A STUDY OF THE RELATION OF RAINFALL TO CROP YIELDS OF SANDY SOILS IN WISCONSIN

by

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A Thesis Submitted for the Degree of

BACHELOR OF SCIENCE

(Agriculture)

UNIVERSITY OF WISCONSIN

1933

Approximately six million acres or about one-fifth of the total area of Wisconsin is classed as sandy soil. It is often a serious problem to obtain profitable crop production from many of these soils due to their low water holding capacity.

The data for this study were obtained from the Branch Experiment Farm at Hancock, Wisconsin, which lies in the central sandy area of the state. The crops studied were rye, corn, clover and alfalfa and were grown on Plainfield sand, which is a level and light colored soil. The crops were grown under various fertilizer treatments so that lack of fertility was not a limiting factor in the production. The rainfall records were obtained from the Climatological Data compiled by the United States Weather Bureau. The weather station is located on the Experiment Farm at Hancock.

One of the factors that determines successful crop production is a fertile soil. In order to be fertile a soil should have the following qualifications; first, favorable moisture; second, sufficient air; third, good tilth; fourth, sufficient supplies of available plant food elements; and fifth, be free from harmful influences (6). The two most important of these as related to sandy soils are the first and fourth. The effectiveness of the latter is largely dependent upon the former because the soil moisture dissolves the plant food elements, making them available to the plants.

The water in a soil is present as hygroscopic, capillary, and gravitational. Hygroscopic water is water that an absolutely dry soil will absorb from a moist atmosphere. This

water is tightly held by the soil and cannot be used by plants.

If more moisture is added to the soil until the water starts to flow through it, that above the hygroscopic water is capillary water. This is the most important moisture in the soil for it is this water that is available to the plant.

Water that is free to respond to the pull of gravity is called gravitational water. This water moves downward through the soil and leaches out soluble salts that are present. This water is not readily available for the use of plants.

The capillary water holding capacity of a soil depends upon texture, structure, organic matter and surface tension. The finer the texture of a soil the higher is its capillary capacity. This is due to the presence of colloidal materials and to the larger number of spaces in which capillary water can be held. Clay soils expose a much larger amount of internal surface than do sandy soils. The structure of a soil will determine the amount of capillary water held in the active film-like portion. In a granulated clay the interstitial spaces are enlarged and the capillary capacity is increased. By compacting a sand a larger capillary water holding capacity is secured by increasing the actual effective surface and the number of angles possible for capillary concentration. Too much compaction of a sand will cause a decrease in the capillary capacity.

Well decayed organic matter greatly increases the capillary capacity of a soil, because its porosity affords an enormous internal surface, and its colloids exert an affinity for moisture.

Table I shows the water holding capacities of various surface soils. (1)

Table I

The Maximum Water Capacity of Various Surface Soils as Determined in the Laboratory and Under Field Conditions, Respectively.

Soil	Organic Matter %	Hygroscopic coefficient %	Field water capacity %	Maximum water capacity (Laboratory) method %
Sand	---	1.1	11.7	37.0
Sand	---	1.7	12.8	27.1
Sandy soil, Residual	1.22	3.3	19.6	34.2
Red loam, Residual	1.07	10.0	31.5	49.0
Silt loam, Loess	1.55	10.1	31.3	56.8
Silt loam, Loess	4.93	10.2	39.2	60.9
Black adobe	2.22	12.9	47.6	60.3

Table I shows the effect of texture on water holding capacity very well, the sands having a low capacity and the silt loams a high holding capacity. The influence of organic matter is also shown by the two silt loams. The one with a higher amount of organic matter has the greater water holding capacity.

Water movement in the soil is the fastest when the soil is near its maximum water holding capacity and slowest when the percentage of moisture is low. The texture also influences the rate of movement. A fine textured soil will have a slow movement of capillary water while a coarser textured soil

will have a faster movement, but it will not move it as great a distance. Table II shows the relation of texture to the rate and height of capillary movement in air-dry soils as obtained in the laboratory of the Department of Soil Technology, Cornell University (4).

Table II

Effect of Moisture on Rate and Height of Capillary Rise from a Water-table Through Air-dry Soil.

Soil	1 hour	1 day	2 days	3 days	4 days	5 days
	Inches	Inches	Inches	Inches	Inches	Inches
Sandy soil	3.5	5.0	5.9	6.8	6.8	6.9
Clayey soil	.5	5.7	8.9	10.9	12.2	13.3
Silt loam	2.5	14.5	20.6	24.2	26.2	27.4

The movement in sand is rapid, one half of the total rise being attained in one hour and the maximum height in about three days. The clay has greater friction so the rate is slower. The silt loam has a fairly rapid rise and enough capillary pull to attain a good height above the water table.

Under certain conditions a great deal of the soil moisture is lost through evaporation. The rate of evaporation is affected by the moistness of the soil, wind, and temperature. The greatest loss by evaporation comes after a rain when the surface soil is still wet. Fortier (5) states that during 28 days, after receiving six inches of water, uncultivated soil lost 2.13 inches and cultivated 1.58 inches. Fifty-one percent

of the loss from cultivated soil occurred during the three days between watering and beginning of cultivation. The cultivation caused a reduction of 26 percent in evaporation. Table III shows the loss of water from a sandy loam soil by evaporation.

Table III

Weekly Evaporation from Sandy Loam Soil and Water Free Surface

Percent Water	Evaporation in inches	Mean temperature in sun 0^{o} F.
Free water surface	1.94	80
Soil saturated	4.75	95
17.5 percent	1.33 1st week	106
11.9 "	1.13 2nd week	106
8.9 "	.88 3rd week	108
4.8 "	.25 4th week	108

Table III shows that evaporation from the soil was about two and one-half times that from a free water surface, due to the heat of the sun being absorbed at the surface of the soil. In the water, the rays of the sun penetrate to the lower depths so that the temperature at the surface is not as high as at the surface of the soil, thus causing less evaporation from the water. The table also shows that evaporation is greatest when the water content of the soil is the highest.

The type of rainfall is of great importance in agriculture for it determines the type of crops that can be grown successfully in that region. The manner in which the rainfall is distributed throughout the year is as important as the

total precipitation. In the semi-arid region of the United States they have selected crops whose periods of growth and maturity coincide with the season of most abundant rainfall. In the earlier years failure often resulted from attempts to raise crops which were not adapted to the rainfall type in that district. A relatively small amount of precipitation may be so distributed that most of it comes when crops have the greatest need for it and the crop yields will be high. On the other hand a large amount of rainfall may come in a few heavy showers and a great deal of it lost by run-off so that the crop does not receive full benefit from the rain and as a result the yield will be low. It takes a larger amount of rainfall to produce a good crop if the rains come during the winter months because of the loss of moisture due to evaporation and percolation. If the rains come during the growing period, these losses are reduced to a minimum.

There are many various types of rainfall throughout the World, ranging from the heavy tropical rainy regions near the equator to the rainless deserts. One distinct type of rainfall is the Mediterranean type or, as often called in the United States, the Pacific type because it occurs along the Pacific Coast (7). In this type there are well marked winter rains which extend from October to May and the summers are relatively dry. The rain comes in slow steady showers, except on some of the mountainous slopes where it comes in heavy downpours. The soil has a chance to absorb most of the precipitation and the run-off is low except on heavy packed soils. In this region, crops with low water requirements or

crops that mature early in the year are the most successful because they use the water supply before it is lost by evaporation. Here light silt loams and loams are the best farm lands because they have a high water holding capacity and by capillary action the water retained from the winter rains is available to the crops in the summer. Sand soils are not able to hold as much of the rainfall and as a result become dry sooner in the hot dry summer weather and produce poor crops.

In the dry farming region of the United States, most of the rainfall comes in the spring and early summer and the late summer and winter are quite dry. The late summer rains are not of much value because the ground has been baked by the heat, causing loss of moisture by run-off and evaporation. A light textured soil under these conditions absorbs most all of the rainfall and does not lose as much of it by evaporation as a heavy textured soil would. In this region sandy loams and fine sandy loams give the best yields.

Wisconsin lies in the semi-humid region and receives most of its rainfall during the summer months when growing crops need it the most. The mean annual rainfall for Wisconsin, as cited by Whitson and Baker (8) is 31 inches, about half during May, June, July and August and nearly 70 per cent from April to September inclusive. This amount, with its favorable distribution just preceding and during the period of plant growth, normally supplies the needs of crops on sandy soils very well. These soils are loose and porous and absorb practically all of the rainfall so that there is no run-off. With a light shower a crop on a sandy soil gets the benefit of the

moisture while a crop on a heavier soil does not. The heavier soil holds the water tighter, causing a slower movement of the water.

Precipitation of less than .3 of an inch, coming as an individual shower or as an accumulation over two or three days, has practically no beneficial effect on the crops on sandy soils. If the dry period extends beyond ten days, the crops begin to feel the effects of drought.

Table IV shows that the largest amount of precipitation comes during the summer months when it is most beneficial to growing crops. There is only a small amount of precipitation during the winter months. What does occur is retained by the soil so that there is little loss of moisture during the non-growing period.

Equally important as the amount of rainfall per month is the manner in which it is distributed throughout the month. If the monthly rainfall comes in one heavy shower, there is loss by run-off and percolation and the crops will feel the effect of drought before the month is over. On the other hand, numerous light showers are of no great value unless they are close enough together so that the combined showers give enough moisture to wet the soil. A light shower only wets the surface soil and is soon evaporated unless the land is cultivated. The ideal rainfall for a sandy soil would be .5 of an inch of rain about once every four days. This would supply the needs of plants and be often enough to prevent any effects from drought.

Table IV

Rainfall by Months at Hancock Experiment Farm

Month	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932
January	.24	.65	.36	.09	.37	.79	.38	1.62	.67	.61	1.82
February	3.95	.33	.45	.76	1.22	.23	3.08	.70	1.46	.89	1.50
March	3.28	1.22	1.73	.27	1.10	.92	1.01	1.33	2.31	1.37	.66
April	4.62	3.50	5.57	1.96	2.15	1.69	1.99	3.98	2.52	.80	.37
May	3.60	1.92	3.75	1.30	8.19	5.11	2.05	1.47	3.14	1.74	3.31
June	5.10	2.60	4.36	7.40	4.71	3.38	3.06	3.96	4.64	3.55	4.30
July	2.85	1.10	2.66	5.45	3.50	3.96	3.44	1.99	4.33	1.07	2.73
August	1.49	2.85	5.65	1.77	5.71	1.07	6.06	2.17	.89	3.07	3.25
September	2.40	4.12	4.42	6.00	5.27	3.64	4.60	2.41	1.01	6.50	1.89
October	.56	.83	.31	1.87	2.64	3.31	3.48	1.49	2.32	3.90	1.31
November	3.99	.77	2.35	.76	1.83	1.12	1.36	.53	.82	3.99	2.30
December	.74	.86	.56	1.29	.78	1.47	.82	.38	.16	.83	
Total	32.82	21.75	32.96	28.94	37.47	26.69	31.33	22.03	24.27	28.32	

Table V gives the rainfall records for the Hancock Experiment Farm by days during the summer months (9).

Table VI gives a summary of Table V and shows the amount of rain that falls in the form of showers of less than .50 of an inch, in showers from .50 to 1.00 of an inch, and in showers that give over 1.00 of an inch.

Table VI

Rainfall at Hancock

Between	Ave. rate	Ave. No. rains per month	Apr.	May	June	July	Aug.	Sept	Total	Per cent
.01 - .50 inches	.19	6	1.25	1.26	1.48	1.20	1.08	1.20	7.47	36
.51 -1.00 inches	.69	1	.78	.93	.74	.99	.55	1.31	5.30	26
1.00 and over	1.43	1	1.29	1.02	1.95	.81	1.45	1.31	7.83	38
Total			3.32	3.21	4.17	3.00	3.08	3.82	20.60	

Table VI shows that 36 per cent of the precipitation during the growing period comes in rain of less than .50 of an inch. There are six of these rains a month and the average precipitation for each rain is .19 of an inch. This is a light rainfall and is not of much benefit to the growing crop unless several of these light showers occur close together and moisten the soil to a depth of several inches.

There is usually one shower a month that gives between .51 and 1.00 of an inch of rain. The average precipitation in this group is .69 of an inch. This is a good rain and

Table V

Daily Precipitation at Hancock, Wisconsin

Year	Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
1922	April		.10	.20	.45	.07				1.75		1.00					.26	.65		.15													4.62
	May			.20	.07		.75		.10								.25	.05	.30	.40					.50	.40						.58	3.60
	June								.75		3.25			.82														.28					5.10
	July						.78			.47			.47			.03	.04	.47					.46							.13		2.85
	Aug.	.15	.17	.18		.11	.28	.05									.15			.09									.20			.11	1.49
	Sept.							.03	1.12				.21	.72					.32														2.40
1923	April		1.00	.90			.04	.50								.18						.85					.03					3.50
	May						.15	.13							.65					.99												1.92
	June		.25				.28													.35		.20		.15	.17	1.20						2.60
	July						.25																	.37			.40			.08			1.10
	Aug.							.07			.12							.23			.97					.07	.62	.34				.43	2.85
	Sept.	1.10				.36	.48	.02										.42			.85							.89					4.12
1924	April					.22		.33	.45					.04			.92			.27		.52			.53	.82		1.47					5.57
	May					.30	.07			1.70				.55	.05								.08	.60			.40						3.75
	June		.14			.11	.06			.40		.03	.23			.45		1.33			.03			1.01					.45		.12		4.36
	July	.02	.01			.05	.05		.03	.25			.84								.64	.08		.35	.03	.25				.66			2.66
	Aug.			2.10		.31	.07		.38		.04					1.09							1.66										5.65
	Sept.	.37			.12			.57	.17			.58									.25	1.75							.61				4.42
1925	April													.05	.13				1.13	.15	.40		.10										1.96
	May				.04												.60						.15		.20				.31				1.30
	June	.30	.15	1.27	.27							1.50	2.04	.72		.28		.39							.07	.16	.03	.22					7.40

Year	Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
1925	July			1.65			.25		.24	1.70		.30	.10		.30					.58		.15			.08						.10		5.45
	Aug.				.11	.12	.31	.53	.60				.07	.03																			1.77
	Sept.					.77	.75		.71										.66	.65							.35	.47			1.64		6.00
1926	April					.07	.04							.10											1.68			.26					2.15
	May		.60	.05	.24									.21					.45		1.46	.10		.50		2.60	.80			.75		.43	8.19
	June						.40		.03			.27		2.10	1.25		.17					.30			.16								4.71
	July									.52		.25								.60		.05			.06	.62			.05		.11	1.24	3.50
	Aug.	.07			.05					.85		.26	.05				.06		.02	1.10	3.25												5.71
	Sept.			.07	.15	.57			.59			.85			.30	.43			.43	.36		.05		1.07	.42					.03		5.27
1927	April				.12	.06							.06			.07	.36		.03	.26	.01	.27			.05	.17	.01			.20	.02		1.69
	May		.10	.04					.08	.84	.08			.18	.16	.06		.04			.04	.09	.15	1.85	.03		.12		1.25				5.11
	June	.03			.26	.26				.10	.08	.24						.18	.35	.04	.50	1.45	.15										3.38
	July	.07				.12	.07			.07		.14	.05	1.04			.15	.02				1.03					.40	.40	.40				3.96
	Aug.																	.22	.02				.70							.13			1.07
	Sept.						.18	.68		.07	.11		.01						.40				.03			.22	.89	.28	.42	.13	.22		3.64
1928	April			.09	.06	.25	.40	.09	.40				.05	.01	.24		.07		.22	.05					.01					.05			1.99
	May				.64											.03	.23	.01	.57	.11	.01						.29	.16					2.05
	June				.03	.01			.25	.02			.78					.13	.05	.12		.16	.80	.20		.02			.49				3.06
	July		.61	.12					.40					.67						.50		.16	.22				.15			.59		.02	3.44
	Aug.		1.12	.16	.04		.42	.11									.05	.08			.11	1.17		1.65				.50		.65			6.06
	Sept.		.02	.01							.68	.03	.30	.02	2.82	.13						.54											4.60
1929	April	.05			.15	.02		1.40				.39	.02												.33	1.35		.21			.06		3.98

Year	Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
1929	May	.21										.72			.18	.08								.18			.01	.01		.08			1.47
	June					.02					.09	1.17		.55			.25		1.10	.08			.13		.16	.01		.40					3.96
	July			.35			.85		.08					.02									.01	.08	.30	.18	.07		.05				1.99
	Aug.			.01					1.25				.29	.38				.08										.14	.02			2.17
	Sept.				.04	.24				1.06			.05	.50			.05										.30		.14	.03			2.41
1930	April												.33			.53	.14	.86	.48												.19		2.52
	May	.05	.35		.10	.36	.03				.01	.09	.15	.12				.02	.03			.05	1.68				.10						3.14
	June				.40	.12	1.28		.08			.09		1.29	.47	.06	.14													.01	.70		4.64
	July				.62		.25														.22	.07			1.00		1.05	.66	.46				4.33
	Aug.		.43							.22																			.24				.89
	Sept.	.18												.10												.18	.55						1.01
1931	April															.21					.28	.30			.01								.80
	May	.01				.06	.20	.01		.34	.05	.05	.13						.66											.23			1.74
	June		.09		.17			.08		.82			.63			.19					.65		.91	.01								3.55
	July	.25				.70			.02									.10															1.07
	Aug.	.46	.16						.59		.15													.01				.07	.53			1.10	3.07
	Sept.	.67			.06									.05	.67	1.51	.37	.20		1.10	.10	.10	.27	.10		1.15					.15		6.50
1932	April		.02		.24			.02																	.07	.02							.37
	May					.31	1.75	.02	.15	.11						.05			.02			.18				.35	.35	.02					3.31
	June			.35	.32	.43		.04										.02	.50		.04					2.34				.23	.03		4.30
	July			1.20			.10				.72											.10				.61							2.73
	Aug.						.31										2.48	.02								.39	.30		.05				3.25
	Sept.												.10	.32		.02			.02	.01	1.40							.02					1.89

large enough to insure ample moisture for the growth of crops for a considerable period. These rains furnish 26 per cent of the moisture that falls during the growing period.

There is generally one shower a month that gives over 1.00 inch of rain. The average precipitation in this group is 1.43 inches per shower. This group supplies 38 per cent of the summer rainfall. This is a large amount of rainfall to come in one shower. There is no loss by run-off during these heavy rains because the open structure of the sandy soil allows all of the rainfall to penetrate the soil. These heavy rains generally come in the hot summer months and the lighter rains in the early spring and late fall.

Rye is one of the main crops that are grown on sandy soils and it is well adapted to these soils. Rye requires the greatest amount of moisture when the grain is being filled out which occurs in June before the hot dry summer weather comes so the crop is not often affected by drought. The crop is usually planted about the middle of September and the hottest and driest weather is over and the early fall rains are beginning. This gives the crop a good start and insures a good stand of rye. If September is dry, the seed does not all germinate and a poor stand results, which gives a small yield the following year even if the spring is favorable for good production.

Table VII gives the rye yields at the Hancock Experiment Farm since 1922.

Table VII

Rye Yields at Hancock Experiment Farm

Year	Date planted	Date harvested	Yield in bushels
1922	Sept. 19, 1921	July 8	15.0
1923	Aug. 31, 1922	July 9	14.0
1924	Sept. 9, 1923	July 28	21.3
1925	Sept. 16, 1924	July 14	20.5
1926	Sept. 18, 1925	July 19	19.7
1927	Aug. 26, 1926	July 20	18.0
1928	Sept. 8, 1927	July 23	15.6
1929	Aug. 27, 1928	July 18	18.0
1930	Sept. 6, 1929	July 11	17.0
1931	Sept. 27, 1930	July 9	18.1
1932	Sept. 23, 1931	July 9	15.9
		Average yield	17.5

In 1922 the production of rye was 15 bushels per acre. There were two fairly dry spells during the growing season, both of 13 days without rain. One was from the 19th of April to the 3rd of May and the other from the 13th to the 27th of June. The rest of the time there was ample rainfall to give good production with 4.62 inches of rain in April, 3.60 inches in May, and 5.10 inches in June.

The yield was 14 bushels per acre in 1923. It was dry when the rye was sown and the rainfall in September was less than usual, so the stand was poor. The rainfall was less than

in 1922 and less uniformly distributed. There were 3.50 inches in April, chiefly in the first part of the month. May was fairly dry with only four rains giving a total of 1.92 inches. There were 2.60 inches in June with a 13 day dry spell near the middle of the month.

In 1924 the yield was 21.3 bushels per acre. There were several good rains just before seeding time and three good rains in September after seeding, so the crop got a good start. The rainfall was uniformly distributed throughout the growing season, there being no dry period longer than seven days. The rainfall in April was 5.57 inches, in May 3.75 inches, and 4.36 inches in June.

The yield was 20.5 bushels in 1925. There were two good rains shortly after the rye was planted so the crop started off in fine shape. The month of April was quite dry at the beginning and end, and the first part of May was also dry. This is a good yield for such unfavorable moisture distribution. The rain for April was 1.96 inches, for May 1.30 inches and for June 7.40 inches.

In 1926 the production was 19.7 bushels per acre. The precipitation was favorably distributed except during the early part of April. The rainfall was 2.15 inches in April, 8.19 inches in May, and 4.71 inches in June.

The yield was 18 bushels per acre in 1927. The driest weather came in the latter part of June. The rainfall for April was 1.69 inches, for May 5.11 inches, and 3.38 inches in June.

In 1928 the yield was 15.6 bushels per acre. There were numerous rains in April but many of them were too light to be of any value. The rainfall was 1.99 inches in April, 2.05 inches in May, and 3.06 inches in June.

The yield was 18.0 bushels per acre in 1929. The middle of April and the first part of May were quite dry but the remainder of the time there was plenty of rain for good growth. The rainfall was 3.98 inches in April, 1.47 inches in May, and 3.96 inches in June.

In 1930 the yield of rye was 17.0 bushels per acre. It was dry during the first and latter parts of April and the latter part of June. There were 2.52 inches of rain in April, 3.14 inches in May and 4.33 inches in June.

The yield was 18.1 bushels per acre in 1931. April was quite dry, having only .80 inches of rainfall, but the rainfall during May and June was favorably distributed throughout the period so the rye did not suffer from drought.

In 1932 the yield was 15.9 bushels per acre. The rye was sown when the ground was moist and it received plenty of rainfall to give the crop a good start that fall. April was very dry, receiving only .37 inches of rainfall and that in very light showers. May and June had favorable rainfall but this could not overcome the effects of the drought in April.

The best yields of rye are obtained when the rainfall is uniformly distributed throughout the growing period. There must be enough rainfall well distributed in September to insure a good stand, for unless a good thick stand is obtained, good rainfall in the spring cannot produce a good yield. Neither

can a good stand produce a good yield with unusually dry weather in the early spring months. Droughts in the early spring growing period are not as serious as those during the heading and filling out of the grain, but too long a drought cuts down production. The distribution of the rainfall has as much effect on the yield of rye as does the total precipitation.

Corn requires the greatest amount of water during the tasseling and ear-forming stage which generally occurs in July and the first part of August. Summer droughts often occur at this period so the yield is low due to lack of moisture (5).

Table VIII gives the corn yields at the Hancock Experiment Farm in terms of total dry matter from 1922 to 1932.

Table VIII

Corn Yields at Hancock Experiment Farm

Year	Date planted	Date harvested	Total dry matter
1922	May 27	September 4	2600 pounds
1923	May 25	August 24	2098 "
1924	May 17	September 30	5280 "
1925	May 22	September 11	2375 "
1926	May 29	September 27	4545 "
1927	May 19	September 24	4460 "
1928	May 21	September 26	5830 "
1929	May 13	September 3	4711 "
1930	May 10	September 2	3823 "
1931	May 15	September 20	1625 "
1932	May 13	September 19	4056 "
		Average Yield	3763 "

The greatest amount of dry matter was obtained in 1928 when 5830 pounds per acre were produced. Looking at the critical growing period, July and August, we find that there were 3.44 inches of rain in July and that the longest period without a rain was five days. In August the rainfall was 6.06 inches with an eight day dry period near the middle of the month. The favorable distribution in these two months had a great deal to do with the maximum yield of corn in 1928. The rainfall in the early growing months was also well distributed so the crop was not affected by drought.

The second highest yield was obtained in 1924 when the crop was 5280 pounds of dry matter. In July the rainfall was 2.66 inches, well distributed throughout the month. There were 5.65 inches of rain in August and the major portion of this came during the first part of the month when the corn was making its most vigorous growth. While the distribution is not as favorable as in 1928, it gave a good corn crop.

In 1929 the yield was 4711 pounds of dry matter per acre. The rainfall in July was 1.99 inches but the middle of the month was quite dry, there being 14 days with only a very light shower. In August the rainfall was 2.17 inches which came the first part of the month. In 1929 the rainfall was not as great as in the best producing years and the distribution was not as good. The rainfall in the early growing season was also below normal.

The yield in 1926 was 4545 pounds of dry matter. There were 3.50 inches of rain in July and it was fairly well distributed throughout the month. The rainfall was 5.71 inches

in August and it all came during the first 20 days.

There were 4460 pounds of dry matter per acre in 1927. The precipitation in July was 3.96 inches and was well scattered over the month. In August the rainfall was 1.07 inches which came in four showers during the latter part of the month. There was a dry period of 19 days from the 28th of July to the 22nd of August which, no doubt, reduced the yield.

In 1932 the yield was 4056 pounds of dry matter per acre. The rainfall for July was 2.73 inches and was well distributed. There was a ten day dry period near the middle of the month. The precipitation in August was 3.25 inches and it was fairly well distributed.

The yield was 3823 pounds of dry matter per acre in 1930. There was a 14 day dry period from the 6th to the 20th of July and the total precipitation for July was 4.33 inches. August received only three rains with a total of .89 inches. The dry weather in August and September cut down the yield for the crop had ample moisture up to that time.

The corn produced 2600 pounds of dry matter per acre in 1922. The rainfall was 2.85 inches in July and most of it came during the first half of the month. The precipitation was 1.49 inches in August and the greater portion of it came in the first part of the month. The rainfall was not uniformly distributed to give the best yields. The distribution during the earlier growing period was also rather unfavorable.

The yield was 2375 pounds of dry matter per acre in 1925. The precipitation was 5.45 inches in July and it was

favorably distributed throughout the month. The rainfall was 1.77 inches in August and it came in the first 13 days and there was a 22 day dry period before another rain occurred, which cut down the yield.

In 1923 the yield was 2098 pounds of dry matter per acre. The precipitation for July was 1.10 inches which came in four showers. Three of these came the last week of the month so the first part of the month was dry. The rainfall in August was 2.85 which came chiefly in the last half of the month. The distribution of the rainfall in the critical months was unfavorable for the best production of corn and the distribution in the early growing period was also unfavorable, so the yield in 1923 was low.

The lowest production of a crop came in 1931 when only 1625 pounds of dry matter per acre was obtained. A drought of 12 days occurred in the middle of July. There were 1.07 inches of rain in July but it came in the first and latter parts of the month. The rainfall of 3.07 inches in August occurred in somewhat the same manner. The rainfall in the early growing months was also light. These conditions combined to produce a small corn crop.

The yield of corn depends to a large extent upon the amount and distribution of rainfall during July and August when the corn is tasseling out and making its greatest growth. If the rainfall is well distributed during this period, a good crop will be obtained. If the rainfall is large but confined to a short period, the yield will not be as great as for a smaller rainfall which is more evenly distributed throughout the

month.

In 1929 the rainfall during July and August was 4.16 inches and the yield was 4711 pounds of dry matter per acre, while in 1926 the rainfall was 9.21 inches in July and August and the yield was 4545 pounds of dry matter per acre. Looking at the daily rainfall table we find that rainfall in 1929 was somewhat better distributed over the period especially in the earlier parts of July than in 1926;although the total rainfall was not as great, the yields were practically the same. In 1925 the rainfall during July and August was 7.22 with the greatest part of this coming the first part of July and the first part of August. The last good rain fell on August 8th and the next beneficial rain fell on September 5th, making a dry period of 27 days which cut down the yield. There was plenty of rainfall but the corn could not make the best use of it due to its uneven distribution. In 1922 a rainfall of 4.34 inches in July and August gave a corn crop of 2600 pounds of dry matter per acre. While the rainfall was not as great as in 1925, it was more uniformly distributed. The longest dry period was nine days so the corn was not affected by drought.

Clover requires plenty of moisture during the early growing period for the best production. If the rainfall is great enough in April and May to give the crop a good start the yield will be high and if April and May are unusually dry the yield will be low.

Table IX gives the yields of clover at the Hancock Experiment Farm.

Table IX

Clover Yields at Hancock Experiment Farm

Year	Date Planted	Date harvested		Yield in pounds		Total yield in pounds
		First	Second	First cutting	Second cutting	
1922	April, 1921	June 26		2700		2700
1923	April 22, 1922	July 21		1060		1060
1924	No clover					
1925	April, 1924	July 17		1720		1720
1926	No clover					
1927	April, 1926	July 10		4060		4060
1928	April, 1927	July 5	Aug. 13	786	660	1446
1929	April 25, 1928	July 23		2660		2660
1930	No clover					
1931	April 19, 1930	July 2		1895		1895
1932	No clover					
				Average yield		2220

The new seedings of clover died out because of dry weather in 1923, 1925, 1929 and 1931 so there was no clover the following years.

The best yield was obtained in 1927 when 4060 pounds per acre were produced. The rainfall was 1.69 inches in April, 5.11 inches in May, and 3.38 inches in June. These rains were well distributed throughout the months so the clover was not wanting for moisture at any time.

The yield in 1922 was 2700 pounds per acre. The precipitation was 4.62 inches in April, 3.60 inches in May, and 5.10 inches in June. The distribution in April and May

was spread throughout the months, but in June a rain of 3.25 inches fell on the 10th and the rest of the month was fairly dry.

There were 2660 pounds of clover per acre in 1929, when the rainfall in April was 3.98 inches, 1.47 inches in May, and 3.96 inches in June. The rains were not quite as evenly distributed as in 1927 and 1922 but the yield was good.

In 1931 the yield was 1895 pounds per acre. April was quite dry with .80 inches of rain in four rains so the crop did not get a good start. There were 1.74 inches of rain in May and it was well scattered throughout the month. The rainfall in June was 3.55 inches, well distributed throughout the month. The dry weather in April reduced the yield considerably.

The yield was 1720 pounds per acre in 1925. April received 1.96 inches of rain in six showers that came the middle of the month and May received 1.30 inches of rain in five showers which came the latter part of the month. The rainfall in June was 7.40 inches and it was spread throughout the month. The distribution in April and May caused several periods when drought affected the growth of the clover.

In 1928 two cuttings of clover gave a yield of 1446 pounds per acre. In this case there does not seem to be any relation to rainfall and yield for the precipitation was 1.99 inches in April, 2.05 inches in May, and 3.06 inches in June and it was fairly well distributed throughout the period.

The lowest yield of clover was obtained in 1923 when only 1060 pounds per acre were produced. The rainfall in April was 3.50 inches and came in the first 21 days. In May

the rainfall was 1.92 inches and came in four showers before the 19th. In June the precipitation was 2.60 inches and most of this came between the 19th and 25th. There was plenty of rainfall but it was not distributed evenly enough to produce the best results, so the yield of clover was low.

A good supply of moisture, evenly distributed throughout April, May and June, gives the highest yield of clover. The rainfall that comes in May appears to be the most important. If there is moisture enough during April and May to start a large vigorous growth, medium spells of dry weather in June do not cause much reduction in yields. If the spring months are dry the nurse crop will use most of the available moisture as it starts to grow first and has a better root system. The clover may never get a chance to grow as happened in 1923, 1925, 1929 and 1931. If the rainfall is large enough it will supply the nurse crop and also the new clover so that a good thick stand will be obtained. Good distribution and ample rainfall in the second year will not produce the maximum yield if the rainfall the first year was so light that a poor thin stand of clover was obtained.

Table X gives the alfalfa yields at the Hancock Experiment Farm.

Table X

Alfalfa Yields at Hancock Experiment Farm

Year	Date Planted	Date harvested		Yield in pounds		
		First	Second	First cutting	Second cutting	Total
1922	May 29, 1918	June 15	Aug. 1	3490	1850	5340
1923	" " "	June 19	July 25	2000	2269*	4269
1924	June 8, 1920	July 2	Sept. 2	2470	1755	4225
1925	" " "	June 29	Aug. 21	1663	1175	2838
1926	April 16, 1925	July 1	Sept. 6	2825	1185	4010
1927	" " "	July 6	Aug. 30	2300	1800	4100
1928	" " "	July 7	Aug. 25	1730	984	2714
1929	" " "	July 5	----	1625	----	1625
1930	" " "	July 1	Aug. 23	1425	1350	2775
1931	April 25, 1930	June 29	----	1900	----	1900
1932	April 17, 1931	June 28	Aug. 8	1418	1258	2676
					Average	3315

* 2nd and 3rd cuttings combined.

The best yield of alfalfa was obtained in 1922 when 5340 pounds per acre were produced. In that year the rainfall was above the average and was quite evenly distributed throughout the growing season.

The years 1923, 1924, 1926 and 1927 gave approximately the same results, producing 4269 pounds in 1923, 4225 pounds in 1924, 4010 pounds in 1926, and 4100 pounds in 1927. Three cuttings were made in 1923 and even with the rainfall below normal a good crop was obtained. The years 1924, 1926

and 1927 had better distribution of rainfall but the yield was about the same.

The yields in 1925, 1928, 1930 and 1932 were fair, being 2838, 2714, 2775 and 2676 pounds per acre respectively. The rainfall was somewhat lighter in these years and perhaps not quite as uniformly distributed over the growing season.

The yields of 1625 pounds per acre in 1929 and of 1900 pounds per acre in 1931 can hardly be compared because only one cutting was made in these two years, while two cuttings were made in the other year.

Because of its deep root system, alfalfa is able to withstand longer periods of drought than most crops and the effects of rainfall are not as pronounced as is the case with many crops. Good moisture conditions in the early growing months gives the best results. It does not require as much moisture to start a stand of alfalfa as it does for a stand of clover, for on these sandy soils alfalfa is sown without a nurse crop so there is nothing to compete for the moisture while clover has to compete with a nurse crop.

Alfalfa also draws part of its water from lower depths than do most crops. The soil is able to hold more water at lower levels than at the surface because the temperature is lower, which increases the surface tension of the water and holds it closer around the soil particles.

Summary

Rainfall is one of the most important factors in the production of good crops on sandy soil. If the rainfall is

well distributed throughout the growing season, crops on sandy soils do very well, but if the rainfall is unevenly distributed they soon suffer from drought for these soils have a low water holding capacity.

Rye is one of the best crops for sandy soils because it matures early before the hot dry summer weather begins and it makes the best use of the late fall and early spring rains.

Corn does not require as much water to produce a pound of dry matter as does the grain crops so it is able to produce a fair crop on sandy soils when the supply of moisture is fairly low. Corn requires the greatest amount of water during July and August when the crop is making its maximum growth. The amount and distribution of precipitation during these two months determines the yield of corn to a large extent. The distribution is of more importance than the total precipitation, for medium amounts of rainfall well distributed give better yields than large amounts of rainfall with long dry spells between rains.

The yield of clover depends upon getting a good stand of clover the first year and then having enough early rains to give it a good start the second year. As clover is usually sown with a nurse crop, the rainfall must be great enough to supply both crops, for if the rainfall is deficient, the clover is the first to feel the effects of drought.

It does not require as much moisture to start alfalfa as it does clover for on sandy soils alfalfa is usually sown alone so does not compete for moisture with a nurse crop. Alfalfa can also stand dry weather better than most crops because of its deep root system which enables it to obtain at

lower levels the water which is unavailable to shallow rooted crops.

Bibliography

1. Alway, F. J. and McDole, G. R. The Relation of Movement of Water in a Soil to its Hygroscopicity and Initial Water Moistness: Jour. of Agr. Res., 10:8, 291-428. 1917.

2. Fortier, Samuel. Use of Water in Irrigation. P. 131. 1915.

3. Kendrew, W. G. Climate. 1930.

4. Lyon, T. L. and Buckman, H. O. The Nature and Properties of Soils. P. 174. 1927.

5. Smith, J. W. Agricultural Meteorology. P. 150-151. 1920.

6. Stewart, H. W. A Study of the Factors Affecting the Supply of Moisture to Crops in Sandy Soils. Soil Science: 21: 197-223. 1926.

7. Ward, R. D. The Climate of United States. P. 198-201. 1925.

8. Whitson, A. R. and Baker, O. E. The Climate of Wisconsin and Its Relation to Agriculture. Wis. Agr. Expt. Sta. Bul. 223. 2nd Rev. 1928.

9. U. S. Dept. of Agr. Weather Bureau. Climatological Data for United States, Wisconsin Section. Vols. 9 - 19. 1922-1932.

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DATE: Jan. 27 - 1933.