Using Rainfall Records as Guides to Predict Yields of Cotton on Drylands of the High and Rolling Plains of Texas

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CONTENTS

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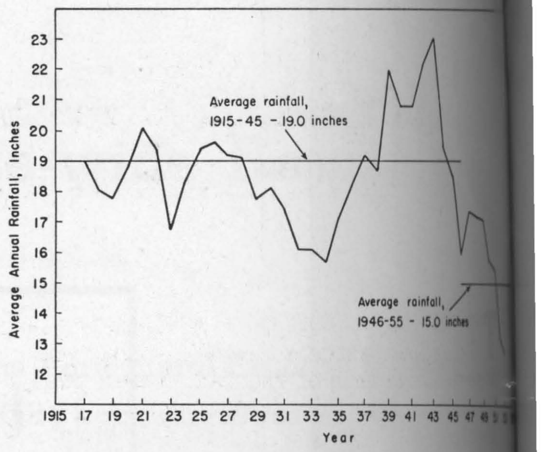

Figure 1. Five-year moving averages of annual rai at Lubbock during 1915-55 on a crop-year basis as record by the Texas Agricultural Experiment Station.

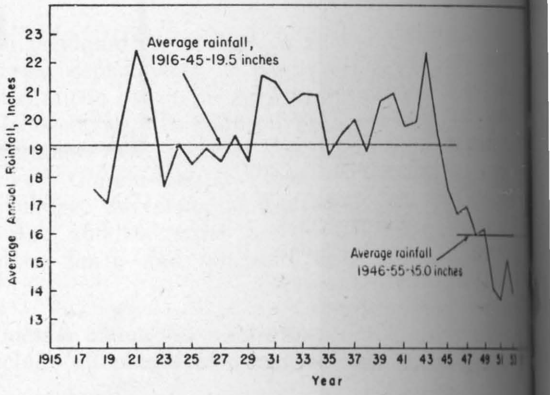

Figure 2. Five-year moving averages of annual rai at Big Spring during 1915-55 on a crop-year basis as record by the Texas Agricultural Experiment Station.

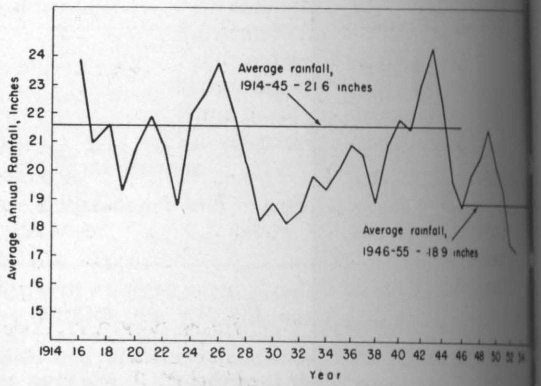

Figure 3. Five-year moving averages of annual rai at Spur during 1911-55 on a crop-year basis as recorded b the Texas Agricultural Experiment Station.

Using Rainfall Records as Guides to Predict Yields of Cotton on Drylands of the High and Rolling Plains of Texas

Earl Burnett and W. C. Moldenhauer*

THE HIGH AND ROLLING PLAINS cotton area of Texas has extreme climatic variations. This is particularly true of rainfall, which normally is the limiting factor in dryland cotton production. Moisture conservation practices, such as contouring and terracing, land leveling, crop residue management and good tillage methods, are important for successful farming in the area. Many times, however, rainfall limits crop production despite the moisture conservation practices used. Under these conditions, the farmer must reduce production costs if he is to stay in business.

A knowledge of the probabilities of rainfall adequate for economic yields is necessary for the farmer to make wise decisions whereby his costs may be reduced. These decisions may involve reduction of the cotton acreage with a corresponding increase in fallow, sorghum, cover crops, soil improving crops or other crops that are cheaper to produce than cotton. In addition, decisions to purchase new equipment should be made on the basis of calculated probable income rather than simply guessing that enough money will be available to make the payments when due at the end of the harvest season.

This publication presents an analysis of the rainfall characteristics of three locations on the High and Rolling Plains. Probabilities of cotton yields have been designed to aid the farmer in determining cotton yields with various amounts of rainfall.

PRECIPITATION PATTERN OF THE AREA

The drouth of the 1950's far exceeds in length and intensity any on record at most locations in West Texas. The average crop year rainfall at Lubbock, Big Spring and Spur are shown in Figures 1, 2 and 3. The data are presented as 5-year moving averages. Each yearly point on the lines represents an average of 5 years, 2 years before and 2 years after, plus the year on which the point falls.

The figures show that there was a marked decline in annual rainfall at each station since about 1945. The average annual rainfall for the period of record up to 1945 is considerably higher than the 10-year period, 1946-55, at each station.

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Average rainfall on a crop year basis at Lubbock (Figure 1) during 1915-45 was 19.0 inches, compared with an average of 15.0 inches during 1946-55. The drouth of the early 1930's did not approach the present one in length or intensity. Only expanded irrigation apparently has prevented an extremely critical situation from developing in the Lubbock area.

Annual crop year rainfall at Big Spring (Figure 2) during 1915-45 averaged 19.5 inches, compared with the 1946-55 average of 15.0 inches. There were two other drouth periods but neither was as severe. With the exception of the 1915-18 period, there were not more than 2 dry years together until the present drouth occurred.

The rainfall pattern at Spur was somewhat different than the other two stations, as shown in Figure 3. Average crop year rainfall during 1914-45, was 21.6 inches, compared with the 1946-55 average of 18.9 inches. The drouth of the 1950's was not as severe as at Big Spring or Lubbock, being partially broken during 1949-51. It also was exceeded in duration by the period 1928-40. However, the 5-year average 1951-55 of 17.4 inches was below that of the 1928-40 average of 18.6 inches.

NATURE AND LIMITATIONS OF THE DATA

Rainfall and cotton yield records (Table 1) from three research locations on the High and Rolling Plains were analyzed to determine the effect of rainfall on the yields of dryland cotton. These locations were Big Spring, Lubbock and Spur. Some of the data from individual stations have been published elsewhere (2) (4).

The rainfall data were grouped into two categories: preseasonal (September 1 to April 30) and seasonal (May 1 to August 31). The relationship of preseasonal and seasonal rainfall on yields of lint cotton, while far from perfect, provide a measure of probability which is considerably more reliable than guessing. Total rainfall is not always a reliable index of the amount of moisture available for plant growth. Length and quantity at each rain period, with runoff and other factors, affect the amount of water that enters the soil and becomes available for plant growth. Burnett and Fisher have shown that the amount of available soil moisture at planting time serves as a more reliable index to probable yield (1). However, when soil moisture data are limited, as was the case in this study, rainfall may be used as a reasonably good forecast to probable production, provided that runoff is controlled adequately with level terraces, land leveling, crop residue management or good tillage practices.

Soils at the three research stations are typical of a large portion of the cotton soils of the area. At both the Big Spring and Lubbock stations, they are classed as Amarillo fine sandy loam. This soil is freely-permeable, medium-textured, 3 to 4 four feet deep and underlain by a calcium carbonate (caliche) layer. It is the predominant cotton soil of the Southern High Plains and is commonly called mixed land, mixed sandy land or red catclaw land. It is an efficient soil from a water relations standpoint because the surface soil is coarse enough to take water rapidly while the sandy clay subsoil has a high enough water-holding capacity to permit considerable storage for future use. This soil type becomes slightly heavier from south to north, which may account for some of the differences in the crop yield results between Big Spring and Lubbock.

The soil at the Spur station is Abilene clay loam. It has a very heavy brown clay loam surface underlain by a darker brown clay subsoil. Generally, it is 4 to 6 feet deep, and has ample water-holding capacity. The infiltration rate of this soil is very slow. Because of the low rate of water intake, it is less desirable for dryland farming than the fine sandy loams.

Cotton is grown on a number of other soil types on the High and Rolling Plains, but from a crop production standpoint, these do not differ greatly from the ones described. Row crops are not recommended in the areas of deep sands because of the extreme wind erosion hazard.

TABLE 1. DRYLAND COTTON YIELD AND AMOUNTS OF PRESEASONAL (SEPTEMBER 1-APRIL 30) AND SEASONAL (MAY 1-AUGUST 31) RAINFALL AT THE LUBBOCK, BIG SPRING AND SPUR EXPERIMENT STATIONS

Crop year	Lubbock			Big Spring			Spur		
	Cotton yield, pounds per acre	Preseason rainfall, inches	Season rainfall, inches	Cotton yield, pounds per acre	Preseason rainfall, inches	Season rainfall, inches	Cotton yield, pounds per acre	Preseason rainfall, inches	Season rainfall, inches
1914							538	16.8	22.4
1915	485	21.2	9.9				336	22.4	8.6
1916	201	14.1	4.7	129	8.9	8.5	Hail	16.6	8.2
1917	190	7.6	4.3	0	4.7	2.5	167	6.6	5.6
1918	175	5.4	5.9	32	2.4	5.1	97	5.9	6.3
1919	469	11.3	10.7	467	10.8	14.3	422	12.9	11.4
1920	240	15.0	11.4	540	17.0	13.9	Hail	15.0	19.4
1921	315	7.7	9.9	198	7.5	7.8	250	8.2	5.4
1922	171	9.2	7.6	232	15.9	5.8	158	10.8	8.8
1923	270	7.6	10.0	346	12.5	6.5	75	9.7	7.8
1924	218	13.0	5.6	187	11.8	6.7	159	14.2	5.5
1925	141	3.6	9.9	403	6.9	7.3	125	8.3	15.3
1926	284	15.1	10.0	232	11.8	10.2	324	11.4	19.7
1927	135	16.6	5.7	194	13.2	5.1	290	14.7	7.5
1928	144	4.0	15.0	410	6.5	15.6	110	7.6	15.0
1929	257	6.2	9.7	95	7.0	8.8	Hail	5.2	5.5
1930	163	8.1	4.9	220	12.4	6.5	49	10.2	4.9
1931	379	11.9	6.9	209	12.6	4.8	206	15.6	5.4
1932	521	10.9	13.1	360	19.2	14.7	Hail	12.1	13.0
1933	282	8.6	6.7	320	13.3	7.3	369	10.5	8.7
1934	23	5.4	3.8	178	7.0	5.3	0	8.8	3.9
1935	133	4.3	9.0	394	7.2	13.0	191	7.6	13.5
1936	231	9.2	8.0	119	11.1	6.0	48	11.8	7.2
1937	449	20.5	10.5	390	16.3	7.3	224	16.8	11.8
1938	340	10.4	12.4	254	9.8	14.4	186	11.3	11.6
1939	207	4.4	7.0	200	5.3	9.4	3	5.3	6.2
1940	189	5.8	5.4	246	4.8	10.0	38	7.0	5.5
1941	277	11.3	22.4	468	12.2	14.2	472	13.7	15.5
1942	461	15.2	9.6	220	12.2	12.1	309	23.0	10.1
1943	313	14.6	8.2	244	10.0	8.5	115	10.2	11.1
1944	450	8.3	10.1	229	8.2	7.4	78	9.7	9.8
1945	8	9.5	6.1	280	9.7	17.1	70	9.8	9.4
1946	0	7.2	8.3	234	7.3	4.2	143	10.3	8.7
1947	343	12.5	8.0	240	8.8	6.7	176	10.6	8.7
1948	81	5.2	4.8	121	5.1	9.0	141	8.2	9.0
1949	355	8.9	16.4	282	8.0	8.6	386	8.5	16.4
1950	222	7.3	7.4	355	7.7	14.6	141	9.1	12.9
1951	191	4.7	10.4	180	3.6	8.7	162	9.9	14.0
1952	169	6.0	8.0	0	3.3	2.2	23	8.1	4.7
1953	0	3.8	4.6	29	9.4	2.4	0	5.7	7.4
1954	284	6.2	7.8	140	10.6	13.3	147	8.3	7.6
1955	192	4.4	8.0	348	3.0	13.0	124	6.8	14.4
Average	243	9.3	8.7	243	9.4	9.0	163	10.8	10.1

TABLE 2. SEASONAL RAINFALL FREQUENCY, LUBBOCK, 1915-55

Seasonal precipitation, inches	Number of times occurring	Percentage of time occurring
Less than 5	6	14.6
5 to 9	18	43.9
9 to 13	13	31.7
More than 13	4	9.8
	41	100.0

The most desirable soil for crop production in a limited rainfall area is one with a sandy loam surface texture underlain by a sandy clay subsoil. A soil of this type takes up water readily, runoff is reduced and there is ample water holding capacity to carry crops through mid-summer when rainfall is low.

The rainfall-crop relationships presented are applicable to the cotton growing portions of the High and Rolling Plains having similar rainfall and soil conditions.

Several factors other than water influence the yields of cotton and other crops. The more important are soil fertility, insects, diseases, extremes of temperature and length of growing season. These factors, coupled with tillage practices and other variations in farm management, make is impossible to predict yields accurately on the basis of rainfall. However, a knowledge of the relationship between crop yields and rainfall can be of considerable value to the individual farmer, if properly applied.

Soil fertility normally is not a limiting factor on the dryland cotton soils because most of them are relatively fertile. Where erosion has been controlled, they are still fertile enough to produce maximum yields consistent with the amount of rainfall available. Until recent years, insects and diseases were not considered serious factors in dryland cotton production except in wet years.

Temperature extremes and length of the growing season are not under the control of the farmer, but they may affect crop yields. Length of the growing season becomes an important factor in the northern part of the cotton area. Cotton is a long-season crop and in some years unfavorable planting weather delays the crop to the extent that frost reduces yields so that it is impossible to predict yields entirely on the basis of rainfall.

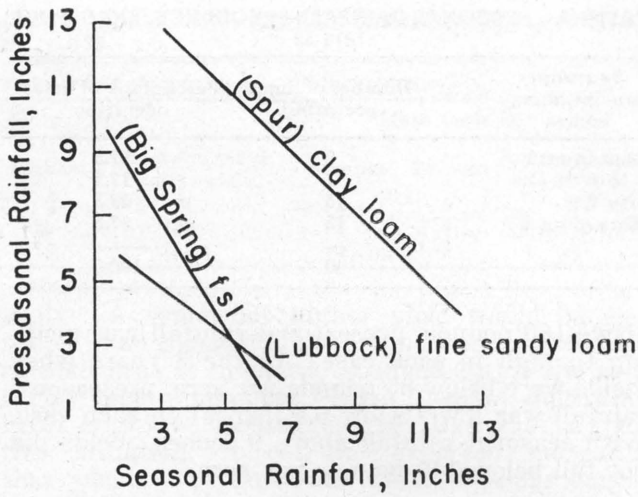

Figure 4. Effect of soil type on the amount of rainfall necessary to produce 100 pounds of lint cotton per acre.

EFFECT OF PRECIPITATION ON YIELD

Approximately 40 years of yield and rainfall records are available from each of the experiment stations at Lubbock, Big Spring and Spur and are presented in Table 1.

Figure 4 shows that, at both Lubbock and Big Spring, comparable yields can be obtained with less rainfall than at Spur. While it has required an average of 8 inches preseasonal and 8 inches of seasonal rainfall to produce a 100-pound yield of cotton on the clay loam soil or hardlands at Spur, an average of only 4 inches each of preseasonal and seasonal rainfall produced this yield on the sandy loam soils or mixed land at Lubbock, and an average of only 4.5 inches each of preseasonal and seasonal rainfall were required for the same yield on the sandy loam soil or mixed land at Big Spring. This results from the fact that the clay loam soils are more drouthy since they have a lower infiltration rate.

The frequency of occurrence of certain amounts of rainfall give a more significant indication of the true nature and variability of rainfall than does an average figure. Frequency of seasonal rainfall of various amounts at Lubbock is given in Table 2.

Of the 6 years when seasonal rainfall was less than 5 inches, the yields in 3 were above 160 pounds per acre and in 3 they were below 85 pounds per acre. In the 3 years when yields were

TABLE 3. FREQUENCY OF VARYING AMOUNTS OF PRESEASONAL RAINFALL WITH CERTAIN AMOUNTS OF SEASONAL RAINFALL, LUBBOCK, 1915-55

Preseasonal precipitation	Number and percentage of years when seasonal precipitation was:								
	Less than 5 inches			5 to 9 inches			More than 9 inches		
Inches	Number	Percent	Average yield lint, pounds	Number	Percent	Average yield lint, pounds	Number	Percent	Average yield lint, pounds
Less than 5	1	2	0	3	7	177	3	7	159
5 to 9	4	10	114	7	17	189	5	12	329
More than 9	1	2	201	8	20	225	9	22	392

TABLE 4. SEASONAL RAINFALL FREQUENCY, BIG SPRING, 1916-55

Seasonal precipitation, inches	Number of times occurring	Percentage of times occurring
Less than 3	3	7.5
3 to 6	7	17.5
6 to 9	15	37.5
More than 9	15	37.5
	40	100.0

above 160 pounds, preseasonal rainfall was medium to high in each case. In the 3 years when yields were below 85 pounds per acre, preseasonal rainfall was low (below 5.5 inches) in each case. With seasonal rainfall above 9 inches, yields did not fall below 140 pounds per acre.

Since yields of cotton at Lubbock depend to such a large degree on preseasonal rainfall, the frequency of occurrence of certain amounts of preseasonal rainfall, with certain amounts of seasonal rainfall, give another indication of the variability of precipitation at this location (Table 3).

The 1 year when both preseasonal and seasonal rainfall were low (below 5 inches), cotton yield was 0. In the other combinations, yields were highly variable.

The frequency of seasonal precipitation during 1916-55 at Big Spring is presented in Table 4.

Seasonal rainfall was low (less than 6 inches) 10 times, or 25 percent of the time, and medium or high 30 times. In 3 years when seasonal rainfall was very low (less than 3 inches), yields were less than 30 pounds per acre. When seasonal rainfall was medium or high (more than 6 inches), yields were never less than 95 pounds per acre. When seasonal rainfall was high (more than 9 inches), yields were never less than 140 pounds per acre.

Table 5 shows the number of years certain amounts of seasonal rainfall occurred with certain amounts of preseasonal rainfall at Big Spring.

Of the 6 years when preseasonal rainfall was less than 5 inches, seasonal rainfall was less than 6 inches in 3 and more than 6 inches in 3 years. This indicates that there was a 50-50 chance of getting high seasonal with low preseasonal rainfall. In the 3 years when seasonal rainfall was below 6 inches, yields were below 35 pounds per acre.

TABLE 6. SEASONAL RAINFALL FREQUENCY, SPUR, 1914-55

Seasonal precipitation, inches	Number of times occurring	Percentage of times occurring
Less than 8	16	38
8 to 14	18	43
More than 14	8	19
	42	100

When preseasonal rainfall was above 5 inches, only 1 year (1953) occurred with seasonal rainfall less than 3 inches and cotton yield was 29 pounds per acre. This indicates that the chances of seasonal rainfall less than 3 inches occurring with preseasonal rainfall over 5 inches were very low. It is significant, however, that preseasonal rainfall less than 5 inches had occurred four times since 1950 (including 1956), and seasonal rainfall less than 3 inches has occurred four times since 1951 (including 1956).

The frequency of occurrence of seasonal rainfall at Spur is shown in Table 6. Seasonal rainfall over 8 inches occurred 62 percent of the time with an average cotton yield of 103 pounds.

Since preseasonal and seasonal rainfall are of equal importance at Spur, both periods need to be considered simultaneously. Table 7 shows the number of years certain amounts of preseasonal rainfall have occurred with certain amounts of seasonal rainfall at Spur.

When preseasonal rainfall was low (5 to 8 inches) seasonal rainfall was low (4 to 8 inches) six times and medium to high three times. In the 6 years when low preseasonal and seasonal rainfall occurred together, yields less than 100 pounds per acre resulted except in 1 year when there was a moisture carry-over from the previous year. In the 3 years of low preseasonal rainfall and medium to high seasonal rainfall, yields of more than 100 pounds per acre were produced.

In 20 years when preseasonal rainfall was medium (8 to 12 inches), seasonal rainfall was low seven times and medium or high 13 times. Of the 7 years of low seasonal rainfall, there were 5 in which yields of less than 100 pounds per acre were produced. Of the other two, 1 (1921) undoubtedly had considerable moisture carry-over and the other (1954) may have had some. When preseasonal rainfall was high, yields of

TABLE 5. FREQUENCY OF VARYING AMOUNTS OF PRESEASONAL RAINFALL WITH CERTAIN AMOUNTS OF SEASONAL RAINFALL, BIG SPRING, 1916-55

Preseasonal precipitation	Number and percentage of years when seasonal precipitation was:								
	Less than 3 inches			3 to 6 inches			More than 6 inches		
Inches	Number	Percent	Average yield lint, pounds	Number	Percent	Average yield lint, pounds	Number	Percent	Average yield lint, pounds
2 to 5	2	5	0	1	2	32	3	8	258
5 to 9	0	0	0	2	5	206	12	30	255
More than 9	1	2	29	4	10	188	15	38	311

TABLE 7. FREQUENCY OF VARYING AMOUNTS OF PRESEASONAL RAINFALL WITH CERTAIN AMOUNTS OF SEASONAL RAINFALL, SPUR, 1914-55

Preseasonal precipitation	Number and percentage of years when seasonal precipitation was:								
	4 to 8 inches			8 to 14 inches			More than 14		
Inches	Number	Percent	Average yield lint, pounds	Number	Percent	Average yield lint, pounds	Number	Percent	Average yield lint, pounds
5 to 8	6	15	51	1	2	191	2	5	117
8 to 12	7	17	85	11	26	158	3	7	278
More than 12	3	7	218	6	14	215	3	7	337

more than 100 pounds per acre resulted regardless of seasonal rainfall.

PREDICTIONS OF YIELD

Alignment charts for determining cotton yields at the three stations from given amounts of preseasonal and seasonal rainfall are shown in Figures 5, 6 and 7. These charts serve only as estimates of probable production and not as completely accurate predictions.

In using these charts for prediction of yield, it should be kept in mind that soil conditions on a particular farm as well as the amount of rainfall are important in determining yields. For example, if soil conditions are more nearly like the sandy loam at Lubbock, use Figure 5, although the farm may be closer to Spur geographically. A somewhat higher yield would be expected than the average at Lubbock since a higher rainfall area is involved. Conversely, if the soil is clay loam or clay, use Figure 7, even though the farm might be located on the High Plains. In this situation, it can be expected normally that yields will be lower than at Spur since rainfall is lower. Farmers on the High and Rolling Plains may refer to MP-154 of the Texas Agricultural Experiment Station by Hildreth and Thomas (3) to find the rainfall conditions at stations nearest their farms.

To use these charts for predicting yield, one should keep records of rainfall from September 1 of the previous year until planting time of the current year. With this figure, and an average figure obtained from one of the frequency tables presented previously (Tables 2, 4 and 6), the up-

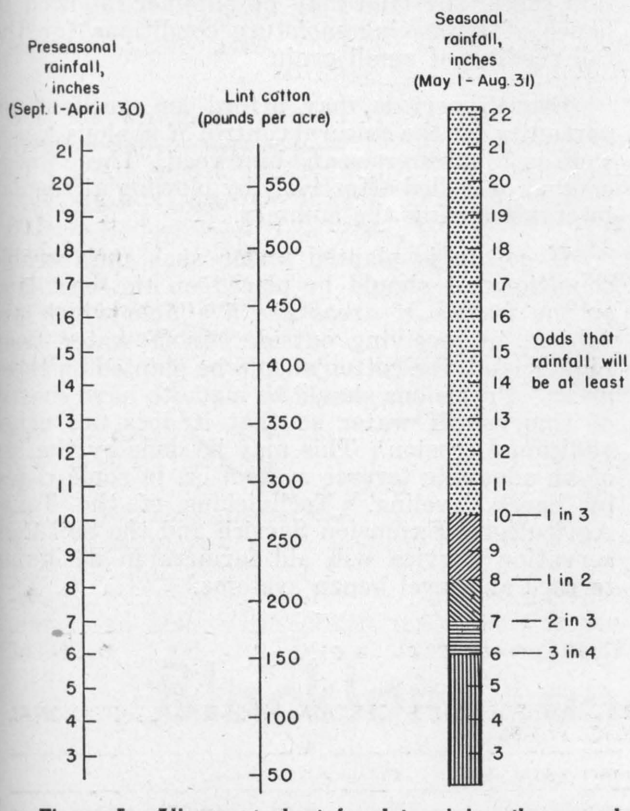

Figure 5. Alignment chart for determining the pounds per acre of lint cotton produced at Lubbock for given amounts of preseasonal and seasonal rainfall. If a ruler or pencil is placed at a point on the preseasonal rainfall column and a point on the seasonal rainfall column, the point where the middle column is crossed will designate the amount of lint cotton produced on the average, for that amount of preseasonal and seasonal rainfall.

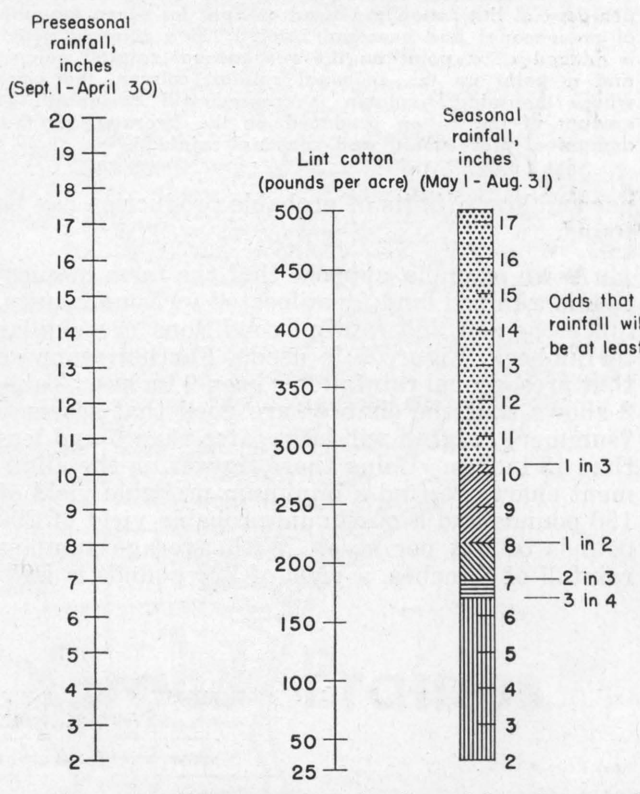

Figure 6. Alignment chart for determining the pounds per acre of lint cotton produced at Big Spring for given amounts of preseasonal and seasonal rainfall. If a ruler or pencil is placed at a point on the preseasonal rainfall column and a point on the seasonal rainfall column, the point where the middle column is crossed will designate the amount of lint cotton produced on the average, for that amount of preseasonal and seasonal rainfall.

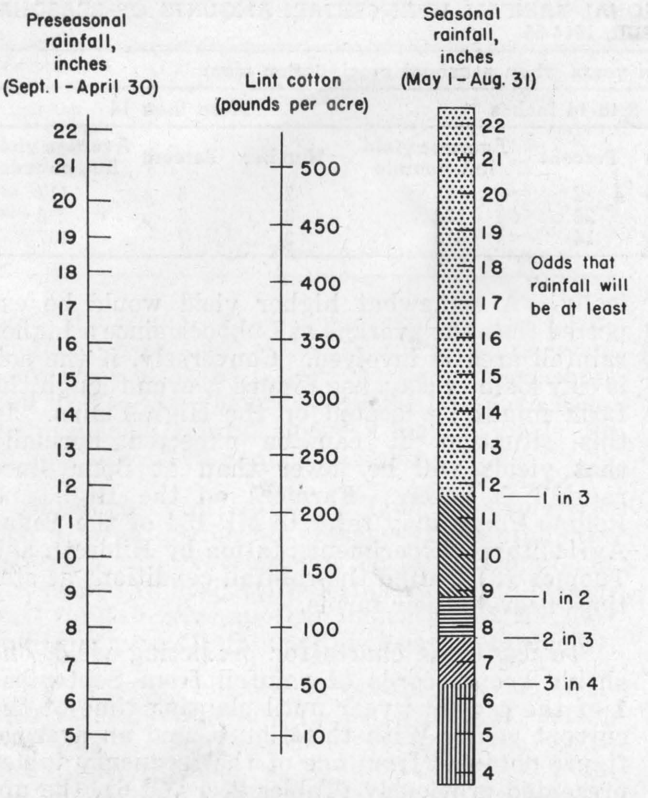

Figure 7. Alignment chart for determining the pounds per acre of lint cotton produced at Spur for given amounts of preseasonal and seasonal rainfall. If a ruler or pencil is placed at a point on the preseasonal rainfall column and a point on the seasonal rainfall column, the point where the middle column is crossed will designate the amount of lint cotton produced on the average, for that amount of preseasonal and seasonal rainfall.

per and lower limits of probable production can be found.

As an example, suppose that the farm in question is a mixed land farm located in Lynn county. Since the soil and rainfall conditions are similar to Lubbock, Figure 5 is used. Further, suppose that preseasonal rainfall has been 9 inches. Table 2 shows that the chances are good that seasonal (summer) rainfall will be greater than 5 and less than 13 inches. Using these figures on the alignment chart, we find a minimum probable yield of 190 pounds and a maximum probable yield of 290 pounds of lint per acre. With average summer rainfall of 8 inches, a yield of 225 pounds is indicated. Under such rainfall conditions, the farmer probably should plan to plant his entire cotton allotment. Suppose, however, that only 3 inches of preseasonal rainfall have been received. The probable limits of production lie between 90 and 190 pounds per acre. Under these conditions, the farmer may wish to place part of his cotton allotment in the government acreage reserve program.

During periods when there are no government restrictions on cotton acreage, knowledge of probable yields will permit farmers to adjust their farming operations to fit the situation. When conditions are not favorable for cotton producton, there are alternative routes for a farmer to follow. Expenses and capital improvements should be held to a minimum. Replacement of machinery should be postponed until the chances for good yields look more favorable. Household expenses my be curtailed by utilizing more farm-produced food.

In some years unfavorable for cotton production, late summer rains may be sufficient to produce a sorghum crop. Since sorghum is cheaper to produce than cotton, it can be used under such conditions, and even under adverse conditions it may produce cover for wind erosion control. Some farmers might want to grow some soil-improving crops on part of their acreage. In certain cases, the land may be summer-fallowed in hopes of improving moisture conditions for the fall seeding of small grain.

Drouth periods may afford an excellent opportunity for the cultural control of noxious weeds such as Johnsongrass and bindweed. These weeds can be controlled effectively by plowing at regular intervals during the summer.

If cotton is planted under such unfavorable conditions, it should be placed on the best land on the farm. If areas are available which are subject to receiving outside runoff water from higher land, the cotton should be planted on these areas. Provisions should be made to have control of this runoff water so that it does not cause additional erosion. This may be done by the use of an adequate terrace system or, in some cases, by bench leveling. Technicians of the Texas Agricultural Extension Service and the Soil Conservation Service will aid farmers in designing terrace and level bench systems.