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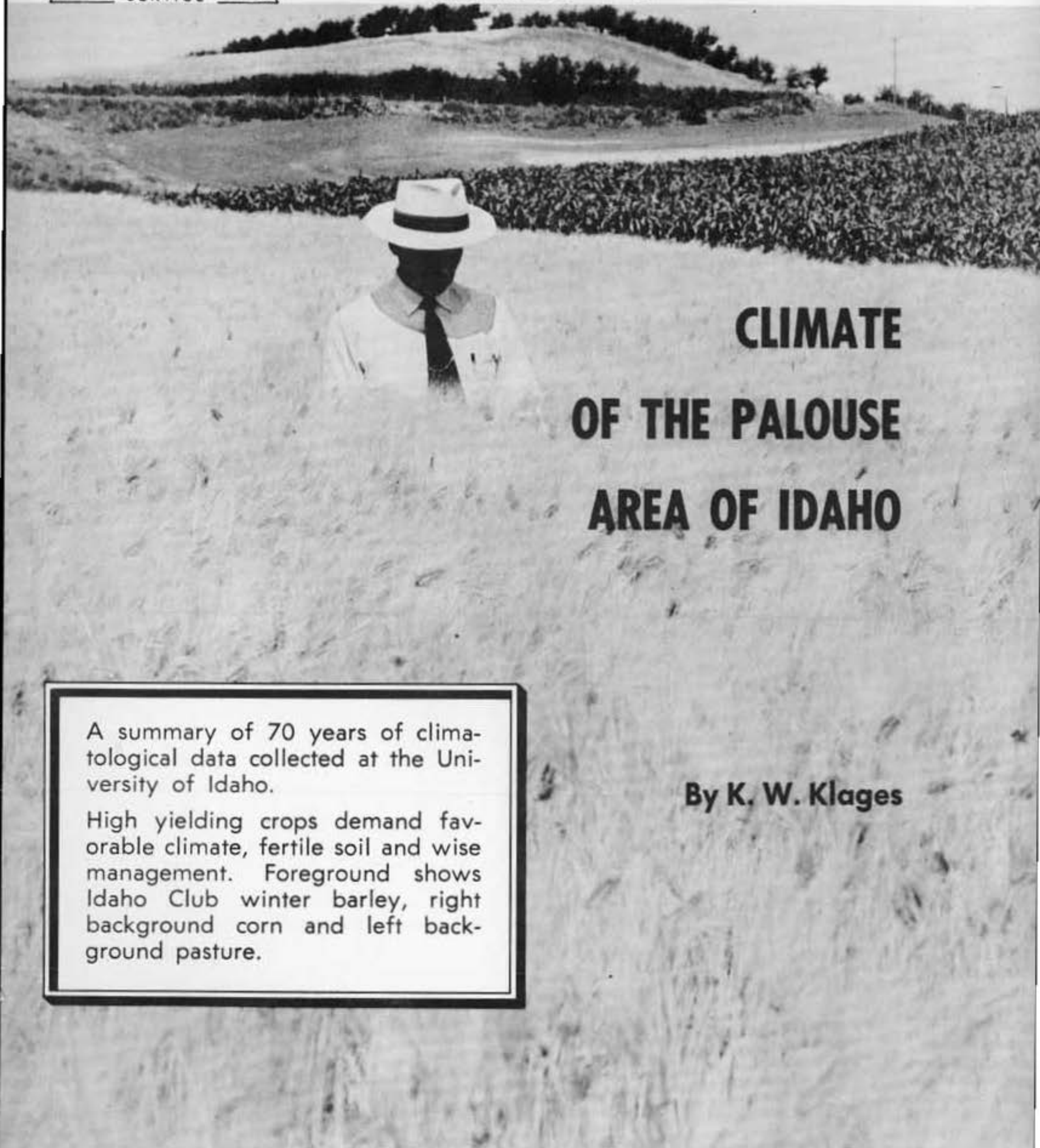

CLIMATE OF THE PALOUSE AREA OF IDAHO

A summary of 70 years of climatological data collected at the University of Idaho.

High yielding crops demand favorable climate, fertile soil and wise management. Foreground shows Idaho Club winter barley, right background corn and left background pasture.

By K. W. Klages

IDAHO Agricultural Experiment Station

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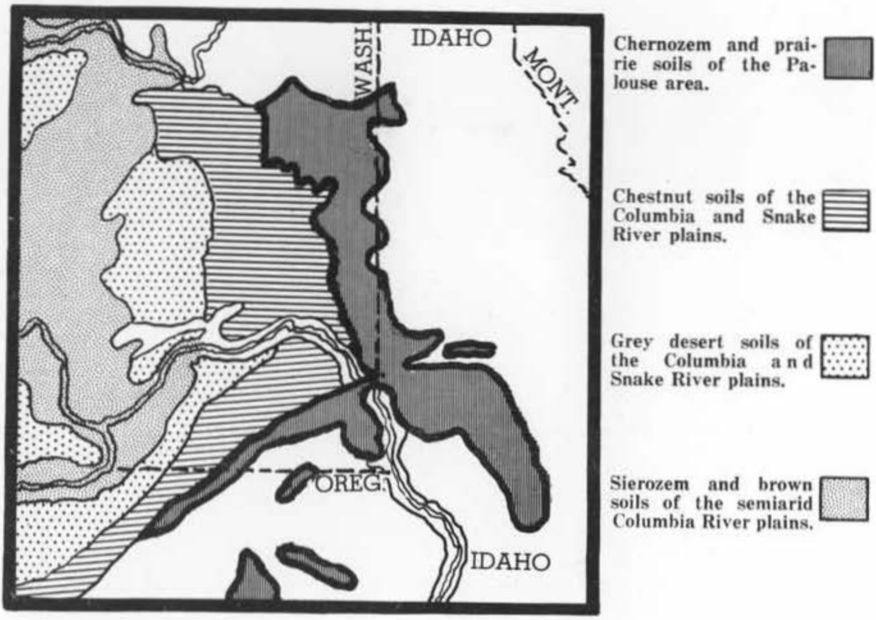

THE AREA REPORTED

The map gives a general outline showing the location and extent of the Palouse area in northern Idaho. The boundary between the Palouse and surrounding areas is often designated by the 18-inch annual precipitation line. The area cannot be too sharply defined due to the location of favored tracts receiving less than 18 inches of precipitation. Such reduced annual precipitation may be compensated for by the effects of good soils high in fertility, organic matter and with good moisture retention. The most important crop grown in the Palouse area is winter wheat.

THE AUTHOR

Karl H. W. Klages is Professor of Plant Sciences, University of Idaho and Agronomist, Idaho Agricultural Experiment Station. The author completed undergraduate training at Oregon State University and his graduate work at the University of Illinois. Upon earning his doctorate, he taught classes and conducted experimental work at Oklahoma and South Dakota State Colleges. Klages joined the Idaho staff in 1936 as Head of the Department of Agronomy. He served in this capacity for 27 years, stepping down in 1963 to devote more time to his specialty, the ecological aspects of climatology. He has observed and reported the climate and weather of the Palouse area for more than 3 decades.

CHARTIST

William C. Oyen, Draftsman in the Department of Agricultural Engineering, prepared the graphs included in this publication.

SUMMARY

The climate of the Palouse area represents a transition between the true grassland and woodland climates. It has many of the characteristics of the grassland climate; namely, good supplies of moisture during the winter and early spring months, followed by increasing scarcity of moisture with the advance of the growing season through late spring and early summer, up to the arrival of autumn.

Moderate temperatures prevail during the demand periods of the vegetative growth of the field crops of the area, followed by relatively high day temperatures towards the middle and later portion of summer.

The climate of the area deviates from the true grassland types in that a high percentage of the moisture comes during the fall and winter months. Yet, sufficient surface moisture is available during the spring months, to insure germination and early growth of seeded crops. Winter stored moisture plays an important role in the production of the crops of the area.

Humidity during the winter is rather high. Above all, the area is favored with relatively calm moist air during the winter months. The absence of cold, drying winds, so common to true grassland areas, is indeed a fortunate circumstance and greatly influences the crop producing potentialities of the area.

The climate of the Palouse, being transitional in nature between those of the true grassland and woodland types, does not experience the extreme moisture and temperature fluctuations so common to the true grassland and definitely continental types of climates. Consequently, this area is relatively free from the damages of extreme droughts and high fluctuations in crop yields. This accounts for the stability of agricultural production of the area.

While the precipitation of the Palouse area is rather moderate, 21.92 inches per annum, the efficiency of moisture utilization by crop plants is high. This is manifested by the high average crop yields attained.

The attainment of high and stable crop yields demands not only favorable climatic conditions but also favorable soil relationships such as a high level of fertility, ready absorption of moisture and good moisture holding abilities. The high organic matter contents of grassland soils enter into these relationships.

The fact that a high percentage of the moisture receipts of this area arrive during the winter and early spring months makes it necessary that considerable amounts of this water must be stored in the soil for future use.

Köppen (10) ascribes a higher efficiency of precipitation to regions with winter concentrations of precipitations than to areas with uniform distributions or with summer concentrations of rainfall, when a high percentage of the precipitation received is lost by evaporation. The high efficiency of moisture ultilizations in the Palouse area supports Köppen's thesis. However, this can be the case only in areas favored with soil conditions enabling the rapid

absorption and storage of moisture received during the winter and early spring months.

The low intensity of precipitation common to the area definitely enters into the capacity of soils to absorb winter and early spring precipitations. Furthermore, the relatively low temperatures and the absence of drying winds during the major portions of the growing season contributes to the efficient use of moisture by the crop plants of the area.

In conclusion it is well to state that a combination of favorable climatic and soil conditions provide the basis for the establishment and maintenance of a prosperous and well balanced agriculture.

CONTENTS

CLIMATE OF THE PALOUSE AREA OF IDAHO

K. H. W. Klages

Limitations of Single Site Data Collection

The selection of a single site to characterize the climate of an area has certain limitations. Even if the area in question is rather limited, it is known that climatic variations are present. This must be taken into consideration in the analysis and application of the data presented in this publication. While the climatological data collected and studied at Moscow is of a single site nature, it nevertheless has real value in placing on record the general features of the climate of the Palouse and adjacent areas.

The climate of the Palouse area and the cropping practices commonly used in the production of the staple crops of the entire region indicate definite areal similarities in climatic conditions, selection of crops and in the methods of handling these crops. The selection of crops grown in the area indicates similarities in climate and crop response rather than outstanding differences between locations within the area. The locational differences are greater in the transitional zones bordering the area than within the area itself.

Crop Years and Plant Response

Since the Palouse is primarily a winter wheat producing area, the climatological data are largely presented on the basis of crop years, that is, from the first of September to the last of August. The use of crop, rather than calendar years, provides greater opportunities for correlating observed climatological data with crop responses.

An interesting illustration of such a correlation is given in Figure 2, which shows not only the effects of climatological factors, but also timeliness in the growth and development of spring and winter wheat, Klages (9)*. The growth curves of these 2 crops are shown in relation to the availability of soil moisture during their critical periods of development when grown under dryland conditions.

*Number refers to section "Literature Cited."

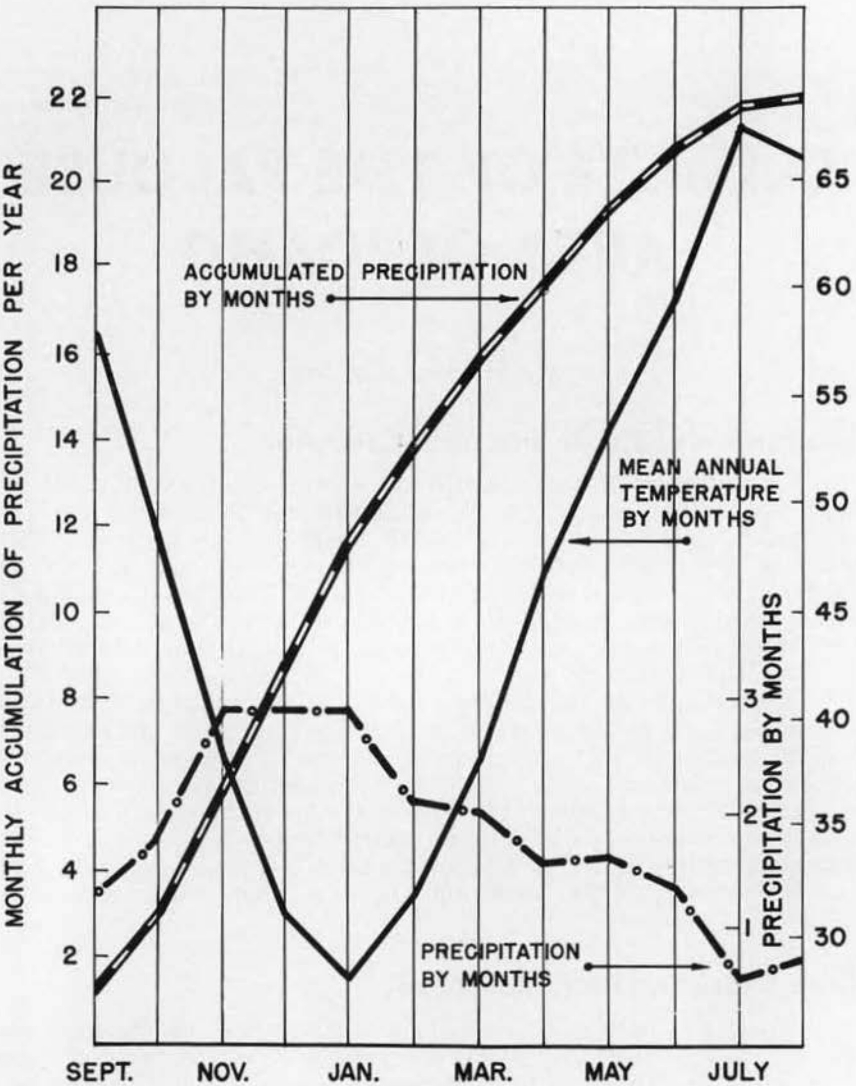

Figure 1. This presentation is by no means complete, but the 3 factors indicated are sufficient in arriving at the main features of the climate of the Palouse. The factors shown are precipitation by months, monthly and annual accumulations of precipitation and annual mean temperatures. These 3 factors characterize the climate of the area. Even though the magnitudes of the climatic factors may be expected to vary somewhat from station to station within the area, the 3 main factors are essential to the characterization of the climate and to the establishment of trends.

Winter wheat, due to its development in autumn, gets off to an earlier start than spring wheat. The timing of its development in relationship to the decreasing availability of soil moisture, with advance of the season, is less critical for winter than for the later starting and later maturing spring wheat. Since winter wheat shows a higher degree of adaptation to conditions prevailing on dryland, it is better adapted to such conditions than spring wheat; or in other words, winter wheat shows a higher degree of correlation between its vegetative and climatic rhythms than spring wheat. This provides the primary reason for its higher yielding capacity when grown under moisture stress during heading and maturation. Winter wheat is an opportunist. Spring wheat, grown on dryland, is forced to complete its cycle of development with decidedly reduced soil moisture.

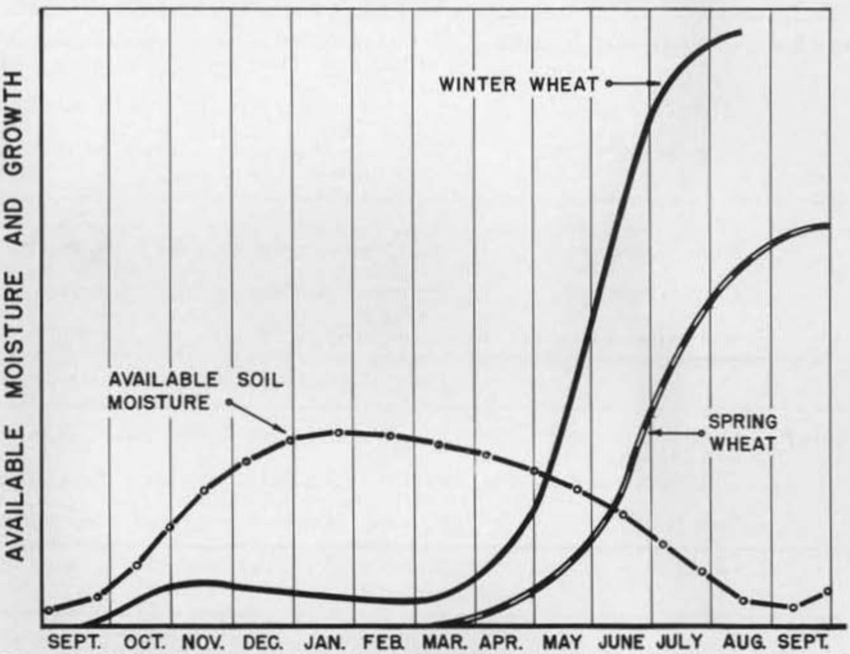

Figure 2. Growth curves of spring and winter wheat in relation to the availability of soil moisture.

Value and Use of Climatological Information

The compilation, summarization and use of climatological data of a station fairly representative of a given area are of value and interest not only to agriculture but also to industry. Location of industrial plants, lumbering, transportation, travel, the planning of recreational activities and a great variety of endeavors requiring timing are often dependent on climate. Past means and normals of climatological data provide significant aid to the planning of future activities.

The greatest and most urgent demand for climatological data in Idaho comes from agriculture. This segment of the population is most directly concerned with weather and climate. It may be said that they not only live with it but are dependent on it for their livelihood. Crop plants and animals are quite specific in their climatic demands.

Table 1, adapted from Kuckuck and Mudra (11), gives an interesting list of unfavorable seasonal climatic conditions in their relationships to the growth and development of winter annual crops. Only the most evident factors are listed. A complete listing of such factors is beyond the scope of this publication.

TABLE 1. Unfavorable seasonal climatic factors in their relationships to the development of winter annual crops

Season	Climatic factors	Type of damage to winter annual crops
Autumn	Dry soils and drought	Delay of germination, increased susceptibility to smut, poor emergence and stands
	Drying winds	Loss of soil moisture, wind erosion, blow-outs
	Low temperatures	Delay of development, little or no fall tillering
Winter	Freezing temperatures	Direct winterkilling
	High winds	Removal of protective snow covers, soil drifting
	Cold drying winds	Physiological drought, desiccation of plants
	Wet snow, ice covers and delayed melting of snow	Suffocation of plants, snow scald and mold
		Substitution of spring for winter crops
Spring	Alternate freezing and thawing	Heaving of plants, drying out of injured plants
	Excessive soil moisture	Poor development, root and stem rots, reduced or no stands
	Late frosts	Damage to tender parts such as floral organs
	Drought	Wilting, delay of growth, drying of plants
Summer	Heat and dry winds	Wilting and drying of plant, shrivelled or no kernels
	Drought	Wilting, plants forced to maturity
	Excessive humidity	Leaf and stem diseases — rusts and mildew, delay of maturity, interference with fertilization
	Low temperatures	Delay of growth, flowering and maturity
	Storms and hail	Lodging and mechanical damage

HISTORICAL

Precipitation data are available for a 72-year period, 1892-1963. Temperature data were not collected until 1 year later. They are available for the period of 1893-1963.

The instruments for the recording of the climatological data were located at various sites on the campus of the University of Idaho from 1892 to 1957. They were moved to the University Plant Science Farm in April of 1957. Areas successively selected for the weather station were as near the same level as possible and in locations with unrestricted air flow. The Plant Science Farm is located 3 miles east of the campus.

Standard instrument shelters and equipment were provided by the United States Weather Bureau.

Klages (7) summarized and published the climatological data of the station in 1942 using the data collected up to that year.

Corless (1) developed a master's thesis dealing with the analysis of the climate data from 1892 to 1938 in 1938 and correlated the collected climatological factors with the response of wheat yields obtained on the University Farm.

PRECIPITATION

The term precipitation refers to all measurable forms of moisture. Moisture received in the form of snow or hail is recorded in terms of inches of water contained in such materials.

Moisture receipts were caught and measured in a standard 8-inch rain gauge.

Importance of Water in the Physiological Environment

The fundamental significance of water in life is well brought out by the fact that all of the vital processes of both the plant and animal cell take place in a water medium. The actual amount of water assimilated is very small. According to Maximov (12), even in moist climates not in excess of 2 to 3 grams of water for every 1,000 grams extracted from the soil are assimilated. In dry continental climates, not more than 1 gram of 1,000 grams of water absorbed from the soil may be assimilated. The remaining 999 grams merely pass through the plant unchanged, to be dispersed into the atmosphere, but not without performing vital functions.

One of the problems in the production of dryland plants is to avoid unwise expenditures of water. Too great a water deficit spells disaster. This situation becomes acute in the dryland areas, where annual receipts of moisture are not only less than in humid regions, but where environmental conditions conspire to demand greater expenditures of the limited moisture available.

Precipitation and Distribution of Plant Life

The 3 most outstanding factors of the physiological environment are moisture, temperature and light. These factors are of necessity closely interrelated. Nevertheless, over large areas with similar temperature conditions, the relative abundance of moisture available to plants has a more pronounced effect on the type of vegetation and on the adaptability of the area to crop production than any other single factor of the environment.

Robbins (13) agrees with the above statement when he writes, "Water is the chief limiting factor in the growth of most crops. For the majority of crops, there is ample sunshine, an abundance of oxygen and carbon dioxide in the air; the temperature of the air and soil is seldom seriously unfavorable; as a rule, there are sufficient nutrients in the soil; but the farmer, except in the most rainy sections of the country, is usually confronted at some time during the season with a shortage of water."

Precipitation Data for 7 Decades

Table 2 gives the monthly amounts and accumulations of precipitation received during seven decades, for the crop years 1892-93 to 1962-63. The first decade, 1892-1903, was high, with an annual receipt of 23.00 inches. The lowest rainfall decade came in 1923-33, with an amount of 20.96 inches of precipitation. The average of all 7 decades came to 21.92 inches per crop year.

Table 2. Variations in monthly and annual precipitation in inches and accumulations for 7 decades from 1893-94 to 1962-63

	CROP YEARS								
Precipitation by months	1893-1903	1903-1913	1913-1923	1923-1933	1933-1943	1943-1953	1953-1963	M'thly aver.	Accumulated precipitation
September	1.43	1.12	1.28	1.19	1.35	1.35	0.99	1.24	1.24
October	1.71	1.54	1.61	1.54	2.06	2.29	1.74	1.78	3.02
November	3.25	3.28	2.71	2.83	2.34	2.88	2.70	2.86	5.88
December	2.60	2.43	2.37	2.92	3.50	3.06	2.81	2.81	8.69
January	2.69	2.55	3.32	2.89	2.77	2.42	2.91	2.79	11.48
February	2.48	1.97	1.98	2.15	2.13	2.31	2.22	2.18	13.66
March	2.04	1.93	2.49	2.36	2.13	1.96	1.91	2.12	15.78
April	1.58	1.19	1.90	1.31	1.77	1.60	1.88	1.61	17.39
May	2.48	2.17	1.78	1.31	1.28	1.83	1.93	1.82	19.21
June	1.26	1.45	1.22	1.55	1.78	2.06	1.32	1.52	20.73
July	0.76	0.79	0.47	0.41	0.48	0.50	0.53	0.56	21.29
August	0.72	0.92	0.60	0.50	0.27	0.41	1.02	0.63	21.92
Means	23.00	21.34	21.73	20.96	21.86	22.67	21.95	21.92	......

Trend in Precipitation

Figure 3 presents the trend of precipitation for the 7 decades of 1893-1963. It will be observed, from the tabulated and graphic data, that a slight negative trend is in evidence. This is largely accounted for by the relatively high moisture receipts during the first decade under consideration.

On the basis of straight line trends, calculated by the method of least squares, the equation of the trend line (regression line) is $Y=21.97-0.013X$. This means that the trend line originated at the level of 21.97 inches when the value of $X=0$ and ended at 21.89 inches with the close of the seventh decade, when the value of $X=6$. The trend line is practically on the level. During the 7 decades the slight downward trend amounts to only 0.013 inches per decade or to 0.0013 inches per year.

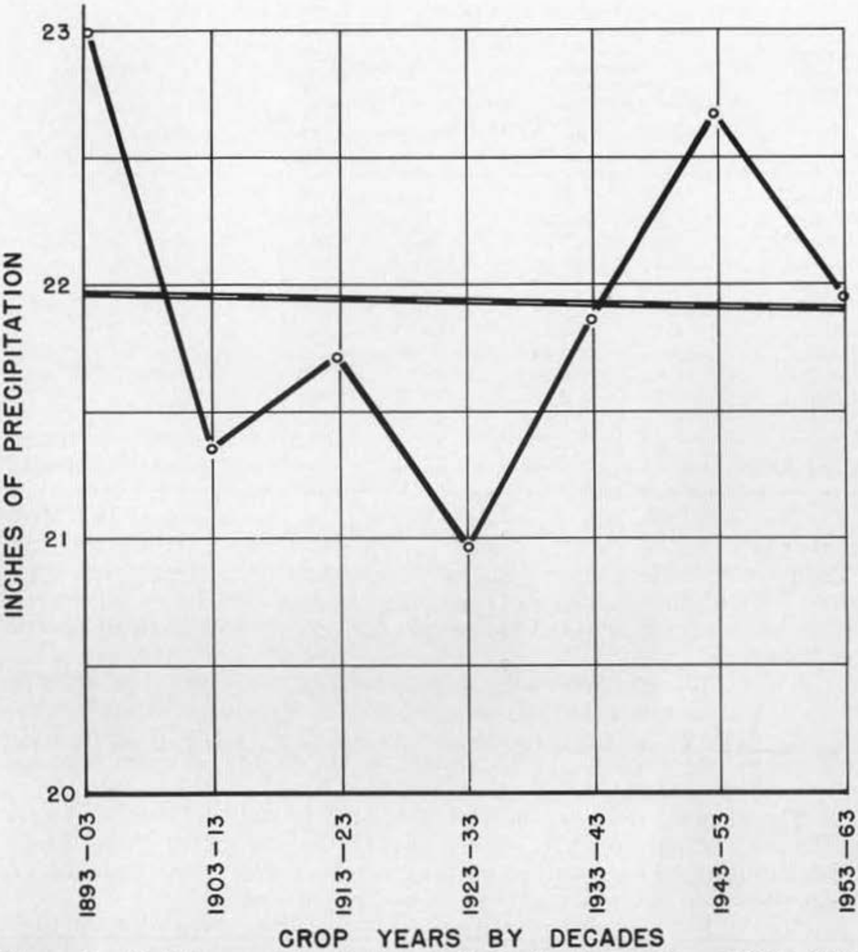

Figure 3. Variations and trend of precipitation by decades from 1893 to 1963. Equation of regression line is Y=21.97—0.013X.

Seasonal Distribution of Precipitation

Table 3 gives the precipitation receipts and accumulations by months and quarters for the crop year. This form of presentation made it necessary to deviate from the usual calendar quarters. Since the crop year begins with September 1, the first quarter includes September, October, and November and so forth. These divisions of the year will be referred to as the fall, winter, spring and summer quarters. Annual accumulations of precipitation stand at 87.64 percent of the crop year total at the end of May. The quarters are ranked as follows in order of their percentage receipts of crop year precipitation, winter 35.50, fall 26.83, spring 25.31 and summer 12.36 percent of the total precipitation.

Table 3. Seventy years average annual precipitation, seasonal distribution and accumulations of moisture by crop years, 1893-94 to 1962-63

Months and quarters	Monthly precipitation		Accumulations of moisture for crop year		Quarterly accumulations	
	Inches	Percent annual prec.	Inches	Percent annual prec.	Inches	Percent annual prec.
September	1.24	5.66	1.24	5.66		
October	1.78	8.12	3.02	13.78		
November	2.86	13.05	5.88	26.93	5.88	26.83
December	2.81	12.82	8.69	39.65		
January	2.79	12.73	11.48	52.38		
February	2.18	9.95	13.66	62.32	7.78	35.50
March	2.12	9.67	15.78	72.00		
April	1.61	7.34	17.39	79.34		
May	1.82	8.30	19.21	87.64	5.55	25.31
June	1.52	6.93	20.73	94.57		
July	0.56	2.55	21.29	97.17		
August	0.63	2.88	21.92	100.00	2.71	12.36
Total Annual	21.92	100.00	21.92	100.00	21.92	100.00

The relatively dry summer months give the stamp of the Mediterranean climate to the area. Based on natural vegetation, the climate of the area may also be designated as a grassland type. Since both of these climatic types occur in areas with dry summers, the area is better adapted to the production of fall than to spring seeded crops.

Soil conditions favorable to rapid entry of water, the storage of such water, and relatively low rates of water loss through evaporation during the growing season make it possible to grow both fall and spring seeded crops. However, the yields of spring seeded crops are lower than of those seeded in fall.

The area is well adapted to fall seeded wheat and barley. Early seeding of cereal crops in spring favors the escape of these crops from drought. Early spring seeding of the cereals is timed so that these plants may make good use of soil moisture.

Due to the special moisture regime and the probability of high temperatures, crops are damaged occasionally by the combined detrimental effects of low availability of soil moisture and high temperatures. Since the fall seeded crops are generally mature when this unhappy combination strikes, they escape damage while spring seeded crops may be severely damaged.

Variability and Frequency of Precipitation

Table 4 gives the frequency distribution of the amounts of precipitation by months in ½-inch class intervals for a period of 70 years.

A word is in order regarding the meaning of frequency distribution for the specific months indicated. Table 4 shows that 2 of the Septembers during the 70-year period received between 4.00 and 4.49 inches precipitation on 2 occasions. The tabulation also shows that 15 Septembers received only between 0.01 and 0.09 inches of rain.

Table 4. Frequency distribution of amounts of precipitation by months in ½-inch class intervals for the 70 crop years from 1892-93 to 1962-63. The underlined figures indicate the class in which the averages for the respective months fall

Frequency classes in inches	Sept.	Oct.	Nov.	Dec.	Jan.	Months Feb.	Mar.	Apr.	May	June	July	Aug.	Totals for 70 years
8.00-8.49				1	1								2
7.50-7.99													0
7.00-7.49			1		1								2
6.50-6.99			1						1				2
6.00-6.49			1	1	1								3
5.50-5.99			2	2	1								5
5.00-5.49			1	1	2		1						5
4.50-4.99		1	3	2	1	2	2	1					12
4.00-4.49	2	1	5	2	5	1	1		3	1			21
3.50-3.99	1	5	7	8	9	6	2	2	1		1		42
3.00-3.49	2	3	10	7	4	7	6	2	6	4			51
2.50-2.99	4	3	8	19	12	10	8	7	5	7		1	84
2.00-2.49	5	11	7	7	11	9	14	7	13	7	2	4	97
1.50-1.99	5	17	10	7	7	17	15	14	10	14	2	3	121
1.00-1.49	12	13	6	12	12	10	16	22	11	13	9	8	144
0.50-0.99	24	10	4	1	3	4	4	8	13	14	14	14	113
0.01-0.49	15	6	4			5	2	7	7	10	42	40	138
Average	1.24	1.78	2.86	2.81	2.79	2.18	2.12	1.61	1.82	1.52	0.56	0.63	21.92
SD	0.97	1.00	1.57	1.36	1.49	1.06	0.97	0.92	1.20	0.92	0.64	0.61	--------
CV	78.2	56.2	54.9	48.4	53.4	48.6	45.8	57.1	65.9	60.5	114.3	96.8	--------

The highest amount of precipitation for any month occurred in January of 1913, when 8.43 inches was recorded. The second highest monthly precipitation came in December of 1933 when 8.03 inches fell. Both of these instances are recorded in the highest frequency class of Table 4; namely, the monthly amounts of precipitation received fell within the limits of the highest frequency class of 8.00-8.49 inches.

The relationship of high precipitation during the month and soil erosion on the slopes of the Palouse area is evident. Table 4 shows that the precipitation for the month is well clustered around the means of the respective frequency classes. The instances of rain in the upper half of the table are relatively few in number. This shows that high monthly receipts of precipitation occur at rather low frequencies. It should be recognized that moderate precipitation for a given time interval is beneficial to all crops, but receipts of excessive amounts per day or even per month can be highly destructive.

The variability of monthly receipts of precipitation is rather high. This is evident from the ranges over which recorded moisture fell and especially by the high values of the calculated standard deviations (SD) and the coefficients of variability (CV).

Rainfall Intensity

The term "rainfall intensity" refers to receipts of precipitation during any stated time interval such as for a fraction of an hour, at hourly intervals, for a 24-hour day.

Yarnell (16) presents rainfall-intensity frequency data for the various areas of the United States. Charts prepared by him show the maximum precipitations in periods of 5 minutes to 2 hours that may be expected to occur with average frequencies in from 2 to 100 years.

Kincer (6) presents maps showing differences in rainfall intensities in the various portions of the United States. The highest intensities occur along the Gulf and South Atlantic coasts. Relatively high intensities are found in the Great Plains and especially in the southern part of this area. The intensities in the Corn Belt states are significantly lower than those in the Cotton Belt. The lowest intensities are found in the Pacific Northwest.

One of the outstanding features of the climate of the Palouse area is the very low rainfall intensity. The low intensity, when supplemented by good soil management, makes it possible to farm the sloping lands of the area without incurring ruinous soil erosion losses.

The relationship of rainfall intensity to possible soil erosion losses is close. One factor of importance, however, is not brought out in the tabulation presented in Table 5; namely, the rate of runoff incurred by melting snow. Such runoff may result in severe soil losses, especially when the soil is frozen with the surface layer thawed out.

Table 5 gives the precipitation frequency distribution, with 0.10-inch class intervals, for the moisture receipts during the days

Table 5. **Frequency distribution of precipitation intensity based on the receipts of moisture per 24-hour period for 70 crop years, 1892-93 to 1963-63, and monthly distribution of days with measurable precipitation**

Precip. classes in inches	Number of days per month with amounts of measured moisture in given precipitation classes												Totals	Percentage of rainy days	Subtotals of percentage
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.			
0.01-0.09	162	234	272	348	367	316	372	297	312	206	95	118	3099	40.75	40.75
0.10-0.19	94	134	172	217	229	221	198	144	145	111	43	45	1753	23.05	63.80
0.20-0.29	57	78	128	152	130	102	110	92	76	73	18	38	1054	13.86	77.66
0.30-0.39	31	50	78	80	88	66	50	43	61	43	18	14	623	8.19	85.85
0.40-0.49	17	44	55	54	34	36	40	32	24	27	11	13	387	5.09	90.94
0.50-0.59	19	26	35	39	29	22	16	17	21	12	7	4	247	3.25	94.19
0.60-0.69	8	16	27	16	20	9	11	12	8	8	2	1	138	1.81	96.00
0.70-0.79	4	10	16	13	3	12	12	4	7	7	2	1	91	1.20	97.20
0.80-0.89	6	4	8	10	10	3	5	4	6	6		5	67	0.88	98.08
0.90-0.99	3	3	8		7	2		2	9	7	2	1	44	0.58	98.66
1.00-1.09			6	5	9	1	2	2	5	3		3	36	0.47	99.13
1.10-1.19	1	1	2	1	3	2			1	1		1	13	0.17	99.30
1.20-1.29	1		3	1	3	1		2	1		1		13	0.17	99.47
1.30-1.39	1	1	2	1		1	1				1	1	9	0.12	99.59
1.40-1.49	1		2	3		2	2	1					11	0.14	99.73
1.50-1.59	1			2									3	0.05	99.77
1.60-1.69					2				1	1			4	0.05	99.82
1.70-1.79		1	1		2		1			1			6	0.08	99.90
1.80-1.89	1										1		2	0.03	99.93
1.90-1.99		1											1	0.01	99.94
2.00-2.09													0	--	
2.10-2.19				1									1	0.01	99.95
2.20-2.29													0	--	
2.30-2.39													0	--	
2.40-2.49			1		1		1						3	0.04	100.00
Rainy days by month for 7 decades	407	603	817	943	937	796	821	652	677	506	201	245	7605	100.00	100.00
Percent of days with precipitation	5.29	8.09	10.61	12.65	12.57	9.66	11.12	8.47	9.09	6.57	2.70	3.29			

classified as rainy. This refers to the days when measurable precipitation was collected, over a 24-hour period. The lowest amount of moisture that could be collected with the equipment available is 0.01 inches.

During the 70 years under consideration 7,605 days were designated as rainy.

The lowest intensity class, 0.01-0.09 inches, accounts for 3,099 of the rainy days. This means that 40.7 percent of the rainy days received only from 0.01 to 0.09 inches of precipitation during a 24-hour period.

The number of instances with 1.49 or more inches of precipitation during any 24-hour period is extremely low.

Figure 4 gives the subtotals of the percentages of instances recorded over the class intervals of from 0.01-0.09 to 1.30-1.39 inches. This range of the frequency classes accounts for 99.5 percent of the total moisture for the days classified as rainy. This is

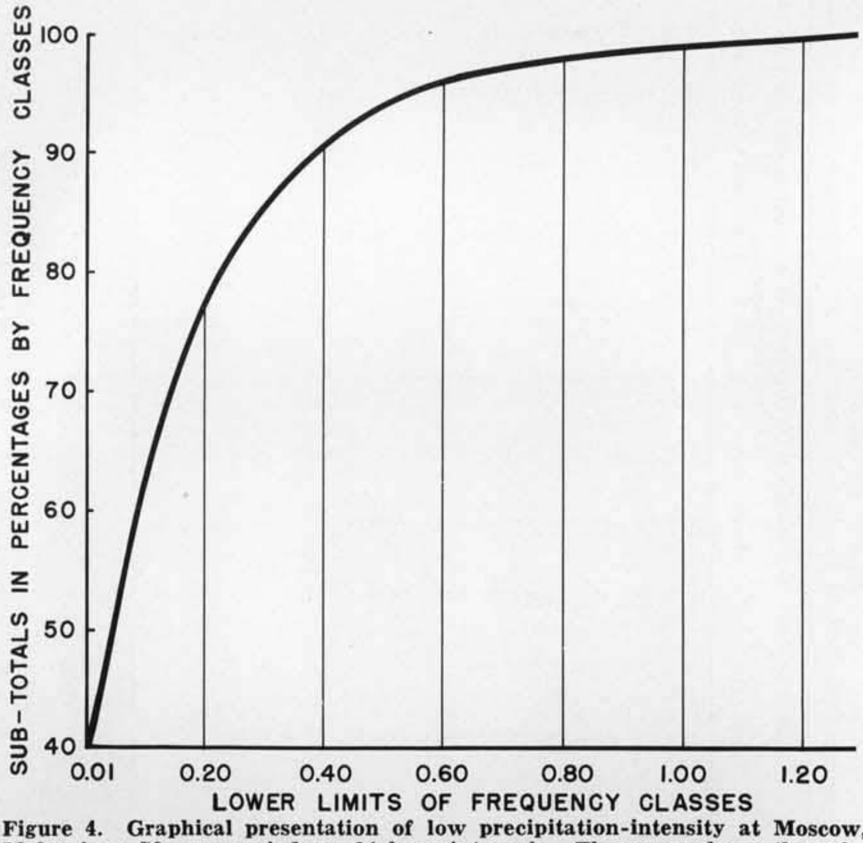

Figure 4. Graphical presentation of low precipitation-intensity at Moscow, Idaho for a 70-year period per 24-hour intervals. The curve shows the subtotals of percentages of rainy days by 0.10-inch class intervals up to frequency class of 1.30-1.39 inches. This range accounts for 99.59 percent of the rainy days per year.

substantiated by the last column of Table 5 showing the subtotals of precipitation for each class interval. Another way of stating this important fact is that 90.9 percent of the rainy days of the area yield less than ½ inch of precipitation per day, or for a 24-hour period.

SNOWFALL

Since snow provides moisture upon thawing, it could well be discussed under the heading of precipitation. However, due to its special importance in northern areas and at high elevations it merits a special heading.

Snowfall is measured in inches as it falls, or upon accumulation, and by the amount of moisture it contains. Both means of recording its amount are of value.

Snow has numerous effects, some good and others not in its favor. It has real agricultural values in the protection of plant life and in providing water storage in the soil for the future use by plants. The later demands soil conditions favoring the penetration of water into the soil.

Among the undesirable features of snow are its removal costs from such areas as highways and city streets.

Köppen (10) ascribes a higher efficiency of precipitation to regions with winter precipitation than to areas with uniform or summer concentrations of moisture. The high efficiency of moisture utilization in the Palouse area supports Köppen's thesis.

Amount of Snowfall

Table 6 gives the total snowfall by months for a period of 58 years for the crop years 1904-05 to 1962-63. It is interesting to note that 76.6 percent of the annual snowfall may be expected during the three months of December, January and February.

Table 6. Average snowfall in inches by months for 5 decades and 8 years for the crop year 1904-05 to 1962-63. The first period is for the 8 years from 1904-05 to 1911-12

Month	CROP YEARS							
	1905-1912	1913-1922	1923-1932	1933-1942	1943-1953	1953-1963	58-year average	Percent of total
September	--	0.1	--	--	--	--	Tr.	Tr.
October	1.0	0.9	--	0.3	0.1	--	0.4	0.8
November	5.2	7.5	6.3	3.2	4.0	4.2	5.1	10.4
December	13.3	11.0	15.0	10.5	14.6	7.4	12.0	24.4
January	12.0	20.1	17.2	16.3	14.9	10.7	15.2	30.9
February	11.1	14.8	7.3	14.3	7.8	7.4	10.5	21.3
March	2.7	8.6	5.2	6.3	2.8	6.1	5.3	10.8
April	0.4	1.1	1.5	0.9	0.2	0.3	0.7	1.4
May	0.3	--	--	--	--	--	Tr.	Tr.
Annual Totals	46.0	64.1	52.5	51.8	44.4	36.1	49.2	100.0

Variability of Snowfall

The annual snowfall receipts showed a high degree of variability. This is shown graphically on Figure 5. The standard deviation is 34.2 inches. The data presented on Figure 5 shows that an amount of snowfall of 0-9.0 inches was recorded in only 1 instance, crop year 1957-58. The modal class of 50.0-59.9 inches appeared 10 times during the 58 years for which records are available. The highest recorded amounts of snowfall are found in 3 frequency classes, 90.0-99.9, 100-109.9 and 110-119 inches. The all-time high snowfall for the 58-year period came in 1932-33 when

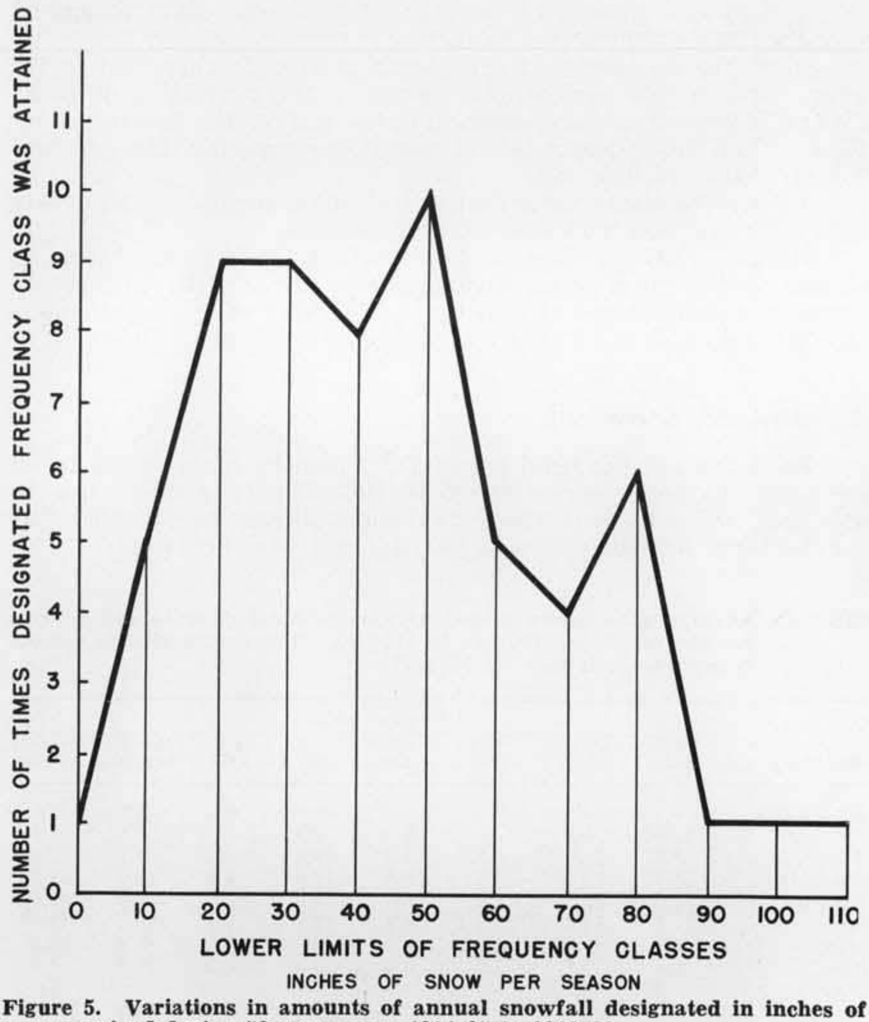

Figure 5. Variations in amounts of annual snowfall designated in inches of snow received during 58 crop years, 1904-05 to 1962-63.

109.2 inches fell. Other high snowfall years were 1948-49 with 102.8 inches and 1932-33 when 98.9 inches of snow fell.

The greatest snowfall for any one day is recorded for January 13, 1913, when 24 inches fell. The second highest snowfall came on January 2, 1933, with 19 inches.

The 3 highest snowfall months on record fell on January 1913, with 66.0; January 1950, with 48.2 and January 1933, with 42.3 inches for the month.

Snowfall Trend

A glance at Figure 6 reveals that snowfall receipts by decades are highly variable but do show a very definite downward trend.

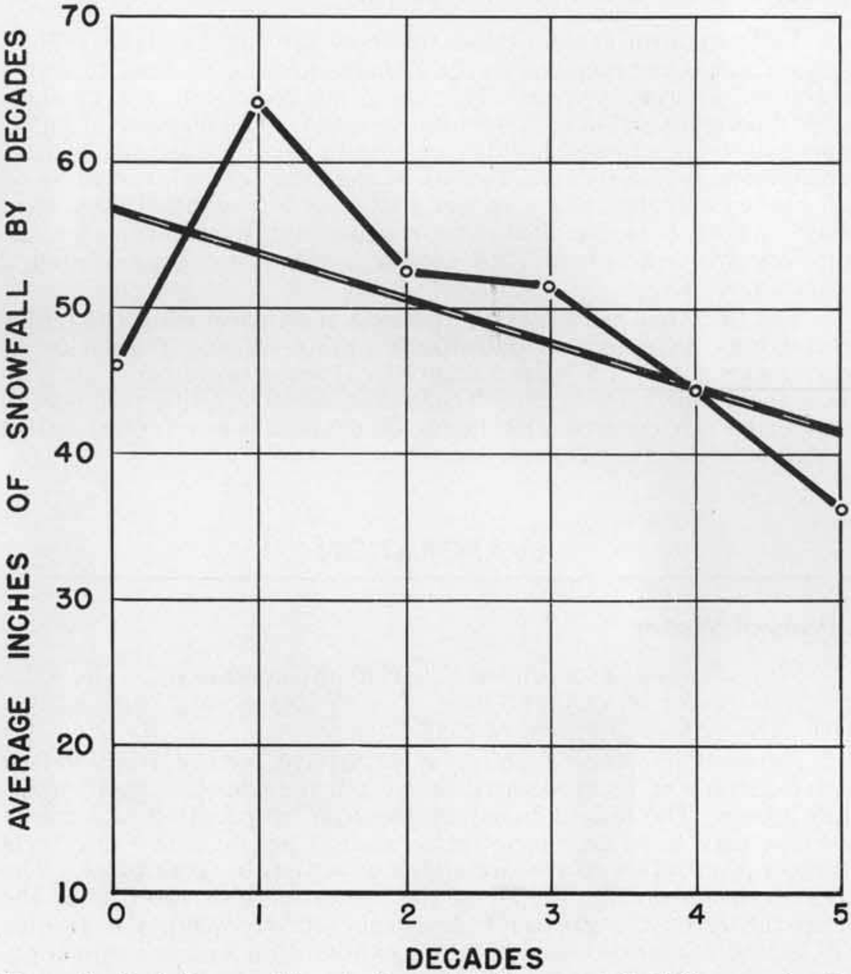

Figure 6 Variations and trend of snowfall for a period of 58 years, for the crop years 1904-05 to 1962-63. Equation of regression line is Y=56.96—3.12X.

Snowfall in the second decade, 1912-13 to 1921-22, was considerably higher than the average of the 6 decades considered. In addition the amount of snow received during the final decade was quite low. These 2 deviations largely determine the trend in snowfall and account for the negative trend shown in Figure 6. The equation of the regression line is $Y=56.96-3.12X$. There is no doubt about the calculated regression line. It must be recognized that the significance of this line must be discounted on account of the extreme variations of its component parts. In other words, too much faith should not be given to the validity of this line and especially not for projecting its values into the future.

Ground Cover and Plant Response

Valid data on ground cover by snow are not available. Most of the snow cover received in the Palouse area is reduced to water or thawed between storms. This condition results in lack of snow cover during a portion of the winter months. The absence of snow, especially from exposed hilltops, results in certain amounts of winter damage, but in only rare cases to the complete winterkilling of fall seeded cereals. Since winter barley is less winterhardy than winter wheat, it is damaged more readily than winter wheat. The complete winterkilling of fall seeded barley may be expected 2 years out of 10.

The fact that snow may not blanket the field during the entire winter may have certain definite favorable effects in relation to winter damage to fall seeded plants by disease organisms, such as snow mold and snow scald. These diseases are quite common in areas generally covered with heavy blankets of snow for the entire winter or even into early spring.

EVAPORATION

Losses of Water

Water losses occur under a variety of conditions. The relative importance of various forms of such losses vary considerably with different environmental conditions.

Exposed moisture supplies of any form, either from a free water surface or from exposed moist soil may lead to rapid moisture losses. The loss of moisture through evaporation and transpiration may have decided effects on crop production. The term transpiration refers to the giving off of moisture from plants. The greater the saturation deficit of the atmosphere or the higher the temperature or the greater the velocity of the wind, the greater will be the moisture losses through evaporation and transpiration. Severe evapo-transpiration losses may contribute to drought conditions and severe crop damage.

Figure 7 shows the positive effects of seasonal wind velocity on the evaporation losses from a free water surface at Moscow for a period of 16 growing seasons. It will be observed that 12 of the 16 instances are located in the positive quadrants. The value of the correlation coefficient "r" equals 0.67.

Not all moisture losses have detrimental effects. When excess moisture is encountered it is often to the interest of agricultural use of land to remove this excess, either by the establishment of drainage, or by means of improved percolation, or by evaporation. Uncontrolled runoff from fields may not only result in high water losses, but may also be associated with soil erosion. Runoff may be of use in providing water for streams, for the filling of ponds, reservoirs and lakes. It is also associated with the accumulation of ground water.

One important source of water loss is from the transpiration of plants. The pumping action of plants removes large amounts of water from the soil. This water is used in the vital processes of plant growth. Some biologists have referred to transpiration as a necessary evil. Obviously any process that is vital to plant growth cannot be regarded as evil even though it dissipates tremendous amounts of water from the soil into the surrounding atmosphere.

Economy in the use of water by plants or specific crops demands, above all, the full adaptation of a crop to be grown in a given area or environment. A crop cannot survive for any great length of time in a given area unless its production represents a profitable enterprise. As stated by Hughes and Henson (5) "the major crop of most sections is a high profit crop for that section."

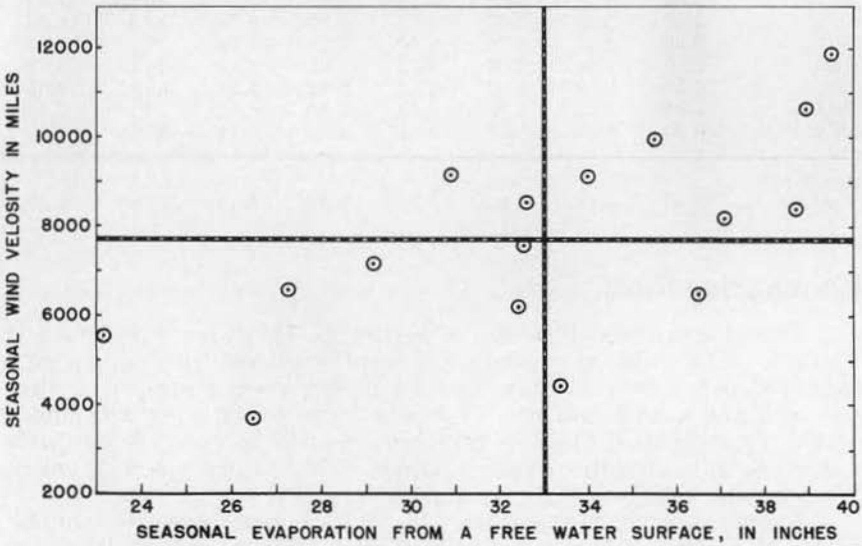

Figure 7. Correlation diagram showing the positive effect of seasonal wind velocity on the evaporation losses from a free water surface, r = 0.67.

Most of the water absorbed by plants is spent. One of the chief problems confronting the grower of dryland plants is to prevent these from spending more water than they absorb. Becoming liable to too great a water deficit spells disaster. This situation becomes acute in the dryland areas, where annual receipts of moisture are not only less than in humid regions, but where environmental conditions conspire to demand greater expenditures of the more limited moisture available for absorption.

The environmental factors responsible for the greater expenditures of moisture under dryland conditions are the greater saturation deficit of the atmosphere, the greater solar radiation, higher daytime temperatures and greater air movement. All of these factors increase rates of evaporation from a free water surface as well as transpiration losses from exposed plants.

Table 7. Evaporation from a free water surface by months and years—April to September, inclusive. Data for 18 years

Year	Apr.	May	June	July	Aug.	Sept.	Six mo. totals	Monthly average
	Evaporation in inches by months							
1940	3.38	5.15	7.64	6.90	6.93	3.37	33.37	5.56
1941	2.95	3.84	4.38	7.48	5.35	2.49	26.49	4.42
1942	2.99	3.10	4.67	7.75	7.14	3.58	29.23	4.87
1946	2.62	3.39	5.37	7.34	5.66	2.93	27.31	4.55
1948	1.90	3.28	5.16	5.69	4.18	3.00	23.21	3.87
1949	3.12	4.38	6.75	8.42	8.62	5.16	36.45	6.08
1950	3.53	6.12	5.32	8.10	7.39	5.07	35.53	5.92
1951	4.92	5.39	6.35	9.10	7.87	5.03	38.66	6.44
1954	3.67	5.18	4.85	7.75	5.52	3.97	30.94	5.16
1955	2.42	4.74	6.56	6.25	8.01	4.58	32.56	5.43
1956	4.29	3.57	5.09	8.30	6.37	4.76	32.38	5.38
1957	3.33	4.37	5.82	6.19	7.45	5.40	32.56	5.43
1958	2.23	6.17	5.95	9.53	9.70	5.36	38.94	6.49
1959	3.89	4.47	6.30	9.41	8.14	3.34	35.57	5.93
1960	2.96	4.64	7.36	8.93	5.68	4.46	34.03	5.67
1961	3.16	5.98	6.45	9.32	9.02	5.59	39.52	6.59
1962	5.01	3.68	6.32	8.97	7.10	6.02	37.10	6.18
1963	3.00	6.07	5.65	8.11	8.57	6.21	37.61	6.27
Monthly means	3.30	4.64	5.89	7.97	7.15	4.46	33.41	5.57

Evaporation Data

The evaporation data for a period of 18 years are given in Table 7. The data on evaporation were obtained by the use of a standard pan 4 feet in diameter, 12 inches deep equipped with a still-well and a hook gauge. The data were taken over a 6-month period, from April through September. It will be noted from Table 7 that the data contains missing years. These were years in which the 6-month data were not available.

Evaporation is highest for the 2 high temperature months, July and August, followed by June, May and September, with April as the lowest month.

AIR MOVEMENT OR WIND

As stated by Ward (15), many of the important characteristics of climate are due to prevailing winds. Winds import temperatures and moisture from a distance. If their paths are not obstructed by mountain barriers, they tend to produce uniformity of climate over extensive areas. They largely determine rainfall and thus control the distribution of life. They bring clean, pure air and are active in promoting health; or by carrying dust and microorganisms they may contribute to the prevalence of human, animal and plant diseases.

Wind velocities have many human relationships. The difference in the feeling of physical comfort or discomfort largely depends upon the amount of air movements. The more extreme manifestations of wind force are to damage buildings and crops, wreck vessels and endanger human life.

Table 8. Air movement in miles by months and by growing season—6 months for a period of 16 years

	Miles of movement by months						Seasonal movements	
Year	Apr.	May	June	July	Aug.	Sept.	Totals	Av. per mo.
1940	734	923	771	675	575	722	4400	733
1941	922	881	480	378	378	634	3673	612
1942	1535	1438	1256	1049	1117	892	7287	1215
1946	1278	1133	1402	1036	902	828	6579	1096
1948	1422	1380	797	793	652	533	5577	930
1949	1131	790	865	1098	1214	1402	6500	1083
1950	2692	3465	1395	989	749	727	10017	1670
1951	1828	2095	1313	1043	1011	1138	8428	1405
1954	1730	1720	2092	1278	1204	1180	9204	1534
1955	2491	2002	1263	975	841	975	8547	1425
1956	1557	773	1051	801	874	1167	6223	1037
1957	2052	821	1425	1403	1060	875	7636	1273
1958	2360	1446	1562	1485	1734	2103	10690	1782
1960	2334	2284	1784	843	1024	789	9158	1526
1961	2782	2314	1740	1595	1540	1905	11876	1979
1962	2321	1564	1138	1132	1221	812	8188	1365
Monthly averages	1823	1571	1271	1036	1006	1043	7749	1292
Daily average	60.8	50.7	42.5	33.4	32.5	34.8	42.3	
Av. miles per hour	2.53	2.11	1.77	1.39	1.35	1.46	1.76	

Data on wind movement for the 6 summer months of the year, April through September, are presented in Table 8. The data presented were collected with a standard 3-cup anemometer mounted at a height of 18 inches. The mounting of the instrument to a higher level increases the magnitude of the readings.

The greatest velocity, in number of miles in a 24-hour period, was 461 miles. This record high occurred on May 11, 1950. The second high came on the previous day, May 10, with 435 miles. The third high velocity was recorded on April 1, 1954, with 310 miles. The remainder of the 16 high readings occurred within the range of 200 to 264 miles for the 24-hour period. The highest wind velocity averaged 19.2 miles per hour. The wind velocity data given here were for the 16 years listed in Table 8. Wind movement data were taken only during the warmer half of the year, from April through September.

Table 9. Interrelationships of monthly and seasonal wind movements, rates of evaporation and average monthly temperatures

Element	Months					
	April	May	June	July	Aug.	Sept.
Air movement—miles	1823	1571	1271	1036	1006	1043
Evaporation—inches	3.30	4.64	5.89	7.97	7.15	4.46
Temperature—F	46.6	53.3	59.5	67.2	66.1	58.1

Seasonal Movement of Wind

Table 9 and Figure 8 show the relationships of air movement to evaporation and temperature during the warmer half of the year. The trend of the air movement from April to July is def-

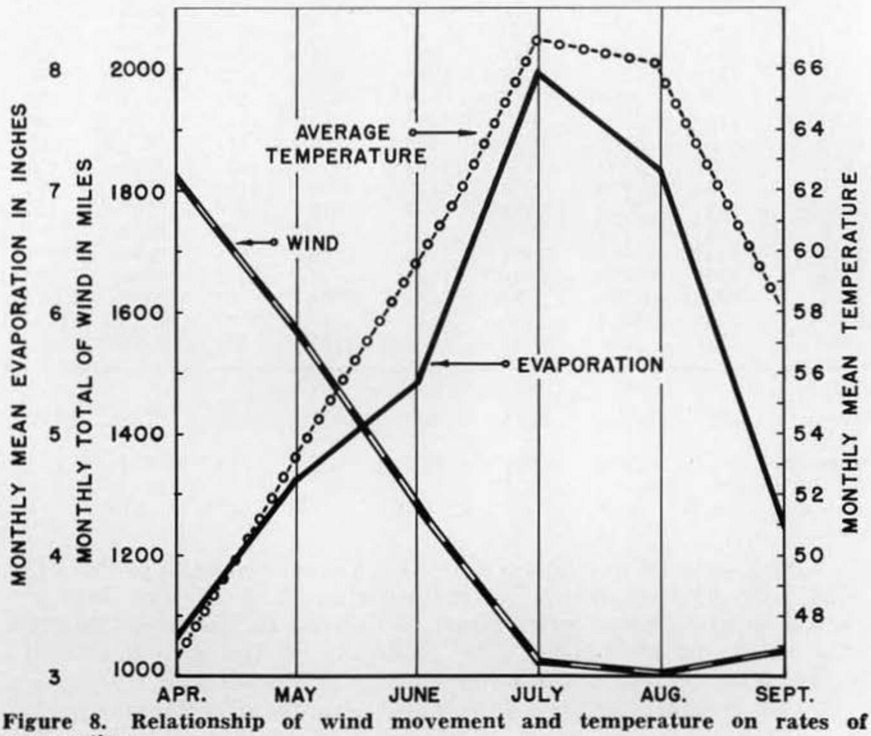

Figure 8. Relationship of wind movement and temperature on rates of evaporation.

initely downward. The air movement remains low during July, August and September. The low wind velocity for July and through September is favorable to cereal and pea production.

The curves of Figure 8 for the average monthly evaporation and temperatures are closely correlated. Both curves rise from April through May and June, reach their peaks in July and then decline. All 3 curves of Figure 8 show a seasonal rhythm.

TEMPERATURE

Temperature Provides a Working Condition

No description of the physiological environment is complete without a notation of the existing temperature. Temperature provides the working condition for nearly all plant functions. More than that, it provides the necessary energy for some processes; radiant energy for example, is absorbed in photosynthesis and released in respiration. Certain winterhardy plants, by virtue of their structural and chemical modifications, are able to survive periods of low temperatures but resume growth only when proper temperatures are again established to provide the necessary growing conditions.

High temperatures and especially the relationship of this climatic factor to increased water use of plants is of great agricultural significance. High temperatures may readily contribute to the occurrence of droughts and severe crop damage. This is especially the case when high temperature incidents correspond with critical periods of the main crops of a given area.

Low temperatures and variations in the length of the growing season are directly associated with the response of plants.

Average, or mean, temperatures above a certain threshold or base are accumulated for given parts or for the entire growing season and are correlated with the seasonal response of plants. The units under study are designated as degree days, heat units, ef-

Table 10. Mean monthly and annual temperatures in degrees F by one 8-year period and 6 decades for the crop years 1894-95 to 1961-62

	CROP YEARS								
Month	1895-1902	1903-1912	1913-1922	1923-1932	1933-1942	1943-1952	1953-1962	Totals	M'thly aver.
September	55.5	58.5	57.0	57.9	59.0	59.4	59.5	406.8	58.1
October	48.5	49.5	46.7	48.9	48.7	49.2	49.6	341.1	48.7
November	37.0	38.8	37.2	37.3	39.1	37.7	37.4	264.5	37.8
December	31.8	31.5	28.9	29.0	33.6	30.7	33.6	219.1	31.3
January	29.0	29.3	26.7	26.9	29.2	25.1	30.4	196.6	28.1
February	33.0	31.4	30.1	32.9	31.7	32.9	34.6	226.6	32.4
March	37.0	37.6	37.5	39.3	38.5	37.8	38.6	266.3	38.0
April	46.2	46.7	43.9	47.1	48.2	47.4	46.5	326.0	46.6
May	52.4	52.8	50.8	54.7	54.3	54.6	53.8	373.4	53.3
June	58.2	58.9	58.9	60.3	60.4	59.5	60.6	416.8	59.5
July	65.7	66.8	66.7	68.6	68.1	66.9	67.5	470.3	67.2
August	64.8	66.1	66.6	67.1	66.4	65.4	66.0	462.4	66.1
Totals	559.1	567.9	551.0	570.0	577.2	566.6	578.1	3969.9	567.1
Averages	46.6	47.3	45.9	47.5	48.1	47.2	48.2	330.8	47.3

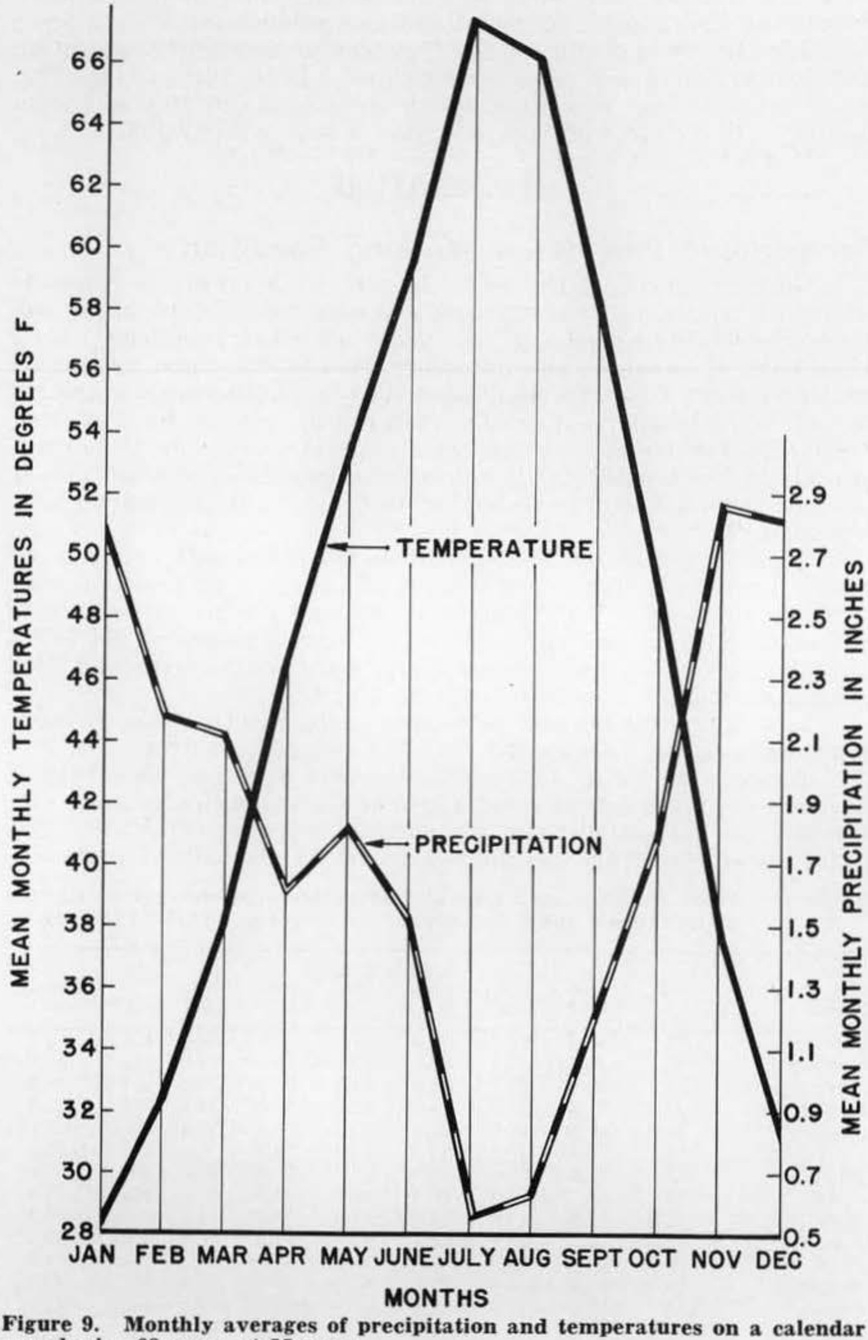

Figure 9. Monthly averages of precipitation and temperatures on a calendar year basis—68 years at Moscow.

fective heat units or growth units, Dethier and Vittum (3). These units are of value in predicting specific stages of development of crops in question, such as the date when cereals may be expected to be ready for harvest, or at what date peas may be ready for canning.

Average, Monthly and Annual Temperatures

Temperature data are available for a 68-year period. Table 10 gives the mean monthly and annual temperatures on a crop year basis. Figure 9 shows the monthly mean temperatures and monthly receipts of precipitation on a calendar year basis.

It is interesting to note that the temperature curve is somewhat more symmetrical than the precipitation curve. Both of the curves depict definite seasonal trends. Summer temperatures are moderately high while the receipts of precipitation are low. This is one of the outstanding characteristics of the climate of the Palouse and adjacent areas.

Mean daily temperatures are calculated from the average of the minimum and maximum for the particular day. The monthly means represent the average of the daily temperatures of the month, while the mean annual temperatures represent the average of the 12 monthly means.

Table 11. Frequency and distribution and variability of monthly minimum, maximum and mean temperatures on an annual basis for 68 crop years from 1894-95 to 1961-62

Frequency class limits	Distribution of: Minimum temps.	Maximum temps.	Mean temps.
0- 4.9	1		
5- 9.9	3		1
10-14.9	7		1
15-19.9	27	2	4
20-24.9	68	5	19
25-29.9	129	12	51
30-34.9	126	42	121
35-39.9	113	108	94
40-44.9	122	88	76
45-49.9	122	59	86
50-54.9	88	55	80
55-59.9	10	65	94
60-64.9		67	85
65-69.9		72	88
70-74.9		78	16
75-79.9		54	
80-84.9		83	
85-89.9		23	
90-94.9		3	
Averages	37.0	57.6	47.3
Range	55.0	75.0	65.0
S.D.	6.41	17.18	13.69
C.V.	17.32	29.78	28.86

Table 12. **Frequency distribution of monthly minimum temperatures, monthly averages and coefficients of variability**

Class limits degrees F	Sept.	Oct.	Nov.	Dec.	Jan.	Feb. (Months)	Mar.	Apr.	May	June	July	Aug.	Total
55.0-59.9											7	3	10
50.0-54.9	3									8	42	35	88
45.0-49.9	25								6	44	19	28	122
40.0-44.9	37	19						4	44	16		2	122
35.0-39.9	2	39	11			1	5	38	17				113
30.0-34.9	1	10	30	10	4	11	33	26	1				126
25.0-29.9			24	31	19	29	26						129
20.0-24.9			2	18	27	18	3						68
15.0-19.9			1	9	10	6	1						27
10.0-14.9					5	2							7
5.0-10.9					2	1							3
0.0- 4.9					1								1
											Total		816
Averages	44.6	38.2	30.6	25.7	22.5	25.5	30.1	36.0	41.5	46.9	51.5	50.6	37.0
S.D.	2.45	2.58	3.61	4.09	5.96	5.22	3.31	2.07	2.04	1.82	1.82	1.98	3.08
C.V.	5.49	6.75	11.80	15.51	26.49	20.47	11.00	5.75	4.92	3.88	3.53	3.91	9.96

Table 13. **Frequency distribution of monthly maximum temperatures, monthly averages and coefficients of variability.**

Class limits degrees F	Sept.	Oct.	Nov.	Dec.	Jan.	Feb. (Months)	Mar.	Apr.	May	June	July	Aug.	Total
90.0-94.9											2	1	3
85.0-89.9											14	9	23
80.0-84.9	2									2	39	40	83
75.0-79.9	14								3	12	11	14	54
70.0-74.9	31	1							7	35	1	3	78
65.0-69.9	16	8						4	24	18	1	1	72
60.0-64.9	5	20						16	25	1			67
55.0-59.9		28					2	27	8				65
50.0-54.9		11	11			1	12	19	1				55
45.0-49.9			20	1	1	6	29	2					59
40.0-44.9			29	12	3	23	21						88
35.0-39.9			8	38	32	26	4						108

30.0-34.9				12	20	10							42
25.0-29.9				5	6	1							12
20.0-24.9					4	1							5
15.0-19.9					2								2
										Total			816
Averages	71.7	59.6	44.8	36.8	34.0	39.1	46.5	57.0	65.1	72.1	82.8	81.5	57.6
S.D.	3.35	3.76	3.90	3.59	5.21	4.79	3.76	3.90	4.44	2.68	2.69	2.98	3.75
C.V.	4.67	6.31	8.71	9.73	15.32	12.25	8.09	6.84	7.22	3.72	3.25	3.66	7.48

Table 14. Frequency distribution of monthly mean temperatures, monthly averages and coefficients of variability

Class limits						Months							
degrees F.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Total
70-74.9											11	5	16
65-69.9	1									4	44	39	88
60-64.9	24								1	25	12	23	85
55-59.9	32	1							22	37	1	1	94
50-54.9	10	26						10	32	2			80
45-49.9	1	31	1				2	38	13				86
40-44.9		12	19		1	3	21	20					76
35-39.9			33	10	3	14	34						94
30-34.9			15	34	28	33	11						121
25-29.9				18	21	12							51
20-24.9				6	8	5							19
15-19.9					3	1							4
10-14.9					1								1
5- 9.9					1								1
										Total			816
Averages	58.2	48.9	37.8	31.3	28.1	32.4	38.4	46.6	53.5	59.6	67.2	66.1	47.3
S.D.	2.75	2.71	3.24	3.66	5.93	4.70	3.06	2.35	2.61	1.91	1.67	1.42	3.00
C.V.	4.73	5.54	8.57	11.69	21.10	14.51	7.97	5.04	4.88	3.20	2.49	2.15	7.66

Tables 12, 13 and 14 shows 3 frequency distributions of the monthly minimum, maximum and mean temperatures and the coefficients of variation for these temperatures for a period of 68 crop years. The variabilities of these temperature averages were calculated by the use of both the standard deviation, S.D., and the coefficient of variation, C.V. The C.V. may be expected to yield a more reliable means of comparing the variability than the S.D., Snedecor (14).

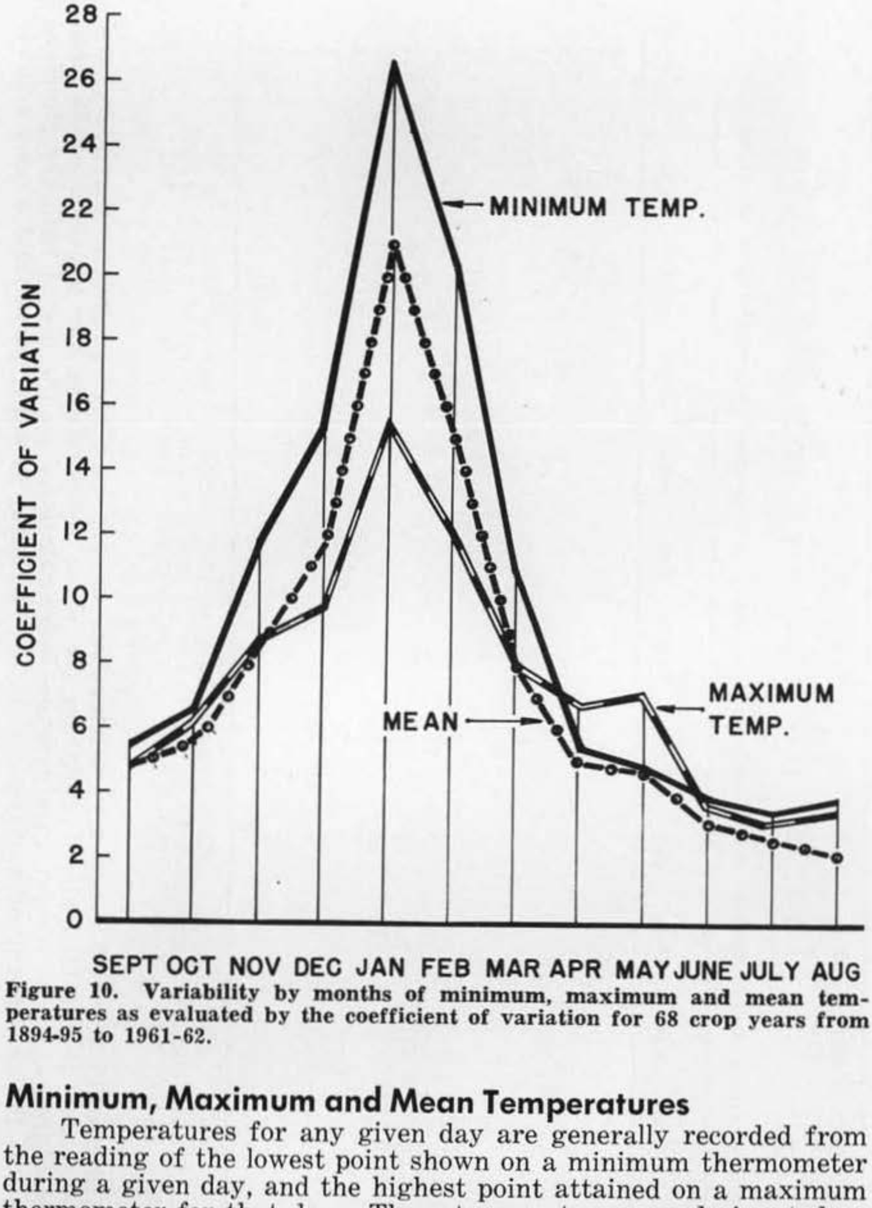

Figure 10. Variability by months of minimum, maximum and mean temperatures as evaluated by the coefficient of variation for 68 crop years from 1894-95 to 1961-62.

Minimum, Maximum and Mean Temperatures

Temperatures for any given day are generally recorded from the reading of the lowest point shown on a minimum thermometer during a given day, and the highest point attained on a maximum thermometer for that day. These temperatures are designated as the minimum—the lowest, and the maximum—the highest temperature attained during a specific day.

Minimum temperatures generally occur just before sunrise, while maximum temperatures occur most frequently around two to three o'clock in the afternoon.

Table 11 gives the frequency and distribution and variability of the monthly minimum, maximum and mean temperatures on an annual basis. It is interesting to note that the maximum temperatures show a greater variability than the mean and minimum temperatures. The evaluation of these three temperature points by the range over which they occur, the standard deviation, and the coefficient of variation brings out that the maximum temperatures have the highest variability as compared to the mean and minimum temperatures. This was not the case when the measures of variability were based on monthly data.

Temperature Trend

The mean monthly temperatures for a period of 8 crop years and 6 decades comprising the crop years from 1894-95 to 1961-62 are given in Table 10. These data were used in calculating the trend, regression or the least squares line. Calculations were by the method of least squares, Gavett (4). The equation of the trend line is $Y=a+bX$.

Figure 11 shows the actual temperatures for the decades indicated. The annual rise of the trend line is small.

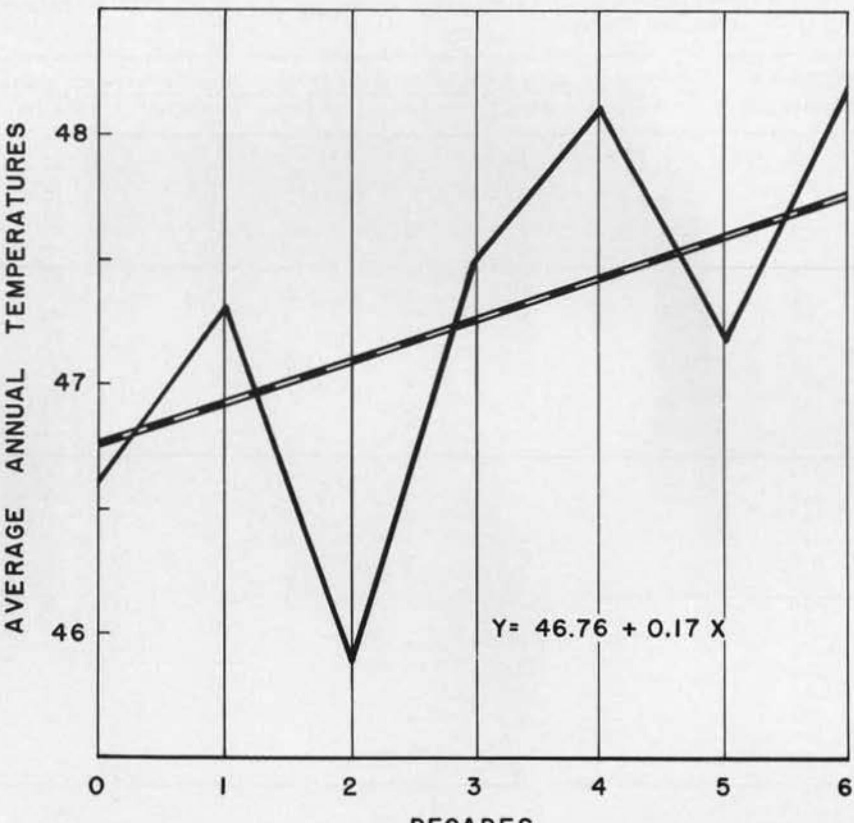

Figure 11. Average annual temperatures and trend for 7 decades. The regression equation is $Y = 46.76+0.17X$.

The calculated value of the trend line used on the data designated is Y=46.76+0.17X. Since the value of "a" is positive, the trend line extends upward from 46.76 to 47.76 at the rate of 0.17 degrees F per decade, or 0.017 degrees per year.

Low and High Temperature Variations and Frequencies

The Palouse area is fortunate in experiencing only limited extremes in climatic variations. Thus the number of days, over a 60-year period, with minimum temperatures of zero or below, as shown in Table 15, lists only 248 such days of temperatures of the range of 0 to -30F. This converted to a precentage basis amounts to only 2.76 percent of the total possibilities of such low temperature levels over this 5-months base, from November to March, inclusive. The climatic controls listed by Critchfield (2) appear to be at work.

Table 15. Frequency of number of days by months with minimum temperatures of zero or below for the 60-year period of 1904 to 1963 of Moscow, Idaho

Minimum	Number of days by months with temperatures of zero or below					
temperatures	Nov.	Dec.	Jan.	Feb.	Mar.	Totals
0	4	5	8	5		22
-1		3	9	6	1	19
-2		5	11	6	1	23
-3	1	2	12	2		17
-4	2	5	9	2		18
-5		4	12	3	1	20
-6		2	8	4		14
-7		1	10	2		13
-8		3	10	1		14
-9		1	4	3		8
-10		1	8	2		11
-11		2	8			10
-12		2	2			4
-13	1	1	6	3		11
-14	1	1	3	2		7
-15			3	1		4
-16		1	2	2		5
-17		3	1	1		5
-18		1	4	1		6
-19			3	2		5
-20			3	2		5
-21						
-22			2			2
-23						
-24			2			2
-25			2*			2
			----			----
-30			1**			1
Totals	9	43	143	50	3	248

* -25 on 2 successive days, January 26 and 27, 1957.
**-30—all-time low on January 20, 1947.

As stated by Critchfield, the weather at a given place or time is a complex combination of several observable elements each of which is important and is used in giving a clear account of the atmospherical conditions. These elements are (a) temperature, (b) sunshine, (c) pressure, (d) winds, (e) humidity, (f) cloudiness, and (g) precipitation.

The climatic elements react with well-recognized climatic controls listed by Critchfield as (a) latitude, (b) altitude, (c) land and water surface, (d) mountain barriers, (e) prevailing winds, (f) air masses, storm and pressure centers, (h) ocean currents and (i) local relief.

The reactions of climatic elements and controls determine regional and local climates and the response of crop plants. Climatic extremes such as low and high temperatures are of special significance to crop production.

In the Palouse area the number of days with zero and subzero readings are higher for the month of January than for the average of the entire tabulation of the cold season. The percentage based on January low temperatures comes to 7.69. This is still a very low percentage probability.

The occurrence of even the lowest winter temperatures does not indicate winterkilling of wheat or barley if the fields are protected by a blanket of snow during the coldest days of the winter months.

Attention is called to the fact that the monthly incident of low temperatures appear more frequently on the upper than on the lower portion of Table 15. The upper part of the tabulation (range 0 to -14F) accounts for 21 out of a total of 248 days.

High temperatures, especially when occurring during the critical periods of the crops grown in an area, may cause considerable damage. The most common types of damage are due either to the increase of the rate of water removal from the soil, leading to soil drought, and high rate of water removal from plants subjected to high water loss, atmospheric drought. These conditions pave the way to drought and drought manifestations. The combination of low moisture availability and increasing demands for water at times result in the forcing of crops to early maturity. This results in lowering yields and to a depreciation of quality.

The onset of high temperatures and dry soil conditions brings the flowering of peas to a close. This reduces yield potentialities, and if hot, dry weather continues, results in small, shrunken peas.

The forcing of cereal crops to early maturity not only reduces yields but also depreciates the quality of the harvested crop. Under these conditions the kernels become small or shrunken, the weight per bushel decreases and the protein percentage of the kernels increases. This trend of events is undesirable in a soft, white winter wheat and a malting barley producing area where the emphasis is placed on the production of large, plump and mellow kernels with only a moderate percentage of protein. This can be accomplished where the post-heading period of malting barley is from 30 to 35 days long rather than only 20 to 25 days. A relatively long

Table 16. Frequency-distribution of daily minimum temperatures into 3-degree class intervals by months recorded at Moscow, Idaho, during the 60-year period from 1904 to 1963

Frequency classes in 3-degree intervals	Number of days by months with minimum temperatures by frequency classes from 0-2 to 30-32F												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals
0 to 2	35	15	1							1	4	5	61
3 to 5	37	31	3								8	22	101
6 to 8	41	27	5								9	25	107
9 to 11	80	47	15	1							18	56	217
12 to 14	75	50	18							1	30	56	230
15 to 17	104	66	27	2						1	26	61	287
18 to 20	144	99	65	5	1				2	15	53	134	518
21 to 23	167	139	83	13					1	22	84	179	688
24 to 26	222	227	170	47	3				4	44	146	256	1119
27 to 29	240	261	312	178	34	1			14	94	245	282	1661
30 to 32	281	315	408	294	93	8	1	2	39	165	345	344	2295
Totals	1426	1277	1107	540	131	9	1	2	60	343	966	1422	7284

Table 16 gives the frequency distribution of daily minimum temperatures by months in 3 degree interval classes over a range of from O to 32F. As to be expected, the highest number of frosts, tabulated over a period of 60 years, occurred within the range of the smaller temperature depressions. These 3 classes are found in the lower class limits of Table 16, within the range of 24 to 32 F. These 3 classes accounted for 5075 days with freezing temperatures out of a total of 7284 such instances.

Table 16 shows that every month of the year had frosts recorded. The July frost was recorded on July 3, 1962, and the August instances occurred on August 16, 1935, and August 29, 1962.

The lowest temperature recorded over the 60 years of observation was -30F. This low temperature was recorded on January 20, 1937. The next lowest temperatures, -25F, came on two successive days, namely, on January 26 and 27 of 1957.

Table 17. Frequency of number of days by months with maximum temperatures of 90F or higher, for the 60-year period from 1904 to 1963, at Moscow, Idaho

Maximum temperatures	Number of days by months with maximum temperatures of 90F or above					
	May	June	July	August	Sept.	Totals
90	2	16	84	79	17	198
91	2	5	53	58	19	137
92		5	62	58	11	136
93		11	44	43	6	104
94	1	3	49	36	7	96
95		6	34	29	5	74
96		4	33	26	1	64
97			14	13		27
98		1	17	18	1	37
99			14	8		22
100		1	13	1		15
101			2	1		3
102			8	2		10
103			3			3
104			2	1		3
105			1			1
106						
107						
108				1*		1
109				1**		1
Totals	5	52	433	375	67	932

** All-time high August 4, 1961.
* Second high August 5, 1961.

post-heading period conditioned by moderate temperatures and the availability of soil moisture is needed for maximum production and for the development of quality.

Fortunately only a relatively small percentage of days with temperatures of 90F or above are encountered in the Palouse area. Table 17 shows that the high temperature dates are concentrated in the months of July and August. These 2 months account for 86.7 percent of the high temperature dates. When considering the total number of days, from May to September inclusive, on which temperatures of 90F or more are a possibility, only 932 days with such temperatures were recorded during the 60-year period. This placed on a percentage basis shows that only 10.36 percent of the possible days could be classified as hot, with temperatures of 90F degrees or above.

The upper portion of Table 17 including the first 6 classes (90-95) shows that 745 cases of the total of 932 recordings were located within the "moderate" group. This upper part of Table 17 accounts for 79.9 percent of the incidents recorded.

The highest daily temperature recorded during the 60-year period of observations, 1904-1963, was 109F. This all-time high temperature was recorded on August 4, 1961. The second highest temperature, 108F, came on August 5 of the same year. Temperature records were broken in 2 successive days. The third highest temperature, 105F, was recorded on July 26, 1928.

LENGTH OF GROWING SEASON

The term growing season refers to the length of time, expressed in number of days, between the last occurrence of critical low temperatures in spring and the first occurrence of these temperatures in fall. The critical temperatures selected for this purpose varies in relation to the uses of the data collected. Plant men generally use 32F. Construction workers and industry are especially interested in 27F as the critical temperature. In this discussion, unless stated otherwise, the term growing season refers to the interval in days between the occurrence of the last freezing temperature of 32F in spring and the reoccurrence of this temperature in fall.

Thermal and Physiological Growing Season

Since the growing season, as commonly used, is determined altogether by the temperature intervals, it may well be designated as a thermal growing season. It provides a means of stating the length of time available for annual plant growth, but there are definite limitations to its use. It must be kept in mind that the growth of plants, or the ability of the environment to support active growth, is dependent on a constellation of factors of which temperature is only one. In many habitats the lack of moisture during certain portions of the frost-free period may force vegetation into a period of dormancy so that 2 and possibly more periods of plant activity rather than only 1 may be in evidence. This is the case in areas with a Mediterranean type of climate. The seasonal moisture cycle of the Palouse area with its dry summers provides a good illustration of this type of climate. Not all of the 138 days of the growing season at Moscow provide conditions favorable to plant growth.

The length of the growing season as commonly used is based on only 1 environmental factor, namely on temperature, or more definitely on the timely occurrence of critical temperatures. It may, therefore, be specified as a thermal growing season. A second type of growing season was designated by Klages (8). In this case only those portions of the frost-free season when not only temperature but also the other essential factors of the environment are favorable to growth are designated as the physiological growing season. The agronomic significance of this distinction is evident.

Table 18. Length of growing season by days for 7 decades at Moscow, Idaho. Established by crtical temperatures of 32F or below

Decade	Length of growing season in days by years										Decade means
1894-1903	103	141	116	106	120	137	152	150	121	162	130.8
1904-1913	128	144	167	156	152	154	108	120	156	128	141.3
1914-1923	162	135	106	135	148	101	136	122	152	176	137.3
1924-1933	132	109	116	140	162	150	156	155	137	135	139.2
1934-1943	162	83	192	115	164	154	201	155	176	154	155.6
1944-1953	138	67	144	144	147	130	119	138	139	121	128.7
1954-1963	139	133	114	153	148	148	122	137	67	161	132.2
										Mean	137.9

Length of Growing Season for 7 Decades

The summarized data on the length of the growing season are given in Tables 18 and 19. The data for Table 18 are by years and decades while those of Table 19 are shown by frequency classes. The average length of the growing season stands at 138 days. It varied considerably over the 70-year period from 1894 to 1963. This is especially evident from Tables 18 and 19. The length of the frost-free season shows a range of 138 days. The shortest season of 67 days was recorded twice, once in 1945 and a second time in 1962. The day of the last killing frost in the spring of 1945 fell on June 14. The first frost in fall occurred on August 20. The corresponding dates for 1962 are July 3, and September 20. The longest growing season was recorded in 1940. In that season the last frost in spring was recorded on April 16, one month earlier than the average date, and the first frost in fall on November 3, 34 days later than the average.

Table 19. Length of growing season by distribution of frequency classes for a 70-year period, 1894-1963

Frequency classes in days	Frequencies by classes (f)
60-69	2
70-79	0
80-89	1
90-99	0
100-109	7
110-119	4
120-129	7
130-139	15
140-149	9
150-159	14
160-169	7
170-179	2
180-189	0
190-199	1
200-209	1
Totals	70
Average	138.4 days
Range	201 - 67=134 days
S.D.	25
C.V.	18.06

Since the length of the growing season is determined by the appearance of the last frost in spring and the first frost in fall it becomes interesting to check these dates and their respective frequencies. This analysis of the data appears in Table 20. The average date of the last frost in spring is May 16. The average date of the first frost in fall is September 30. There is considerable variation in these spring and fall dattes. This is shown by the frequency distribution of these dates, Table 20.

A graphical presentation of the critical dates for frosts in spring and fall is given in Figures 12 and 13 on page 36.

In the case of spring frosts there are 3 temperature hurdles to overcome, namely for the middle of April, the early part of May, and the last part of May and early June. These critical periods may well be of concern to producers of non-hardy plants.

Frost periods during the fall months are evident from Figure 14. These periods cluster around 3 rather distinct dates, namely around September 12 and 27, and October 17.

The frequency distributions of the lengths of the growing season based on 70 years of data are shown in Table 19 and presented graphically in Figure 14. This graph shows 3 peaks as did the graphs on dates of last frost in spring and the first frost in fall.

Table 20. Dates and frequencies of the last frosts in spring and the first frosts in fall for a 70-year period, 1894-1963. Critical temperature 32 F

Last frost in spring			First frost in fall		
By day numbers	By calendar days	Frequencies (f)	By day numbers	By calendar day	Frequencies (f)
96-100	Apr. 6-Apr. 10	1	228-232	Aug. 16-Aug. 20	1
101-105	Apr. 11-Apr. 15	..	233-237	Aug. 21-Aug. 25	1
106-110	Apr. 16-Apr. 20	4	238-242	Aug. 26-Aug. 30	1
111-115	Apr. 21-Apr. 25	4	243-247	Aug. 31-Sept. 4	..
116-120	Apr. 26-Apr. 30	3	248-252	Sept. 5-Sept. 9	4
121-125	May 1-May 5	9	253-257	Sept. 10-Sept. 14	7
126-130	May 6-May 10	10	258-262	Sept. 15-Sept. 19	2
131-135	May 11-May 15	6	263-267	Sept. 20-Sept. 24	9
136-140	May 16-May 20	4	268-272	Sept. 25-Sept. 29	14
141-145	May 21-May 25	5	273-277	Sept. 30-Oct. 4	5
146-150	May 26-May 30	9	278-282	Oct. 5-Oct. 9	4
151-155	May 31-June 4	9	283-287	Oct. 10-Oct. 14	6
156-160	June 5-June 9	1	288-292	Oct. 15-Oct. 19	7
161-165	June 10-June 14	3	292-297	Oct. 20-Oct. 24	4
166-170	June 15-June 19	1	298-302	Oct. 25-Oct. 29	2
171-175	June 20-June 24	....	303-307	Oct. 30-Nov. 3	1
176-180	June 25-June 29	..	308-312	Nov. 4-Nov. 8	2
181-185	June 30-July 4	1			
Av. 136	May 16		273	Sept. 30	
Range	85 days			80 days	
S.D.	16.90			16.90	

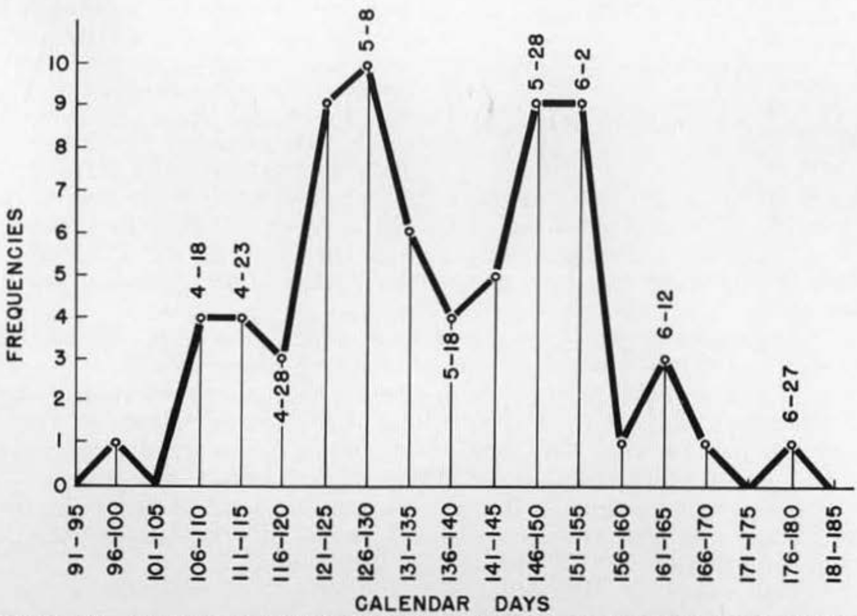

Figure 12. Frequency distribution of last dates of freezing temperatures, 32F or lower, recorded during the spring months for a 70-year period at Moscow, Idaho.

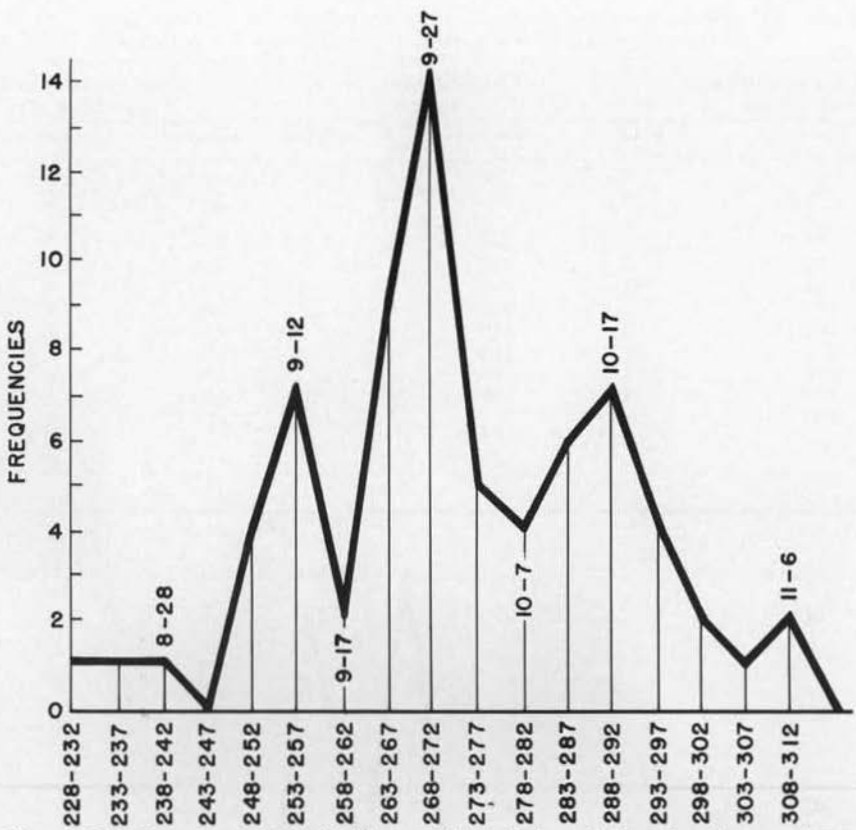

Figure 13. Frequency distribution of first dates of freezing temperatures, 32F or lower, recorded during the fall months at Moscow, Idaho, for a 70-year period from 1894 to 1963.

Trend of Length of Growing Season

The trend of the length of the growing season by decades is shown in Table 18 and in Figure 15. Data for 7 decades are available. The equation of the least square line is Y=138.87—0.096X. The equation shows a slightly negative trend of —.0969 days per decade or the small figure of —.0097 days per year. The level of the least square line dropped from 138.9 to 138.3 days. In view of the very low value of X the trend has no significant application. The extreme variability of the data by the 7 decades contributed materially to the variability of the data available.

Frost Days of 27 F or Less

The frequency distributions of portions of the year with critical temperatures of 27F are given in Table 21. Such tabulations are interesting and of value for noting the response of hardy plants. The occurrence and distribution of such sub-freezing tem-

Table 21. Frequency distributions of temperatures of 27F or less Occurrence of 27F by calendar days, lower class limits.

Last occurrence in spring		First occurrence in fall		Interval between spring & fall	
Classes	Frequency	Classes	Frequency	Classes	Frequency
70	6	250	2	140	2
75	4	260	5	150	2
80	3	270	6	160	5
85	6	280	9	170	5
90	6	290	16	180	11
95	13	300	13	190	5
100	11	310	13	200	15
105	3	320	4	210	10
110	5	330	1	220	7
115	5	340	0	230	3
120	3	350	1	240	2
125	3			250	1
130	2			260	1
				270	0
				280	1

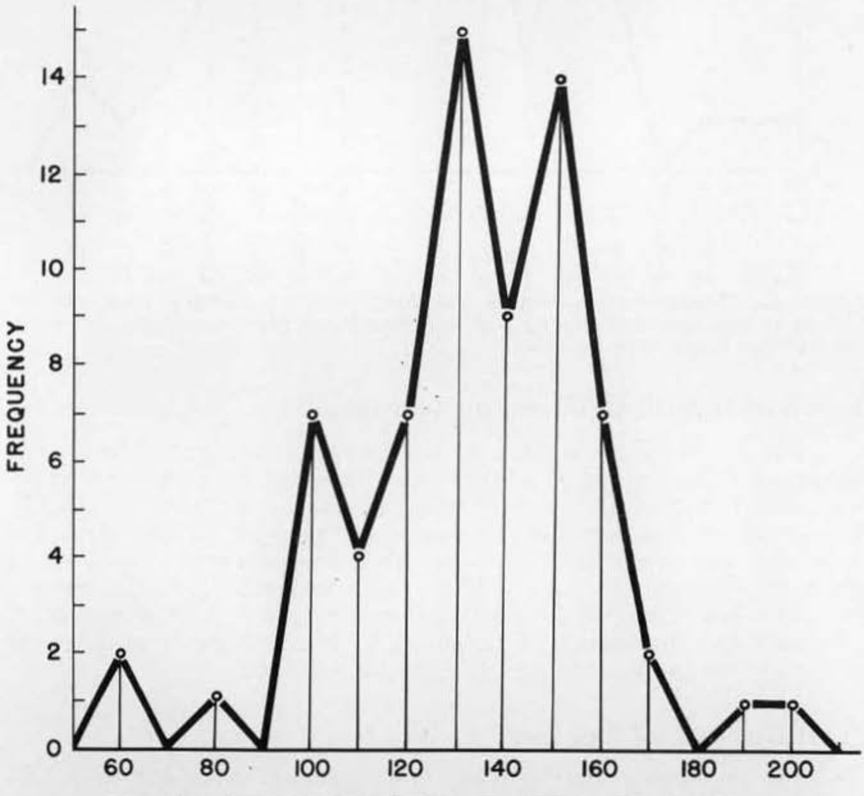

Figure 14. Length of growing season in days for 7 decades at Moscow with the critical temperatures at 32F.

peratures and their likely dates of occurrence are of value in that they provide warning dates that both farm and exposed industrial equipment demand attention.

Table 21 shows less variation on the dates of last occurrence of the 27F temperatures in spring than the first occurrence of this temperature in fall. The average dates, ranges and standard deviations are given at the bottom of Table 21.

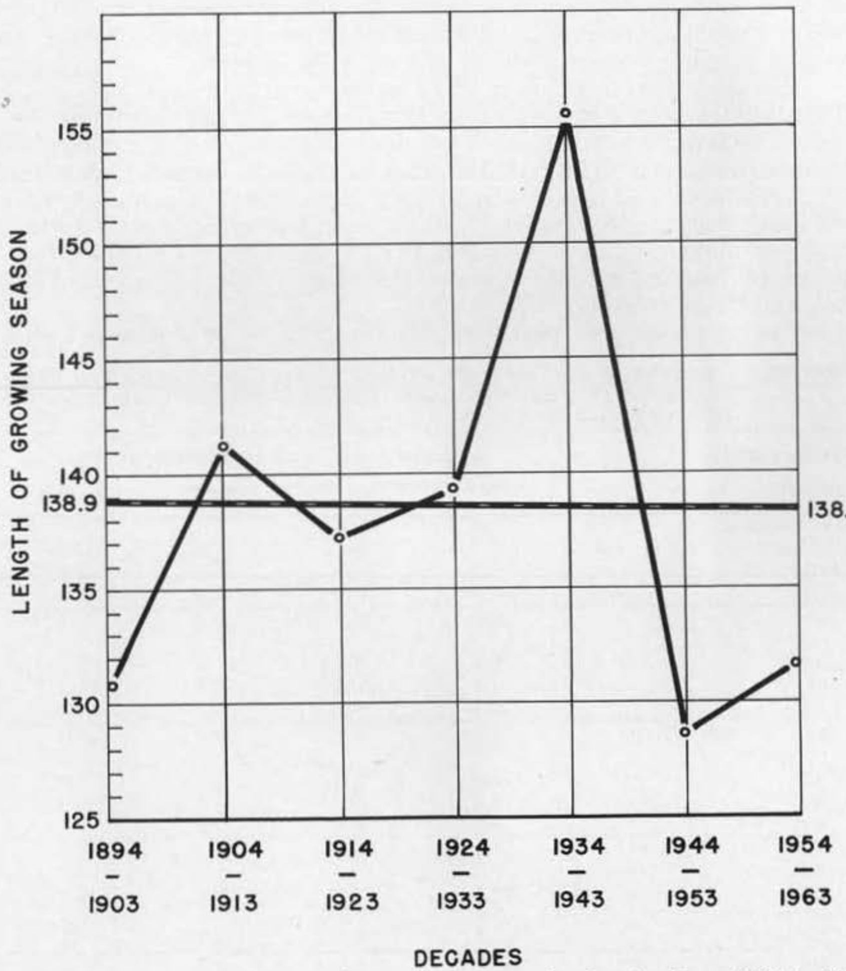

Figure 15. Length and trend of growing seasons by decades from 1894 to 1963 with critical temperature of 32F. The regression equation is Y=138.87—0.096X

CHARACTER OF DAY

The incidence of rainy days is highest during the fall and winter months, tapers down during the spring quarter and reaches its lowest point during the summer quarter. Any day receiving measurable amounts of moisture, 0.01 inches or more, during a 24-hour period was designated as rainy. Traces of precipitation were disregarded.

The incidence of cloudy days is highly correlated with rainy ones and shows the same seasonal trend. However, not all cloudy days bring precipitation. On an annual basis the average number of cloudy days amounted to 144.0, while the average of all rainy days per year was 114.9.

Table 22 gives the average number of days designated as clear, partly cloudy, cloudy and rainy for the 60-year period of 1904 to 1963. The data are tabulated by months and quarters. Figure 16 gives a graphic presentation of the data by months.

The distribution of clear days shows a highly seasonal trend. The greatest abundance of these days occur during July and August; however, a good number of clear days occur during May to October, inclusive. The annual numbers of clear days for this period stands above 12 per month. Clear days during late fall, winter and early spring (November through April) average only 7.1 clear days per month. The lowest number of clear days per month occurred in December, January and February with 5.5, 5.9 and 6.5 such days respectively.

The occurrence of partly cloudy days show no definite trend.

Table 22. Character of day. Average number of days per months and quarters designated as clear, partly cloudy, cloudy and rainy, for the 60-year period 1904 to 1963

Quarters and months	Average number of days designated as: Clear	Partly cloudy	Cloudy	Rainy
First quarter				
January	6.5	6.7	17.9	14.0
February	5.9	6.8	15.9	12.4
March	7.6	8.0	15.4	12.5
Totals—first quarter	20.0	21.5	49.2	38.9
Second quarter				
April	9.8	9.0	11.3	10.0
May	11.1	9.2	10.7	10.3
June	12.3	9.5	8.3	7.7
Totals—second quarter	33.2	27.7	30.3	28.0
Third quarter				
July	21.0	6.5	3.6	2.9
August	19.7	6.7	4.6	3.6
September	14.8	7.1	8.2	6.2
Totals—third quarter	55.5	20.3	16.4	12.7
Fourth quarter				
October	12.1	6.5	12.4	9.1
November	7.3	5.8	17.0	12.1
December	5.5	6.3	19.3	14.1
Totals—fourth quarter	24.9	18.6	48.7	35.3
Annual	133.5	88.1	144.0	114.9

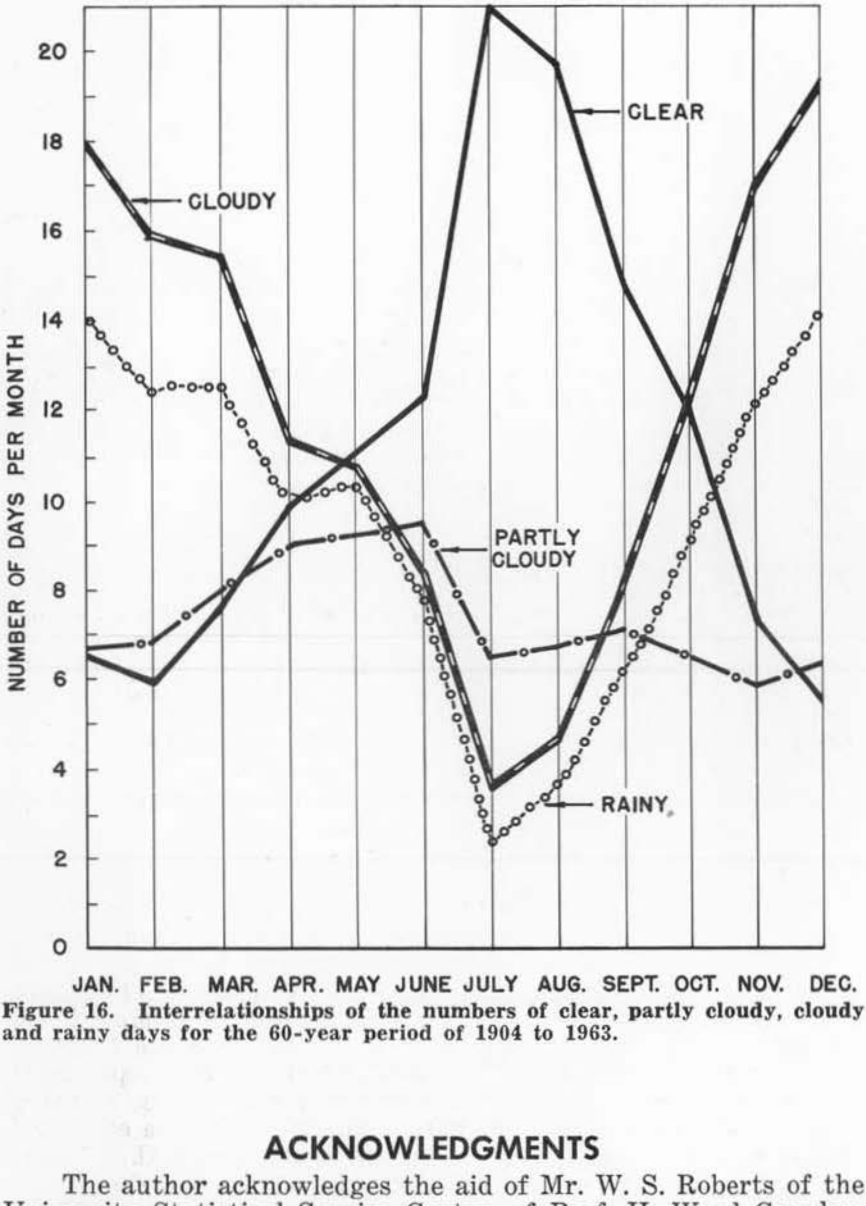

Figure 16. Interrelationships of the numbers of clear, partly cloudy, cloudy and rainy days for the 60-year period of 1904 to 1963.

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LITERATURE CITED

1. Corless, Donald Edward. Climatic factors of the Palouse Area and the relation of precipitation to wheat yields. University of Idaho Master Thesis. 1938.

2. Critchfield, Howard J. General Climatology. Prentice Hall, Englewood, N. J. 1961.

3. Dethier, B. E. and M. T. Vittum. Growing Degree Days. New York State Agricultural Exp. Sta. Bull. 801. 1963.

4. Gavett, G. Irving. Statistical Method. McGraw-Hill, New York. 1925.

5. Hughes, H. D. and E. R. Henson. Crop Production. Macmillan, New York. 1930.

6. Kincer, J. B. Atlas of American Agriculture, Part II, Section A, Precipitation and Humidity. Govt. Printing Office, Washington, D. C. 1922.

7. Klages, K. H. W. Climate of the Palouse Area of Idaho as indicated by fifty years of climatic data on the University farm. Idaho Agr. Exp. Sta. Bull. 1942.

8. ______________ Ecological Crop Goegraphy. Macmillan, New York. 1942.

9. ______________ Crop adaptation in relation to the economic use of water. Idaho Agr. Exp. Sta. Res. Paper 490: Presented at the Arid-Land Symposium held at the University of Wyoming on May 6, 1959.

10. Köppen, W. Klassifikation der Klimate nach Temperatur, Niederschlag und Jahresverlauf Petermann's Mitteilungen. 64:193-202, und 243-248. (Abstr. Mo. Weather Rev. 50:69-72.) 1922.

11. Kuckuck, Hermann and Mudra, Alois. Lehrbuch der Allgemeinen Pfanzüchtung. Hirzel Verlag, Zurich. 1950.

12. Maximov, N. A. The plant in relation to water, authorized translation by R. H. Yapp. Allen and Unwin, London. 1929.

13. Robbins, W. W. Principles of Plant Growth. Wiley, New York. 1927.

14. Snedecor, George W. Statistical Methods. Collegiate Press, Ames, Iowa. 1938.

15. Ward, Robert D. The Climates of the United States. Ginn and Company, Boston. 1925.

16. Yarnell, D. L. Rainfall intensity-frequency data. U. S. Dept. Agr. Misc. Pub. 204. 1935.

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