that in the western third of Kansas the acre yield of wheat is associated with the amount of rainfall received from July 1 to May 31. The correlation coefficient for different series of years usually exceeds 0.80. The regression coefficient indicates that the acre yields of wheat in the western third of the state varies about 1.25 bushels for each one inch variation in the season rainfall. The average precipitation in that region is between 15 and 16 inches during the wheat season from July 1 to May 31. In the central third of the state the correlation is low between yield of wheat and precipitation during the eleven month wheat season. In many seasons damage is done by drought, but in a large proportion of the years the dominant influence on acre yield is due to other causes, in some cases to too much rain. In the eastern third of Kansas, drought causes only slight damage to wheat. Too much rain is a far more serious factor.

MATERIALS AND METHODS

The performance of 9 varieties of hard red winter wheat grown at two stations, Stillwater and Woodward, Oklahoma for the 10-year period, 1943-1952, was studied in relation to precipitation and temperature. The 9 varieties were: Cheyenne, Comanche, Early Blackhull, Pawnee, Red Chief, Tenmarq, Triumph, Wichita, and Kharkof.

The data concerning the yield were obtained from the Oklahoma Agricultural Experiment Station Bulletin, No. B-297, 1946, and from unpublished data of the Oklahoma Agricultural Experiment Station.

The climatological data were obtained from the U. S. Department of Commerce, Weather Bureau. (5)

A brief description of the varieties follows:

Cheyenne--the result of a plant selection made from Crimean in 1922 at the Nebraska Agricultural Experiment station. It has bearded, short erect heads; red kernels, midlong, hard. It is susceptible to stem and leaf rusts and to bunt, but it is tolerant to Hessian fly and does not shatter easily.

Comanche--developed from an Oro X Tenmarq cross. It was released by the Kansas station in 1942. It is a bearded, fairly early, moderately winter hardy wheat that possesses fairly good straw. It has high resistance to many important races of bunt and has some resistance to leaf rust. It is susceptible to loose smut and Hessian fly.

Early Blackhull--selected from a field of Blackhull in 1921. It differs from Blackhull principally in being about a week earlier and having a somewhat shorter straw. It is not disease resistant, but sometimes ripens early enough to escape severe rust infection.

Pawnee--the result of a Kawvale x Tenmarq cross. It is a bearded, hard red winter wheat with smooth, white glumes. It has a short stiff straw, is resistant to loose smut, and moderately resistant to leaf rust, bunt, and Hessian fly. It either has some resistance to or is able to escape severe stem rust damage because of earliness. Pawnee has a slight tendency to shatter when ripe.

Red Chief--the exact origin of the variety is not known, but it may be a selection from a natural Redhull x Chiefkan hybrid. It is beardless, has little or no disease resistance, and is even more susceptible to bunt than is the susceptible Chiefkan.

Tenmarq--was selected from a Marquis (spring) x Crimean selection (winter) cross. It is bearded, early, and has a fair straw. The variety has some resistance to leaf rust, and because of its earliness it may escape serious damage from stem rust.

Triumph--was developed and distributed by Joseph Danne of El Reno, Oklahoma, in about 1940. The originator has not divulged the parentage of this variety. It is an early, bearded, stiff-strawed hard red winter wheat. The variety is extremely susceptible to leaf rust and susceptible to bunt and stem rust, but appears to have some resistance to loose smut. Because of its earliness, it frequently escapes heavy rust infections.

Wichita--was developed from an Early Blackhull x Tenmarq cross. In most plant characteristics it is similar to Early Blackhull but is approximately one or two days later in maturity, has a slightly better straw, and a higher yield.

Kharkof--was introduced into the United States by M. A. Carleton in 1900. It is susceptible to the same diseases as Cheyenne and Tenmarq. It is very similar in appearance and performance to Turkey but is somewhat more uniform. Because of this uniformity, it is a more useful "measure" than Turkey in the yield evaluation of new varieites.

DISCUSSION OF RESULTS

Importance of Wheat Varieties

Oklahoma is one of the important states in production of wheat. According to the census of 1944, the total acreage of wheat in this state was 7,552,000 acres, which ranked fourth after Kansas, North Dakota, and Texas in production of wheat. The wheat is grown mostly in the western and central parts of Oklahoma.

Table 1 shows the estimated percentage of the total wheat area occupied by 9 varieties of wheat grown in Oklahoma at five year intervals since 1919 and the acreage in 1944 and 1949. From this table it is evident that in the last years the varieties Triumph, Pawnee, and Comanche have increased in acreage but other varieties have decreased excessively.

Rainfall influences the yield of wheat directly and also indirectly; directly by supplying water for normal physiological processes of the plant and indirectly by modifying the environment in which plants grow. High temperatures accompanying high rainfall make a very suitable condition for developing diseases, especially rusts. High rainfall also promotes lodging and interferes with harvesting and threshing of the crops.

Table 1.--Estimated percentage of nine varieties of wheat and acreage of wheat in 1944 and 1949*

Variety	Percentage							Acreage	
	1919	1924	1929	1934	1939	1944	1949	1944	1949
Triumph						1.3	41.5	65,878	3,135,287
Pawnee							18.9	228	1,429,932
Comanche							11.0	1,632	827,423
Early Blackhull					1.9	7.0	6.1	363,437	459,014
Red Chief						3.5	5.0	182,155	374,583
Wichita							4.9		371.700
Tenmarq					10.0	40.3	3.6	2,026,400	268,375
Cheyenne					.7	4.0	2.0	210,603	151,955
Turkey	68.6	52.3	47.4	44.9	29.3	15.0	1.6	782,167	118,634

*Data from reference (4).

Effect of Frequency of Rainfall

The frequency of rainfall may be important in production of wheat. Table 2 shows the frequency of rainfall and the amount of rainfall in a crop year at Stillwater and Woodward for a decade, 1943-1952.

Table 2.--Frequency of rainfall and amount of rainfall in crop year

Year	Frequency		Amount of rainfall in crop year	
	Stillwater	Woodward	Stillwater	Woodward
1943	82	80	45.51	25.83
1944	65	71	24.78	27.79
1945	87	77	28.06	28.10
1946	76	44	42.30	20.55
1947	62	64	30.18	30.15
1948	71	66	22.83	14.99
1949	85	83	38.12	32.25
1950	85	57	23.42	24.18
1951	74	68	25.47	31.45
1952	78	80	33.17	21.73

Since a wheat crop at Stillwater and at Woodward approaches maturity about June 1, the foregoing relationships are based on crop year precipitation; that is, June 1 of one year to May 31 of the following year. The rainfall frequency data were obtained by counting the number of days in which there was 0.01 inch or more rainfall.

Figures 1 and 2 show the relation between frequency of rainfall and amount of crop year rainfall. The diagram is divided into four quadrants by drawing the axes intersecting the scales at the mean values of their respective factors. These quadrants have been numbered I to IV in clockwise sequence, beginning with the upper right quartile.

At Stillwater during the 10-year period seven frequency-amount of rainfall occurrences (shown by dots in Figure 1) fell in quadrants I and III, while only three fell in quadrants II and IV. At Woodward quadrants I and III also contain seven dots and quadrants II and IV contain three only.

In both of these figures the dots are spread very widely, and it is an indication that there is little correlation between frequency of rainfall and amount of rainfall during a crop year.

The correlation coefficients between these two factors at Stillwater and Woodward are 0.29 and 0.38, respectively.

From these data it becomes clear that the frequency of rainfall is not correlated with the amount of rainfall during crop year, and consequently must be studied separately.

Correlation coefficients were calculated between frequency of rainfall and the yield of the three varieties of winter wheat, Early Blackhull, Pawnee, and Cheyenne (early,

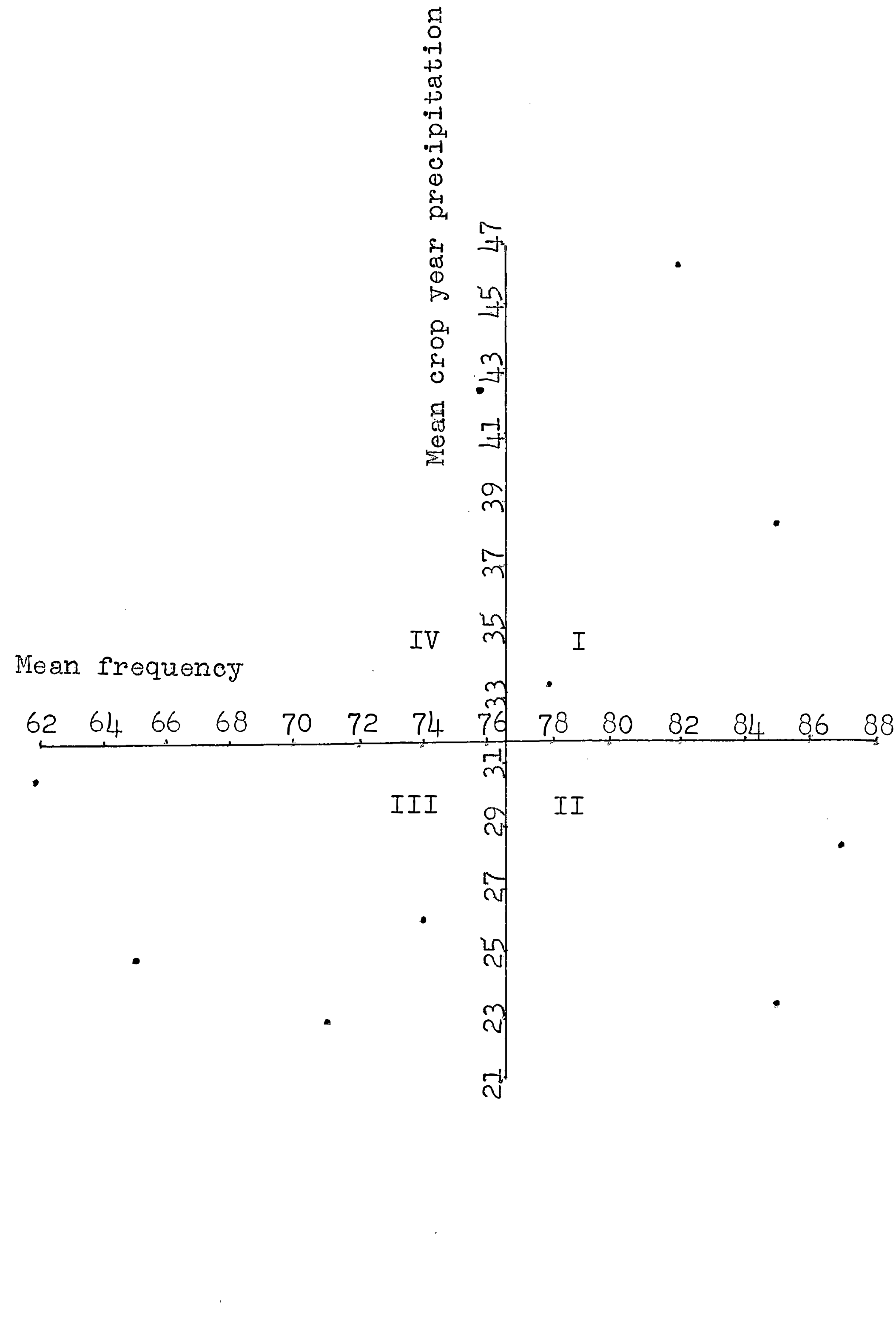

Fig. 1. Relation between frequency and amount of rainfall during the crop year at Stillwater from 1943-1952

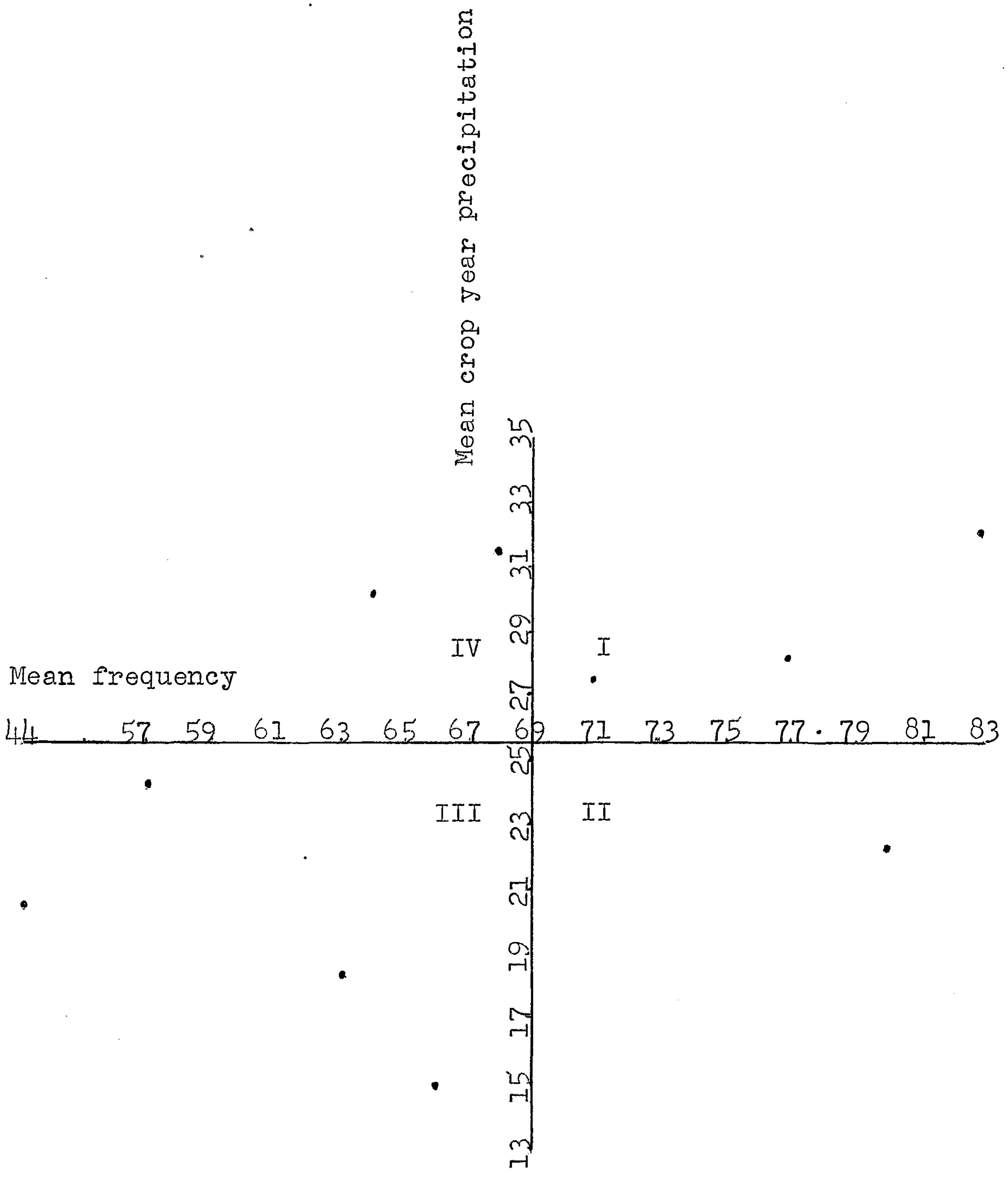

Fig. 2. Relation between frequency and amount of rainfall during the crop year at Woodward from 1943-1952

medium and late maturing wheats), at Stillwater and Woodward. The results are shown as follows:

Variety	Stillwater	Woodward
Early Blackhull	-0.07	0.39
Pawnee	-0.20	0.40
Cheyenne	-0.34	0.24

The correlations are negative and low at Stillwater and positive but low at Woodward. Even though the correlations are low, it may be of some significance that the values increase from early to late maturing varieties at Stillwater while almost the opposite is true for the positive values at Woodward.

Effect of Amount of Rainfall

Reaction of varieties of winter wheats to amount of rainfall during the crop year or growing season in the spring is not the same at Stillwater and at Woodward.

There is evidence that the total rainfall during the three months period, February through April, is extremely critical in determining the magnitude of wheat yield. The most obvious reason for dependence of wheat on the rainfall in February, March, and April is that adequate rainfall in the three months terminates the winter drought period and gives the crop a chance to start rapid growth under favorable conditions.

Tables 3 and 4 show the yield of 9 varieties of winter wheat at Stillwater and Woodward, respectively, during 1943-1952. The yields of Triumph wheat in 1943 and 1944 at Woodward and the yield of Wichita at Stillwater in 1944 are calculated mathematically.

Table 5 shows the amount of crop year rainfall and the amount of three months period, February through April, rainfall at Stillwater and Woodward during 1943-1952.

Table 6 shows correlation coefficients between the yield of nine varieties of winter wheat and amount of rainfall during the crop year and three months period, February through April, at Stillwater and Woodward for the period 1943-1952.

At Woodward the correlation between yield and total rainfall during the three months period, February through April, is highly significant (at 1% level) for four varieties: Pawnee, Cheyenne, Red Chief, and Kharkof. This correlation is significant at the 5% level for Early Blackhull, Wichita, Triumph, and Comanche but not for Tenmarq. At Stillwater this correlation is positive and more or less high, but it is not significant. Four varieties, Pawnee, Red Chief, Tenmarq, and Kharkof, have the highest correlation and it should be noted that all of them are late or medium maturity.

Table 3.--Yields in bushel per acre of nine varieties of winter wheat grown at Stillwater from 1943-1952

Year	Wichita	Early Blackhull	Triumph	Red Chief	Comanche	Pawnee	Kharkof	Cheyenne	Tenmarq
1943	16.5	13.6	10.6	13.2	10.9	9.5	8.1	12.8	9.9
1944	(29.8)*	31.1	32.2	28.5	31.9	32.3	30.4	29.4	28.6
1945	18.5	28.2	26.4	22.9	29.8	30.1	20.2	24.8	20.7
1946	19.2	18.1	18.0	23.5	19.0	27.8	18.8	24.1	14.2
1947	20.6	23.2	25.7	23.3	25.7	24.4	25.2	25.1	23.4
1948	21.4	22.1	21.1	22.2	20.2	19.3	20.6	21.0	21.3
1949	16.9	23.5	21.9	21.3	22.2	21.6	20.9	20.0	20.2
1950	27.6	23.4	24.4	24.3	22.8	23.8	21.7	24.2	21.3
1951	16.9	14.1	15.4	15.1	17.4	16.8	19.0	19.1	16.2
1952	19.3	20.1	18.3	20.4	20.1	17.7	21.1	19.8	19.5
Average	19.6	21.7	21.4	21.4	22.0	22.3	20.6	22.0	19.5

*Calculated by missing plot technique.

Table 4.--Yields in bushel per acre of nine varieties of winter wheat grown at Woodward from 1943-1952

Year	Wichita	Early Blackhull	Triumph	Red Chief	Comanche	Pawnee	Kharkof	Cheyenne	Tenmarq
1943	32.2	29.1	(28.0)*	31.5	33.5	33.3	21.6	28.4	31.2
1944	47.0	42.6	(50.0)*	56.2	46.8	47.9	53.2	58.9	29.4
1945	33.2	24.1	31.1	31.3	32.1	34.2	29.1	30.6	28.5
1946	31.1	26.1	28.6	30.3	28.5	28.4	21.1	25.9	22.7
1947	26.3	25.1	23.9	24.0	24.8	27.3	21.9	24.7	23.7
1948	27.1	25.4	24.6	27.6	23.5	23.1	24.3	25.3	24.7
1949	29.6	23.8	27.6	26.8	22.8	31.8	22.7	25.8	21.8
1950	11.6	9.6	9.5	13.8	11.6	10.9	11.2	15.6	11.4
1951	17.6	17.3	8.4	24.9	21.4	17.2	20.4	21.9	21.0
1952	26.1	23.2	26.4	25.9	26.4	26.4	22.2	29.8	22.9
Average	28.1	24.6	25.8	29.2	27.1	28.0	24.7	28.7	23.7

*Calculated by missing plot technique.

Table 5.--Amount of rainfall, in inches, of crop year and three months period February through April at Stillwater and Woodward during 1943-1952

Year	Amount of Rainfall in Inches: Stillwater, Crop Year	Stillwater, February through April	Woodward, Crop Year	Woodward, February through April
1943	45.51	3.54	25.83	2.20
1944	24.78	7.94	27.79	12.21
1945	28.06	6.58	28.10	6.31
1946	42.30	6.88	20.55	4.64
1947	30.18	8.93	30.15	3.01
1948	22.83	8.59	14.99	6.56
1949	38.12	5.30	32.25	4.46
1950	23.42	2.71	24.18	3.58
1951	25.47	3.76	31.45	3.68
1952	33.17	6.32	21.73	6.26
Average	31.38	6.06	25.70	5.29

Table 6.--Correlation coefficients between yields of varieties of winter wheat and amount of rainfall during crop year and three months period February through April at Stillwater and Woodward

	Correlation Coefficients			
	Stillwater		Woodward	
Variety	With Crop Year Rainfall	With 3 mo. period Rainfall	With Crop Year Rainfall	With 3 mo. period Rainfall
Wichita	-0.580	0.160	0.045	0.688*
Early Blackhull	-0.497	0.498	0.191	0.677*
Triumph	-0.598	0.511	-0.021	0.750*
Red Chief	-0.436	0.550	0.087	0.876**
Comanche	-0.564	0.210	0.091	0.677*
Pawnee	-0.363	0.585	0.202	0.829**
Kharkof	-0.639*	0.559	0.136	0.885**
Cheyenne	-0.537	0.180	0.103	0.864**
Tenmarq	-0.710*	0.568	0.048	0.342

* Significant at 5% level

** Significant at 1% level

The correlation between amount of rainfall during the crop year and yield of wheat varieties at Woodward is very low and near zero. It is useful to remark that average of amount of rainfall in the decade of 1943-1952 is higher than in a normal decade. The average rainfall at Woodward for the period 1915-1948 is 23.76 inches (11), while for 1943-1952, covering the years of this study, the annual precipitation is 25.70 inches.

The correlation between amount of rainfall during the crop year and varieties of wheat at Stillwater is in general relatively high and negative. This correlation at the 5% level is significant for Kharkof and Tenmarq, and that may explain the decline of these varieties in the last decade.

From the negative correlation coefficient between the yield of winter varieties of wheat and amount of rainfall during the crop year, the result is that the varieties of winter wheat that are cultivated at Stillwater do not utilize all the rainfall and even this amount of rainfall is harmful to them; consequently there remains a large possibility for the creation of new varieties of wheat better adapted for this part of the state.

At Woodward, the creation of new varieties that require small quantities of moisture must be accompanied by a program in agrotechnic so as to provide more moisture in the growing season for wheat.

Effect of Temperature

Temperature may affect the yield of winter wheat in many ways:

A. In the fall, temperature helps the plant to tiller and to acquire the necessary hardiness to resist the low temperatures in winter time. For this study it was necessary to take in consideration the average temperature of October and November. Table 7 shows the mean temperature in October and November at Stillwater and Woodward from 1943-1952.

A simple look at this table indicates that the variation of mean temperature during the decade is very small, and so small temperature variation can not have a great influence in growth of plants. On the other hand, daily variation of temperature is much more important.

Also, grazing of all varieties of wheat during the fall confirms the view that the low temperature in October and November is not a limiting factor in Oklahoma.

B. The low temperatures in December, January, and February can kill the wheat plant, and different varieties show different degrees of resistance.

Study of influence of lowest temperature on the yield of wheat is very difficult because the snow covering may diminish or modify the injurious

Table 7.---The mean temperature in October and November and the average of mean temperature in these two months at Stillwater and Woodward

	Stillwater			Woodward		
	Mean Temperature		Average of Mean	Mean Temperature		Average of Mean
Year	Oct.	Nov.	Temperature	Oct.	Nov.	Temperature
1943	61.8	53.1	57.4	60.6	50.4	55.5
1944	60.6	49.0	54.8	58.8	47.6	53.2
1945	63.8	52.1	57.9	62.5	50.8	56.6
1946	61.9	54.6	58.2	61.4	50.3	55.8
1947	66.0	49.8	57.9	62.7	48.4	55.5
1948	70.0	46.1	58.0	67.4	41.9	54.6
1949	61.0	48.0	54.5	58.0	43.1	50.5
1950	62.0	53.3	57.6	60.9	51.7	55.8
1951	67.6	45.4	56.0	66.3	45.1	55.7
1952	61.8	42.7	52.5	60.2	42.3	51.5

effect of low temperature. The lowest temperature in the study decade was -15° F. at Stillwater and -24° F. at Woodward in January of 1947. At Stillwater, the yield of all nine varieties is above the average yield for the decade, and at Woodward the low yield may be attributable to the small amount of rainfall during the growing season. It is evident that at least at Stillwater the low temperature in winter time is not a limiting factor.

C. Spring frost also may affect the yield of wheat. Tables 8 and 9 show the yield of nine varieties and the lowest temperature in March during the studying decade. The yields above average are indicated by + and the yields below average are indicated by -. From these data it is evident that low temperature near 0° F., although it decreases the yield, is not a limiting factor in Oklahoma.

Table 8.--The yields of varieties of wheat and lowest temperature in March at Stillwater during 1943-1952

Year	Yields of Varieties of Wheat in Bushels									Lowest Temp. F° March
	Wichita	Early Blackhull	Triumph	Red Chief	Comanche	Pawnee	Kharkof	Cheyenne	Tenmarq	
1943	16.5 (−)	13.6 (−)	10.6 (−)	13.2 (−)	10.9 (−)	9.5 (−)	8.1 (−)	12.8 (−)	9.9 (−)	2
1944	29.8 (+)	31.1 (+)	32.2 (+)	28.5 (+)	31.9 (+)	32.3 (+)	30.4 (+)	29.4 (+)	28.6 (+)	16
1945	18.5 (−)	28.2 (+)	26.4 (+)	22.9 (+)	29.8 (+)	30.1 (+)	20.2 (−)	24.8 (+)	20.7 (+)	21
1946	19.2 (−)	18.1 (−)	18.0 (−)	23.5 (+)	19.0 (−)	27.8 (+)	18.8 (−)	24.1 (+)	14.2 (−)	30
1947	20.6 (+)	23.2 (+)	25.7 (+)	23.3 (+)	25.7 (+)	24.4 (+)	25.2 (+)	25.1 (+)	23.4 (+)	9
1948	21.4 (+)	22.1 (+)	21.1 (−)	22.2 (+)	20.2 (−)	19.3 (−)	20.6 (+)	21.0 (−)	21.3 (+)	- 5
1949	16.9 (−)	23.5 (+)	21.9 (+)	21.3 (−)	22.2 (+)	21.6 (−)	20.9 (+)	20.0 (−)	20.2 (+)	23
1950	27.6 (+)	23.4 (+)	24.4 (+)	24.3 (+)	22.8 (+)	23.8 (+)	21.7 (+)	24.2 (+)	21.3 (+)	14
1951	16.9 (−)	14.1 (−)	15.4 (−)	15.1 (−)	17.4 (−)	16.8 (−)	19.0 (−)	19.1 (−)	16.2 (−)	18
1952	19.3 (−)	20.1 (−)	18.3 (−)	20.4 (−)	20.1 (−)	17.7 (−)	21.1 (+)	19.8 (−)	19.5 (+)	16
Average	20.6	21.7	21.4	21.4	22.0	22.3	20.6	22.0	19.5	

\+ is above the average yield for studying decade

\- is below the average yield for studying decade

Table 9.--The yields of varieties of winter wheat and lowest temperature in March at Woodward during 1943-1952

Year	Yields of Varieties of Wheat in Bushels									Lowest Temp. F° March
	Wichita	Early Blackhull	Triumph	Red Chief	Comanche	Pawnee	Kharkof	Cheyenne	Tenmarq	
1943	+ 32.2	+ 29.1	+ 28.0	+ 31.5	+ 33.5	+ 33.3	- 21.6	- 28.4	+ 31.2	0
1944	+ 47.0	+ 42.6	+ 50.0	+ 56.2	+ 46.8	+ 47.9	+ 53.2	+ 58.9	+ 29.4	18
1945	+ 33.2	- 24.1	+ 31.1	+ 31.3	+ 32.1	+ 34.2	+ 29.1	+ 30.6	+ 28.5	19
1946	+ 31.1	+ 26.1	+ 28.6	+ 30.3	+ 28.5	+ 28.4	- 21.1	- 25.9	- 22.7	25
1947	- 26.3	+ 25.1	- 23.9	- 24.0	- 24.8	- 27.3	- 21.9	- 24.7	+ 23.7	11
1948	- 27.1	+ 25.4	- 24.6	- 27.6	- 23.5	- 23.1	- 24.3	- 25.3	+ 24.7	- 8
1949	+ 29.6	- 23.8	+ 27.6	- 26.8	- 22.8	+ 31.8	- 22.7	- 25.8	- 21.8	21
1950	- 11.6	- 9.6	- 9.5	- 13.8	- 11.6	- 10.9	- 11.2	- 15.6	- 11.4	9
1951	- 17.6	- 17.3	- 8.4	- 24.9	- 21.4	- 17.2	- 20.4	- 21.9	- 21.0	15
1952	- 26.1	- 23.2	+ 26.6	- 25.9	- 26.4	- 26.4	- 22.2	+ 29.8	- 22.9	10
Average	28.1	24.6	22.5	29.2	27.1	28.0	24.7	28.3	23.7	

+ is above the average yield for studying decade

- is below the average yield for studying decade

D. Different varieties of wheat may present different reactions to the average temperature of the growing season in spring, especially in March and April, and consequently produce different yields.

For studying the effect of temperature during the growing season, correlation coefficients were calculated between the yields of Early Blackhull, Pawnee, and Cheyenne (early, medium, and late maturing wheat) with the average of the mean temperature during March and April at Stillwater and Woodward from 1943-1952. The results are as follows:

Variety	Stillwater	Woodward
Early Blackhull	-0.054	0.015
Pawnee	0.447	0.010
Cheyenne	0.273	0.046

It is evident that there is no correlation between these two factors.

E. The high temperature in May may be harmful for normal maturity of wheat and different varieties may present varietal differences.

At Stillwater, the highest temperature in May during the studying decade was 96° F. in 1950. In this year the yield of nine varieties was above the average, and so the high temperature at Stillwater can not be a limiting factor.

At Woodward, the highest temperature in May was 102° F. in 1945. In that year the yield of eight varieties was above the average, and only the yield of Early Blackhull was near average. So it appears that the high temperature in May is not a limiting factor at Woodward.

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VITA

Ali Mojtahedi
candidate for the degree of
Master of Science

Thesis: EFFECT OF ANNUAL PRECIPITATION AND TEMPERATURE ON THE PERFORMANCE OF WHEAT VARIETIES

Major: Field Crops

Biographical and Other Items:

Born: March 28, 1911, at Tabriz, Iran.

Undergraduate Study: Sarvat, Teheran, Iran; Agriculture College, Montpellier, France.

Graduate Study: O.A.M.C., 1953-1954.

Experiences: Head of Agriculture Department and Supervisor of Plant Breeding Stations in Iran.

Date of Final Examination: May, 1954.

THESIS TITLE: EFFECT OF ANNUAL PRECIPITATION AND TEMPERATURE ON THE PERFORMANCE OF WHEAT VARIETIES

AUTHOR: ALI MOJTAHEDI

THESIS ADVISER: DR. A. M. SCHLEHUBER

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