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KANSAS STATE COLLEGE OF AGRICULTURE
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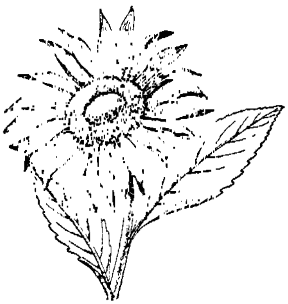
MANHATTAN, KANSAS

SUMMER FALLOW IN KANSAS



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SUMMER FALLOW IN KANSAS[1]

R. I. THROCKMORTON and H. E. MYERS

Summer fallow is the practice of keeping land free of all vegetation throughout one season for the purpose of storing a part of the rainfall of that period in the soil for the use of crops the following year. Summer fallow has been practiced in various parts of the world for several centuries, and to a limited extent in some sections of western United States since the country was settled. It is a common practice in the light-rainfall sections of Canada and of the Pacific Northwest at the present time.

Summer fallowing is needed in those sections of Kansas where the annual rainfall is too low for economical yearly crop production, or where the seasonal distribution of the rainfall is not favorable to the crops otherwise adapted to the region. Under these conditions summer fallow should have a definite place in the agricultural program. The frequency of fallowing should vary with climatic conditions. In some localities, it is necessary to fallow every other year. Under other conditions one year of fallow in three is sufficient, while under conditions of somewhat higher rainfall it is frequently practical to fallow one year out of four.

Summer fallowing is sometimes practiced for the control of bindweed and other noxious weeds, or for the purpose of liberating plant food materials for the following crop. The latter practice is occasionally followed in central and eastern Kansas in preparing land for alfalfa.

Climatic Conditions in Western Kansas

Climatic conditions in western Kansas are such as to favor the use of summer fallow in the production of grain and forage crops. The need of summer fallow cannot be determined by rainfall alone, because it is also influenced by soil conditions, temperatures, wind velocity, and transpiration of water by the plants. The time elapsing between the harvesting of one crop and the seeding of another also is a factor in influencing the need for summer fallow.

The climatic conditions of western Kansas are subject to extremes of temperature and drought. The average annual rainfall in the western half of the state varies from approximately 25 inches in the eastern portion to 15 inches in the western portion, according to average rainfall data shown in Figure 1.

The normal rainfall, however, is not a true measure of the amount of moisture that is available to plants. Figure 2 shows the fluctua-

Acknowledgment: The experimental results from the Colby, Garden City and Hays branch experiment stations were secured in coöperation with the Division of Dry-land Agriculture, Bureau of Plant Industry, United States Department of Agriculture.

1. Contribution No. 313 from the Department of Agronomy.

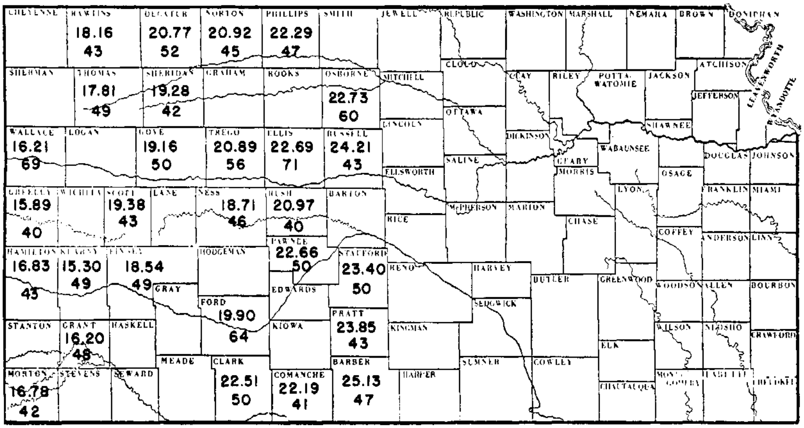

FIG. 1. Average annual rainfall at points in western Kansas. The upper figure denotes the average annual rainfall in inches; the lower figure denotes the number of years of rainfall record. (From the reports of the U. S. Weather Bureau, including data for 1938).

tions in rainfall at Dodge City from 1875 to 1939. It may be noted from this chart that during the 65-year period rainfall was below the average 39 times, and in many instances rainfall was below the average for periods of 2 to 10 years in succession. It is these periods of below normal rainfall that determine the economical production of crops and the need of summer fallow.

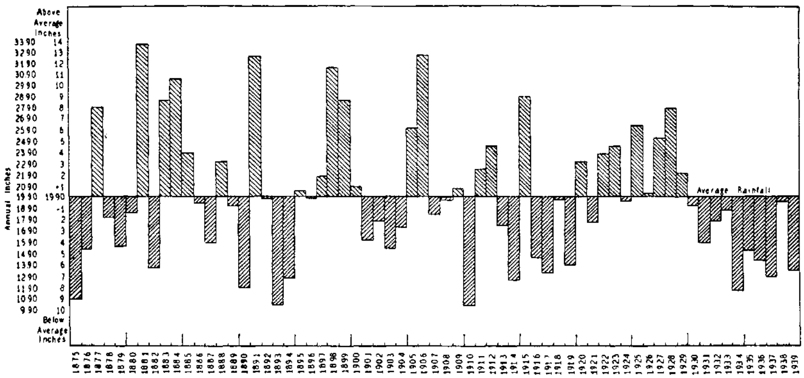

FIG. 2. Departures from average rainfall at Dodge City from 1875 to 1939.

It should also be pointed out in this connection that even the annual rainfall for a given year, particularly under conditions such as exist in the Great Plains, is not an indication of the amount of moisture that will be available to crop plants because much of the rainfall is received either in the form of torrential storms resulting in heavy losses of moisture through surface runoff, or as light showers resulting in a large percentage loss of moisture from the soil by evaporation. Evaporation losses are extremely high throughout the entire western half of the state and are much higher in the southern and low altitude portions of this area than in the northern and high altitude portions, as is indicated by the information presented in Table 1 showing the amount of evaporation from a free water surface at Hays, Colby and Garden City.

TABLE 1. *Seasonal evaporation of water from a free water surface, April to September, inclusive.*

YEAR.	Hays.	Colby.	Garden City.
1908	44.4	....	56.1
1909	47.5	....	51.6
1910	43.8	....	48.4
1911	59.8	....	58.0
1912	47.0	....	53.1
1913	58.3	....	54.5
1914	47.1	33.5	52.7
1915	33.3	31.7	41.8
1916	50.2	45.5	57.5
1917	50.5	38.7	54.8
1918	47.6	41.4	54.1
1919	41.0	39.6	51.5
1920	39.8	33.1	51.2
1921	44.6	39.4	53.4
1922	47.3	42.6	57.5
1923	42.8	37.4	47.9
1924	48.6	45.3	53.3
1925	48.8	49.0	58.8
1926	52.0	49.3	55.9
1927	42.5	43.2	56.6
1928	42.3	40.6	51.0
1929	43.7	41.9	53.9
1930	46.4	40.1	61.6
1931	52.3	44.9	58.7
1932	46.3	46.0	56.6
1933	56.5	45.7	63.9
1934	66.4	57.5	70.5
1935	51.7	47.3	60.8
1936	59.0	50.1	63.4
1937	56.3	45.6	65.4
1938	49.1	43.8	61.3
1939	60.7	51.1	67.5
Average	32 yrs., 49.0	26 yrs., 43.2	32 yrs., 56.4
Average, 1933–39	57.1	48.7	64.7

Under conditions of high temperatures and low humidity, more moisture is required to produce a pound of dry matter in plants than is required under conditions of lower temperatures and higher humidity. Therefore, the amount of moisture required to produce a pound of dry matter under conditions in western Kansas is higher than that required to produce a pound of similar dry matter under eastern Kansas conditions. This means that it actually requires more moisture to produce a given weight of crop in western Kansas than it does in eastern Kansas. Offsetting the higher water requirement of plants growing in light rainfall regions, however, is the tendency of plants to produce a greater production of grain as compared with straw in such regions than under more humid conditions.

High winds, especially when accompanied by high temperatures, result in a rapid rate of transpiration and therefore the loss of large quantities of water from the soil through the plants. Under extreme conditions, the rate of loss of water from plants may be more rapid than the intake of water through the plant roots. Under such conditions plants will first wilt, and this condition may be followed by a destruction of the cells of the plant, and later the death of the plant. This is spoken of as "firing" or "burning" of the plant, and is common during periods of hot winds, especially when the moisture content of the soil is relatively low.

SOIL MOISTURE IN CROP PRODUCTION

The yield of winter wheat in western Kansas is influenced materially by the amount of moisture in the soil at the time the crop is seeded in the fall. The amount of rainfall received between the time of seeding wheat, usually in September, and the time of harvest the following season is not usually sufficient or properly distributed for the production of a profitable yield of grain. Table 2 shows the average annual and monthly distribution of precipitation at Hays, Colby and Garden City. It may be noted from this table that most of the rainfall is received during the months of May, June, July and August. Although May and June rainfall is decidedly beneficial in wheat production, the possibility of producing a satisfactory crop is usually determined previous to these months. The uncertainty of an adequate, well distributed rainfall during these months in most seasons makes the crop partly or wholly dependent upon a reserve supply of water stored in the soil. It is essential, therefore, in wheat production, under such conditions, that the soil be well supplied with moisture at the time the crop is seeded.

Hallsted and Mathews[2] have pointed out that when the soil contains from 1.5 to 2.9 inches of available water at seeding time, there is enough moisture to give wheat a good start but not a sufficient quantity to enable the crop to survive long periods of drought. They found that the ultimate yields, under such conditions, are dependent upon whether conditions following seeding are favorable or unfavorable. In other words, this amount of moisture provides the possibility of producing a crop but not the assurance of a satisfactory

2. Hallsted, A. L., and Mathews, O. R. Soil Moisture and Winter Wheat with Suggestions on Abandonment. Kansas Agr. Exp. Sta. Bul. 273, 1936.

TABLE 2. *Average annual and monthly distribution of precipitation at Hays, Garden City and Colby, Kansas.*

STATION.	Period of years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Average annual precipitation.
Hays	1909–1939	.30	.73	.89	2.04	3.31	3.90	2.55	2.96	2.12	1.30	.94	.57	21.61
Colby	1914–1939	.24	.62	.93	1.86	2.68	2.44	2.59	2.26	1.50	1.09	.60	.51	17.32
Garden City	1913–1939	.26	.54	.78	1.75	2.80	2.58	2.09	2.19	1.93	1.31	.48	.45	17.16

yield. They also found that when the soil contains 3 inches or more of available water at seeding time the probability of a complete crop failure from drought almost disappears and the presence of this amount of available moisture is reasonable assurance of a satisfactory yield except under the most adverse conditions.

Although the quantity of available water expressed in inches in the soil at seeding time is a dependable index of what may be expected in production, it is not easy to make such determinations. For this reason Hallsted and Mathews determined the relation of the depth to which moisture penetrated the soil with the quantity of water in the soil at seeding time, and found the two directly related. They found on the average heavy wheat lands that when the soil was wet to a depth of one foot, the quantity of available water in the soil was less than 2 inches in nearly every case. Where the soil was wet to a depth of 2 feet, the available moisture ranged from slightly under 2 inches to 3.5 inches; and where moisture penetrated to a depth of 3 feet or more, the available moisture content was 3.5 inches or more in all but one instance. A sandy soil wet to a given depth would contain less water than the heavy soils. Such a close correlation was found between the yield of wheat and the depth to which the soil was wet at seeding time that this has since been used as a basis for fairly accurately predicting the possible yield the following season.

The probability of obtaining specified yields of wheat when the soil was dry or wet to designated depths at seeding time is indicated in Table 3, which gives the results compiled by Hallsted and Mathews from the experimental data at Hays, Colby and Garden City.

TABLE 3. *Probabilities of obtaining specified yields of wheat when the soil was dry or wet to designated depths at seeding time, as determined by results from Hays, Colby and Garden City.**

DEPTH TO WHICH SOIL WAS WET.	Failure (4 bus. or less).	10 bushels or more.	20 bushels or more.	30 bushels or more.
Dry	27 in 38 or 71%	7 in 38 or 18%	0 in 38 or 0%	0 in 38 or 0%
1 foot	18 in 53 or 34%	23 in 53 or 43%	10 in 53 or 19%	0 in 53 or 0%
2 feet	5 in 34 or 15%	21 in 34 or 62%	10 in 34 or 29%	3 in 34 or 9%
3 feet or more	6 in 61 or 10%	51 in 61 or 84%	43 in 61 or 70%	14 in 61 or 23%

* From Hallsted and Mathews.

It will be noted from the data presented in Table 3 that when the soil was dry at seeding time, a yield of 4 bushels or less was obtained 71 percent of the time, that yields of 10 bushels or more were obtained only 18 percent of the time, and that in no case were yields of 20 bushels or more obtained. When the soil was wet to a depth of one foot at seeding time the yields produced were 4 bushels or less 34 percent of the time, 10 bushels or more 43 percent of the time, and

20 bushels or more only 19 percent of the time, while in no case was a yield of 30 bushels or more obtained when moisture had penetrated the soil to a depth of only one foot or less at seeding time.

When the soil was wet to a depth of 2 feet at seeding time a yield of 4 bushels or less was secured in only 15 percent of the cases. With this amount of moisture, yields of 10 bushels or more per acre were obtained 62 percent of the time and yields of 20 bushels or more were secured in 29 percent of the cases, while in 9 percent, yields were 30 bushels or more an acre.

When moisture penetrated to a depth of 3 feet or more failures resulted only 10 percent of the time, while yields of 10 bushels or more an acre were secured in 84 percent of the cases. Twenty bushels or more were produced an acre in 70 percent and 30 bushels or more in 23 percent of the cases.

These data show definitely the importance of having a good supply of moisture in the soil at seeding time if satisfactory yields of wheat are to be secured. Furthermore these data leave no doubt that an adequate supply of available water in the soil at seeding time is one of the best assurances of a crop, and that the possibility of obtaining a good crop in spite of poor conditions at seeding time is not likely to be fulfilled.

The uncertainty of the rainfall and the practical certainty of one or more extended drought periods during the growth period in this region makes a reserve supply of soil moisture highly desirable. The greater this reserve of moisture the greater the chance of the crop surviving a drought period. Yield is related to the water used by the crop, and stored water, which will add to the supply available for use, will tend to increase the yield as well as provide water for insurance against drought.

Total Moisture Used for Wheat Production

The total moisture required for the production of a crop includes the moisture used and transpired by the plants during the life of the crop. A portion of this moisture is usually stored in the soil at seeding time and the remainder represents the moisture received between seeding time and harvest. It is almost impossible under field conditions to determine the amount of water that is required to produce a crop. Mathews and Brown[3] consider the quantity of water used during the life of the crop to be the water available in the soil at seeding time expressed in inches plus precipitation from seeding time to harvest. The inches of available water in the soil at seeding time does not refer to the depth of moisture penetration but to the actual inches of available water stored in the soil. An inch of available water will wet a heavy soil to a depth of approximately 6 to 8 inches,

Mathews and Brown, by the use of this method of determining the total water used by wheat, found that at Colby and at Garden City

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3. Mathews, O. R. and Brown, Lindsey A. Winter Wheat and Sorghum Production in the Southern Great Plains under Limited Rainfall. U. S. D. A. Cir. No. 477, 1938.

no profitable yield was obtained over a period of 17 years from the use of less than 10 inches of water. It appears that the wheat crop must use about 10 inches of water before it reaches the point where the production of grain is possible. This seems to hold equally on both cropped and fallowed soil. Therefore an inch of water stored in the soil before seeding as a result of summer fallowing is practically equivalent to an inch of rain falling after the crop is seeded. Mathews and Brown found no yield of as much as 20 bushels an acre from the use of less than 14 inches of water and approximately 17 inches of water were required to produce a 30-bushel yield. At these two stations each inch of water above 10 inches and up to 20 inches produced on an average about 3 to 3½ bushels of wheat an acre. It is evident from these figures that after the minimum water need of the crop is satisfied it requires only a small amount of water to increase materially the yield of grain.

In general the amount of moisture that can be stored in heavy soils between harvest and wheat seeding time in the fall, plus the precipitation during the remainder of the year will not be adequate for the production of satisfactory yields of wheat under conditions of 20 inches or less of average annual rainfall. Even under conditions of 20 to 25 inches of rainfall annually there will be seasons when it will not be possible to store sufficient moisture in the soil between harvest and seeding time to provide the necessary moisture for successful wheat production. This means that for reasonable assurance of a profitable crop, methods must be used whereby the amount of moisture stored in the soil at seeding time will be greater than that usually provided when continuous crop production is practiced. Summer fallowing will aid in accomplishing this end but the total storage of water as a result of fallowing usually is not large in proportion to the total precipitation during the fallow period. It has already been stated, however, that it does not require a large quantity of available water above the minimum for crop production, to produce relatively satisfactory yields.

SEEDBED PREPARATION AND MOISTURE STORAGE

The average rainfall at all points in western Kansas is adequate for successful crop production if all of it could be used by the crop. Unfortunately much of the moisture is lost and plants do not have an opportunity to use it. Losses of moisture are due to evaporation, runoff and removal by weeds and crop plants. Evaporation losses are about as great or greater than those resulting from either of the other factors and unfortunately there is no practical means available whereby this loss may be materially reduced. The loss due to weed growth can be controlled by good tillage practices. If weeds are permitted to grow on land that is being prepared for a crop or on fallow or early prepared land they may exhaust the soil of available water previous to wheat seeding time. Losses due to runoff may be materially reduced by proper tillage and soil management practices which are discussed under methods of fallowing.

The time and method of preparing the seedbed under continuous cropping will have some influence on the amount of available moisture in the soil at seeding time. It is evident from the results given in Table 4 that early preparation of the seedbed for wheat is essential for moisture storage and that if a relatively large quantity of water is to be stored it is necessary to fallow for a year. When the seedbed is prepared by late tillage a portion of the precipitation is lost through weed growth and a portion is lost by runoff. Early tillage followed by sufficient cultivation to prevent weed growth and to keep the surface soil rough and in good condition to absorb water are essential for maximum storage of water between harvest and seeding time when wheat follows wheat in the cropping system.

TABLE 4. *Effect of time of seedbed preparation on the quantity of available water in the soil at wheat seeding time.**

Location.	Number of years.	Average inches of available water at seeding time.		
		Late plowed.	Early plowed.	Fallowed.
Hays	23	1.54	2.90	7.96
Colby	19	1.05	1.47	5.16
Garden City	13	0.44	1.08	4.67

The data presented in Table 4 show that fallow is effective in increasing the amount of moisture in the soil at seeding time. It is apparent, however, that there has been a heavy loss of moisture under favorable conditions or otherwise the total amount of available water present under fallow would be far in excess of the amount stated. These losses are due to evaporation and runoff. As much as 60 to 75 percent of the precipitation received during a year of fallow may be lost by evaporation alone. Fallow is extravagant in so far as storage of total precipitation is concerned, but is essential as a means of stabilizing production through having sufficient moisture in the soil at seeding time to justify the seeding of a crop.

Necessity of Soil Moisture at Seeding Time

The amount of available water in a soil at seeding time, has on the average, borne a close relationship to the yields of wheat obtained the following season. The relationship between the amount of available moisture in the soil at seeding time and the yield of wheat is shown in Table 5.

Late plowing or otherwise late preparing of the seedbed for wheat usually results in a small amount of available water in the soil at

* From Hallsted and Mathews.

TABLE 5. *Relation of available moisture to wheat yields.**

STATION.	Number of years.	Available water at seeding time.			Yield per acre.		
		Late plowed.	Early plowed	Fal-lowed.	Late plowed.	Early plowed.	Fal-lowed.
		Ins.	*Ins.*	*Ins.*	*Bus.*	*Bus.*	*Bus.*
Hays.........	23	1.54	2.90	7.96	10.0	17.4	27.3
Colby.........	19	1.05	1.47	5.16	9.4	8.8	18.8
Garden City...	13	0.44	1.08	4.67	5.9	8.2	15.5

seeding time and a correspondingly low yield the following season. It is only during exceptionally favorable seasons that high yields will be received on late-prepared lands.

Early preparation of the seedbed at Hays has resulted in the storage of sufficient available moisture to give the wheat crop a good start in most years. Early preparation was not found effective in storing water at Garden City in all years but was effective in increasing the yields materially in years when a relatively large quantity of water was stored. It is interesting to note in this connection that at Garden City early preparation of the seedbed resulted in an average increase in the yield of wheat but did not materially reduce the danger of crop failure. Early preparation of the land for wheat at Colby increased the average quantity of available water but did not increase the average yield or influence the frequency of failure.

The results secured at Hays, Colby and Garden City indicate that early preparation of the seedbed for wheat in continuous wheat production at Hays is about as effective in increasing crop production at that station as is alternate crop and fallow at Colby and Garden City.

It is evident from the data presented in Table 5 that in much of western Kansas the amount of moisture stored in the soil between the time of harvesting one crop and seeding another is not sufficient to meet the demands of the crop and that fallowing a portion of the land will assist materially in meeting the moisture requirement.

METHODS OF FALLOW FOR WHEAT

A good summer fallow is one in which the soil is free of all growing plants throughout the fallow period and has a rough open surface which will permit a ready and rapid penetration of moisture. Under such a condition no water will be lost through weeds and a minimum amount will be lost by runoff, hence the maximum amount will be stored in the soil. The fallow should be managed in the best possible manner to prevent soil erosion by wind or water. A poor fallow may be subject to erosion but fallow that is properly managed is one of the most effective means of checking erosion by wind.

The implements used in cultivating fallow land during the summer should eradicate all weeds at each tillage operation, thus making

* From Hallsted and Mathews.

frequent cultivations unnecessary. The number of tillage operations necessary during the season will be determined largely by climatic conditions but should be only enough to prevent weed growth and to maintain a rough cloddy condition of the surface soil. Excessively frequent tillage, especially when the soil is dry, tends to produce a fine dust-like condition of the surface which is undesirable because it encourages loss of water by runoff. Insofar as possible, fallow land should be cultivated when the soil is in condition to form clods.

The condition developed by the implements in cultivating fallow is more important than the implement used. In general, such im-

—Photograph Courtesy Soil Conservation Service, U. S. D. A.

FIG. 3. Finely pulverized soil will prevent a ready penetration of rainfall. Such soils are also subject to blowing.

plements as the rotary rod weeder, duckfoot cultivator, and spring-tooth harrow are much safer to use in cultivating fallow than are the disk-types. However, if the soil can be cultivated at the right moisture content and the implements are properly adjusted the disk types may be used effectively. The use of the disk type of implements on dry soil and of the smoothing harrow under almost any condition tends to destroy clods and leave a smooth fine surface which retards the absorption of moisture and increases the hazard of erosion by both wind and water.

Summer fallow frequently fails to be effective in storing moisture because tillage is delayed until after the moisture from spring rains is used by weeds or because weeds are permitted to grow during the summer. Weeds must be eradicated when they are small if moisture is to be conserved. Cultivation for fallow should start just as soon as weeds begin to grow.

—*Photograph Courtesy Soil Conservation Service, U. S. D. A.*

FIG. 4. A coarse, cloddy surface with plant residue, such as this alternate crop and fallow field, is a desirable condition for fallow ground.

The method to be used in fallowing will vary with soil and climatic conditions. It should, however, be a method that will offer maximum protection against water and wind erosion and at the same time store a maximum amount of water. Different methods of fallowing have been tested at Hays, Colby and Garden City for several years. The results of these experiments are given in Table 6.

TABLE 6. *Effect of methods of fallow for winter wheat upon yield.*

STATION.	Years.	Average yield of wheat, bushels per acre.				
		Early fall plowed. Replowed in June.	Late fall plowed.	Late fall listed.	Plowed in May.	Plowed in June.
Hays	1914-39	24.5	24.5	25.7	25.3	22.5
Garden City	1914-39	13.2	12.2	13.6	10.9	8.1
Colby	1922-39	14.2	15.8	17.0	15.4	11.5

The results of the experiment at Hays indicate that the average yield of wheat on fallow will not vary materially whether the fallow period is started in the early fall, late fall, or May of the following season. However, when the first tillage is postponed until June the average yield is reduced. This reduction is due largely to the loss of moisture resulting from weed growth.

At Garden City, the highest average yield was secured when the land to be fallowed was listed deep in the late fall and left rough throughout the winter. Plowing in May, at Garden City, was much less effective than fall plowing while June plowing was relatively low in effectiveness.

Late fall listing was the most effective time and method of starting fallow at Colby. Late fall plowing and May plowing were practically equal in effectiveness. When plowing for fallow was delayed until in June, wheat yields were materially reduced.

These results indicate that at Hays the most practical method of fallowing is that of postponing the first tillage until weed growth starts in the spring, while at Garden City and Colby it is more desirable to start the fallow by listing deep in the fall. However, if the soil is dry and susceptible to wind erosion the stubble of the previous crop should not be disturbed until about May. When tillage for fallow is started in May the number of operations will usually be at least one less than when tillage is started in the fall.

During years of heavy rainfall in the late summer and fall months deep fall listing is usually desirable. In the southern part of the area it may be necessary some years to destroy the weeds during the late summer on land to be fallowed by use of a disk or duckfoot type of implement. It is seldom that climatic conditions make this a desirable practice in the northern portion of the region.

When wheat stubble land is to be fallowed the most practical method under most conditions is to leave the stubble of the preceding crop on the land during the winter and spring to protect the soil against wind action. The field should then be cultivated with the one-way, disk, or duckfoot, as soon as weeds start to grow in the spring. As soon as the second growth of weeds starts, and not later than the middle of May, the land should be plowed or listed. Plowed land may be cultivated with the springtooth harrow, duckfoot cultivator, or rotary rod weeder throughout the summer to prevent weed growth and maintain a cloddy condition of the surface. The use of the rotary rod weeder should be alternated with a shovel or springtooth type of tool since the continuous use of the rod weeder alone results in the formation of a compact layer at the depth to which the rod operates. The shovel cultivator eliminates the compact layer, after which the rod weeder may be again used. If the land is listed it may be cultivated with the lister cultivator or with the duckfoot cultivator. The lister ridges should be practically eliminated by the first of August.

Basin listers and basin cultivators are coming into use in some localities and may be used effectively on fallow land. Basin-listed land may be cultivated in the same manner as other listed land or the basins may be reformed by splitting the lister ridges with the basin lister at the second cultivation. Basin-listed land should, insofar as possible, be cultivated with shovel and springtooth types of implements. When basin forming types of implements are used it is essential that all weed growth be controlled.

Land to be fallowed for wheat following sorghums can usually be tilled to best advantage and with a minimum danger of erosion by wind if it is listed deep during the latter part of November or in December. The tillage operations during the following summer should be the same as those recommended for summer tillage of fall or spring listed wheat stubble.

RELATION OF MOISTURE IN SOIL AT SEEDING TIME TO THE YIELDS OF SORGHUMS

The sorghums make most of their growth during midsummer or during the period of heaviest rainfall. However, this is the period of highest transpiration when the plants use a large quantity of water and also the period of heaviest losses through evaporation. These losses tend to counteract the effects of the heaviest rainfall during the growing period of the crop, and emphasize the importance of a good supply of available soil moisture at the time the sorghums are planted. A good stand of sorghums will remove more moisture from the soil during the growing period than is supplied by a normal rainfall during that period.

In central Kansas, under conditions of 20 to 25 inches of rainfall, there is frequently sufficient annual precipitation for sorghum production. However, during occasional seasons, under such conditions, sorghums will fail because of the lack of available moisture. In the western part of the state where the average annual precipitation varies from 15 to 20 inches, sufficient moisture is usually not stored in the soil during the growing season to meet the requirements of the plants, and therefore practices should be followed which will store moisture previous to the time of planting the sorghums. Under most such conditions the only practical method of such storage is through summer fallow.

FALLOW METHODS FOR SORGHUMS

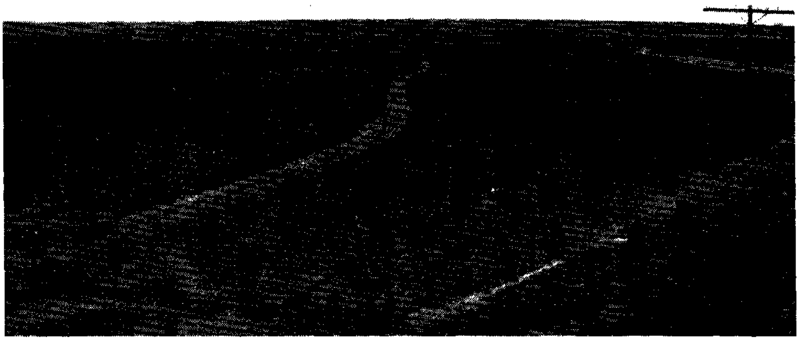
It is more difficult to manage fallow for sorghum production than for the production of wheat. This is due primarily to the differences in the growing season of the two crops and the fact that fallow for sorghums is exposed to the action of wind and water for a longer period of time.

In the northern and central counties when land that has previously been in a small grain crop is to be fallowed for sorghums the stubble should be left standing until weed growth starts in the spring. In the southern counties standing stubble in the winter is also desirable but weed growth in the fall reduces the effectiveness of the fallow to a greater extent in this area. In the southern area tillage of stubble land after wheat harvest in preparation for the fallow is desirable in those years when there is sufficient rainfall to cause weed growth. After weed growth starts in the spring tillage should be started and it should be repeated frequently enough during the summer to prevent weed growth. During the late fall or early winter the land should be strip-listed deep at intervalsof 1 to 2 rods if it is susceptible to erosion by wind, otherwise it should be left rough until spring. If blowing starts or the soil mellows to a fine condition more furrows should be put in as needed. One or more cultivations are nearly always necessary in the spring to control weeds previous to planting. Planting should be done in the usual manner on a weed-free seedbed.

Land that has produced a sorghum crop should be listed deep in the fall after sorghum harvest, if the soil is susceptible to blowing, and should then be managed in the same manner as fallow wheat land during the following summer and fall.

Contour Tillage of Fallow

Since the primary objective of fallowing is to increase the amount of available moisture in the soil, all soil management methods should be directed toward moisture conservation. Losses of water by runoff may be extremely heavy during the fallow period on poorly tilled land, but contour tillage will aid materially in decreasing such losses. For this reason tillage operations should be on the contour on all land except that which is level. Nearly level areas can be contoured easily and frequently with better results than where the land has considerable slope.

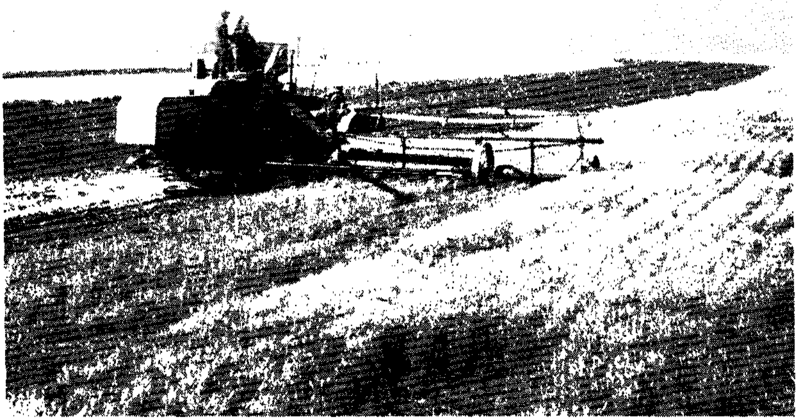


—Photograph Courtesy Soil Conservation Service, U. S. D. A.

FIG. 5. A combination of low terraces and contour tillage aids materially in moisture conservation.

When the basin forming types of implements are used it is more necessary to cultivate on the contour except on land that is practically level. If these implements are operated up and down the slope, water may collect sufficiently to break over the dams at the upper end of the furrows during a period of heavy rainfall and wash out all of the dams farther down the slope and result in the loss of much water and soil.

In those areas where the soils are subject to wind erosion it may be advisable to fallow in strips on the contour, that is, divide the field into several strips and crop and fallow the alternating strips, respectively. This system results in a minimum amount of soil being exposed to the wind each year and if well managed will practically prevent soil blowing except during a period of severe drought lasting for two or more years. When land is practically level and has a gentle elope to the north or south, the strips may be run east, and west and thus offer protection against wind erosion. In general, however, the strips should be on the contour.



—Photograph Courtesy Soil Conservation Service, U. S. D. A.

FIG. 6. Strip cropping with alternate wheat and fallow on the contour.

INFLUENCE OF FALLOW ON CROP PRODUCTION

Fallowing influences crop production primarily in three ways. It results in higher annual acre yields than can be obtained on continuously cropped land, it reduces the frequency of crop failure, and it stabilizes total production. It stabilizes production because its use results in a higher total production during the less favorable years and a lower total production during favorable seasons. In addition the quality of the crop is usually higher on fallowed land than on continuously cropped land. Fallowing also makes possible a better distribution of farm labor and more timely tillage operations.

It is not necessary for crop yields to be doubled as a result of fallowing for the practice to be a profitable one. The cost of seeding and harvesting one-half of a given acreage each year is far less than the cost of seeding and harvesting the entire acreage.

Effect of Fallow on Wheat Yields

The average yields of wheat on fallowed land over a period of several years in comparison with the yield under continuous wheat are given in Table 7.

TABLE 7. *Influence of fallow on yield of winter wheat.*

LOCATION.	Period of years.	Average yield in bus. per acre.	
		Continuous wheat.	Wheat after fallow.
Hays	1908–39	16.7	23.5
Colby	1915–39	8.4	15.7
Garden City	1910–39[1]	5.7	9.0
Tribune	1924–31[2]	9.8[3]	18.4

1. Except 1922 when wind mixed the bundles of the several plots.
2. Except 1925 when rabbits damaged the fallow plot.
3. Wheat after corn.

Wheat yields were practically doubled at all points except Hays by the use of fallow. At Tribune wheat is not produced continuously but is grown in rotation with corn and it will be noted that the yield of wheat on fallow was almost twice the crop following corn in the rotation. Results at the other stations indicate that wheat after corn yields practically the same as wheat after wheat grown continuously.

There is evidence to indicate that with more than 20 inches of annual rainfall fallow may have some residual effect on the second or third crop after the fallow. Under such conditions the frequency of fallowing may be reduced especially in those localities where the soils are deep and have a high water holding capacity.

Experimental results secured at the Hays, Colby and Garden City Branch Experiment Stations and presented in Table 8 show that there is a residual effect of fallow at Hays which influences at least the second crop of wheat and possibly has some influence on the third crop. No residual effect of the fallow has been noted at Colby and Garden City.

The results of these experiments indicate the importance of an alternate crop and fallow system in the western part of the state and of a system with less frequent fallow farther east, one year of fallow followed by three crop years, for example, as far east as Hays.

TABLE 8. *Residual effect of fallow.*

STATION.	Period of years.	Cropping system.	Crop.	Average yield in bushels per acre.			
				Continuous cropping.	First year after fallow.	Second year after fallow.	Third year after fallow.
Hays	1918–1939	Fallow, wheat, wheat, wheat	Wheat	17.2	25.0	19.8	18.6
Colby	1915–1939	Fallow, spring wheat, oats	Oats	15.5	7.2[1]	16.0	....
Garden City	1914–1939	Kafir, fallow, wheat, wheat	Wheat	6.2	8.7	5.6	....

1. Yield of spring wheat.

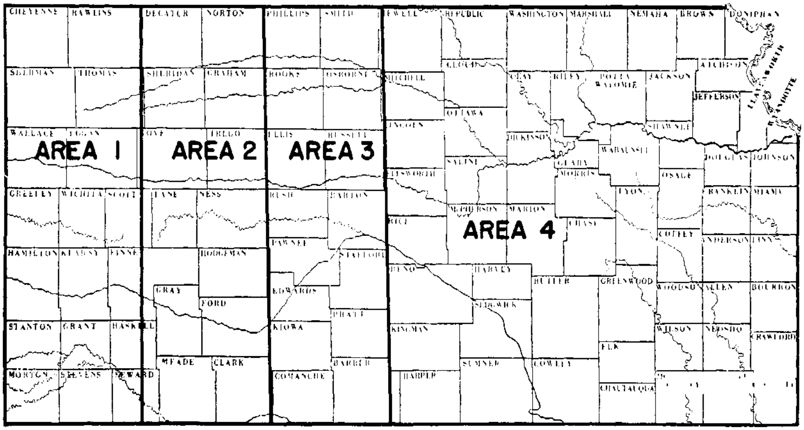


FIG. 7. Fallow areas of Kansas on heavy soils. Area 1, alternate crop and fallow. Area 2, fallow followed by two years of cropping. Area 3, fallow followed by three years of cropping. Area 4, fallow not generally recommended.

Influence of Fallow on Frequency of Wheat Failure

One of the most important reasons for fallowing is that it stabilizes production by reducing the number of crop failures. Table 9 gives the number of failures (less than 5 bushels per acre) of wheat on fallow and wheat on cropped land at Hays, Colby and Garden City.

TABLE 9. *Influence of fallow in reducing wheat failures.*

STATION.	Number of years.	Number of times wheat yields were less than 5 bushels per acre on—	
		Annually cropped land.	Alternate crop and fallow.
Hays	31	7	3
Colby	25	10	8
Garden City	27	17	13

The use of fallow will not prevent crop failures in western Kansas but it is evident from the data presented that it will materially reduce the frequency of failure. At Garden City where continuous wheat failed to produce at least five bushels an acre during 17 years out of the 27 over which the experiment has extended it is evident that failures are too frequent to justify trying to grow wheat continuously in that locality. The fallow reduced the frequency of failure but the crop failed almost 50 percent of the time on fallow land. This means that the best methods of fallowing should be practiced and that wheat should not be seeded even on fallowed land unless there is a good supply of available moisture in the soil at seeding time.

The fallow is of sufficient importance in aiding the stabilization of wheat production in the western one-half of the state that a portion of the cultivated land should be in fallow each year. This applies to years of high yield as well as to those of low production, and to years of high soil moisture content at seeding time as well as years when the moisture content is low. Some of the greatest responses from fallowing occur in the dry years following years of relatively high rainfall. The practice of seeding every acre of land to wheat during favorable seasons and not reserving some land for fallow is not sound. If, during those years when the soil is well supplied with moisture in the fall, all of the crop land is seeded, an over-production will frequently result the following season and if during that season the rainfall is normal or below normal conditions will not be favorable for seeding in the fall because no land will have been fallowed.

Influence of Fallow on Sorghum Yields

The sorghums have been thought of as drought resisting or drought escaping crops for so long that fern people give consideration to the value of fallow in the production of the sorghums for grain or forage. However, in general, the sorghums respond more favorably to fallow than does wheat.

The results given in Table 10 show the practical value of fallow in the production of the grain sorghums. The data indicate that milo responds more profitably to fallow than does kafir although there was little difference at Colby.

TABLE 10. *Influence of fallow on yields of sorghum grain.*

STATION.	Period of time.	Yield in bushels per acre.			
		Milo.		Kafir.	
		Continuous production.	On fallow.	Continuous production.	On fallow.
Hays	1914–39	14.9	31.2	16.2	28.2
Colby	1915–39	10.2	21.6	8.0	17.9
Garden City	1921–39	11.9	27.8	....	....
Garden City	1914–39	....	....	14.0	20.3

The frequency of failure for both milo and kafir grain is materially reduced by growing the crops on fallowed soil as indicated by the data given in Table 11. Fallow is more effective for sorghums than for wheat in this respect. Fallow has reduced the number of yields below 10 bushels an acre 44 percent in the case of milo and 35 percent in the case of kafir.

Failure to produce adequate roughage for livestock is sometimes more disastrous than failure to produce a grain crop. The fallow has materially increased the yield of kafir stover at the Hays, Colby and Garden City Branch Experiment Stations and the yield of Sudan hay at the Tribune station as indicated by the data in Table 12. No experimental results are available for forage sorghums other than Sudan but probably they can be expected to give essentially the same response as the kafir stover.

The practice of utilizing fallowed soil for Sudan grass pasture is encouraged. By this practice many farms now practically devoid of permanent pasture grass could return to a livestock system and those farms with a large pasture area but of low carrying capacity could profitably supplement the native grass.

TABLE 11. *Influence of fallow on frequency of grain sorghum failures.*

STATION.	Number of years.	Number of times sorghum yields were less than 10 bushels per acre on—			
		Milo.		Kafir.	
		Cropped land.	Fallow.	Cropped land.	Fallow.
Hays	30	18	11	15	12
Colby	25	16	7	19	10
Garden City	Milo, 19 Kafir, 26	11	7	14	9

TABLE 12. *Influence of fallow on the yield of sorghum forage.*

STATION.	Period of time.	Yield in pounds per acre.			
		Kafir stover.		Sudan grass hay.	
		Continuous production.	On fallow.	Continuous production.	On fallow.
Hays	1914–39	3,727	5,825	....	....
Colby	1915–39	2,669	4,941	....	....
Garden City	1914–39	2,613	3,679	....	....
Tribune	1923–31	....	....	1,718	3,437

On the heavy soils in central and western Kansas at least a part of the sorghums should be planted on fallow land each year to assist in stabilizing feed supplies and grain production. The increase resulting from fallowing for sorghum production is sufficient to justify planting sorghums only on fallow on these soils.

At Hays and Garden City the grain sorghums produced yields of more than 10 bushels an acre two-thirds of the time on fallow land and only about one-half of the time on cropped land. Yields of less than 10 bushels an acre were produced by milo and kafir only about one-half as frequently on fallowed land as on cropped land at Colby. The fallow has been effective at all three stations in stabilizing the production of grain sorghums.

The data presented in Table 13 show that failure of the sorghums to produce satisfactory yields of stover is materially reduced by use of the fallow, and that fallow should be considered a practical method of stabilizing the production of feed crops.

TABLE 13. *Influence of fallow on frequency of failure of sorghums to produce stover.*

STATION.	Number of years.	Number of times kafir produced yields of less than 3,000 pounds of stover per acre.	
		Cropped land.	Fallow.
Hays	30	10	4
Colby	25	14	8
Garden City	26	17	10

FALLOW FOR BARLEY, OATS AND CORN

Fallow is commonly used in connection with wheat production, is used occasionally in sorghum production, but is seldom considered in the production of barley, oats and corn. These crops have been produced on fallow in comparison with continuous cropping at Hays, Colby and Tribune.

The barley grown on continuously cropped land followed kafir at Hays and corn at Colby and Tribune. Oats on cropped land followed corn at all three of the stations. It is evident from the experimental results presented in Table 14 that when oats and barley are to be grown as far west as Colby or Tribune it is advisable to seed much of the crop on fallowed land. Fallow has had less influence on the yield of oats and barley at Hays than at Colby, Tribune and Garden City. However, since barley and oat failures have been only about one-half as frequent on fallow as on cropped land at Hays (see Table 15) at least a portion of the acreage seeded to these crops might well be on fallow as a means of stabilizing feed supplies and producing higher quality grain.

TABLE 14. *Influence of fallow on yields of barley and oats.*

STATION.	Average yield in bushels per acre.					
	Barley.			Oats.		
	Period of time.	Fallow.	Cropped land.	Period of time.	Fallow.	Cropped land.
Hays	1908-39	26.3	18.5	1908-39	32.9	22.8
Colby	1915-39	27.5	16.1	1915-39	25.2	15.5
Tribune	1924-31	23.7	10.2	1923-31	35.0	14.4
Garden City	1909-20	12.2	7.0	1909-20	15.6	10.0

TABLE 15. *Influence of fallow on frequency of failure of barley and oats.*

STATION.	Number of years.	Number of failures (less than 10 bushels per acre).			
		Barley.		Oats.	
		Fallow.	Cropped land.	Fallow.	Cropped land.
Hays	30	6	10	6	10
Colby	25	9	13	9	15
Garden City	12	4	8	5	7

Wide-spaced Row Crops versus Fallow

The wide spacing of row crops especially on the more sandy soils is sometimes used as a substitute for fallow. Although this practice of spacing the rows of corn and sorghum sufficiently far apart—80 to 120 inches—to permit tillage between the rows throughout the summer and to permit drilling wheat between the rows has given good results on the lighter soils it has not proved to be well adapted to the heavier soils of western Kansas. In practicing wide spacing of row crops some farmers plant two rows and then skip two rows while others may plant two rows and skip four.

The effect of wide spacing of row crops on the yield of following crops has been studied at the Hays, Garden City and Colby branch stations. The results are given in Table 16.

The 80-inch spacing of corn resulted in a satisfactory increase in the yield of the following crop of wheat at Hays and Colby. However, it will be noted that the yields of grain were materially below those resulting from summer fallowing. The 80-inch spacing of kafir or milo resulted in some increase in the yield of the following wheat crop in comparison with the yield under normal spacing. The aver-

TABLE 16. *Influence of wide spaced row crops on the yield of the following wheat crop.*

STATION.	Period.	Average yield of wheat, bushels per acre, after—						
		Corn.		Kafir at Hays and Colby; Milo at Garden City			Contin-uous wheat.	Fallow.
		40″ rows.	80″ rows.	40″ rows.	80″ rows.	120″ rows.		
Hays[1]	1924–39	17.9	21.6	12.1	16.1	....	15.6	26.1
Hays[2]	1924–39	16.3	20.1	9.7	13.3	....	....	....
Colby	1917–39	7.7	10.3	....	....	....	8.3	15.1
Garden City	1928–39	....	....	3.0	7.1	10.3	4.8	10.5

1. Stalks removed.
2. Stalks left standing.

age yields, however, were far below those obtained by fallowing. At Garden City the 120-inch spacing resulted in practically the same yield of wheat as on fallow. The information available indicates that the wide spacing of corn might be considered as a partial substitute for fallow in those areas where corn can be produced successfully. It also indicates that the 80-inch spacing of sorghum cannot be considered as a partial substitute for fallow and that when the kafir rows are 80 inches apart the yields of wheat following the kafir will, in general, be about the same as those obtained when wheat is grown continuously. Spacings greater than 80 inches for the row crop will result in wheat yields approximating those on fallow.

At Hays the average yield of both corn and kafir was lower when the crop was grown in 80-inch rows than when grown in 40-inch rows. At Tribune and at Garden City the average yield of the wide-spaced row crop was as great or greater than the yield of the ordinary spaced crop. This probably means that in southwestern Kansas where crop conditions are quite adverse the wide spacing will result in at least as large a yield of row crop as if it were planted in 40-inch rows.

Influence of Soil Type on Value of Fallow

As has previously been indicated, the value of fallow is influenced materially by the nature of the soil and its depth. The value of fallow is determined by the amount of moisture stored in the soil during the fallow period. Sands, loamy sands and light sandy loams have low water holding capacities and therefore the amount of water that can be stored in such soils is relatively small. The light sandy soils also permit ready penetration of moisture and thus most of the rainfall received during the growing season becomes available to plants. For these reasons, fallowing, in general, is not practical on such soils except where they have a relatively heavy subsoil.

Soils that are shallow have a limited water holding capacity and for this reason usually cannot be fallowed economically. If the fallow is to be successful in storing moisture the soil must be favorable for moisture storage to a depth of three feet or more.

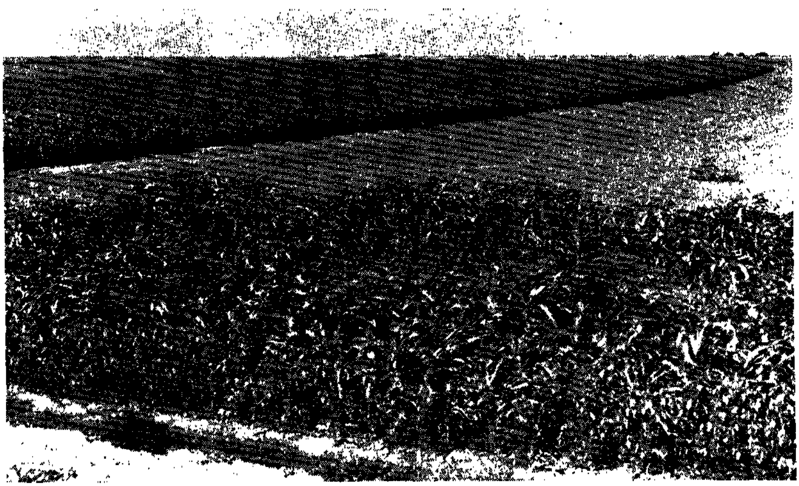
Soil types that occupy a hilly, rolling or steeply sloping topography cannot be fallowed as successfully as can those with a more level topography because of the loss of water by runoff. When soils so situated are fallowed they should be cultivated on the contour and under some conditions should be terraced or strip cropped.

PLACE OF FALLOW IN THE CROPPING SYSTEM

Definite cropping systems are seldom used in central and western Kansas. Some fields are commonly seeded to wheat for many years in succession while others are used for the production of feed crops year after year. By the introduction of fallow a good cropping system can be adapted to most farms. In the extreme western part of the state including about two tiers of counties all crops should be alternated with summer fallow. Thus the cropping systems would become wheat, fallow, sorghum and fallow.

Farther east, a year of sorghum followed by fallow and then one, two or more years of wheat, depending upon rainfall, can be used to advantage on many farms. Even under the latter condition some of the fallowed land should be used for the production of feed crops.

When strip cropping is practiced the danger of grasshopper damage may be increased when wheat is seeded in a strip adjacent to a wheat stubble strip due to an increase in the length of border. How-



—Photograph Courtesy Soil Conservation Service, U. S. D. A.

FIG. 8. A field stripped on the contour with sorghum and fallow. The fallow strip can be planted to wheat with minimum danger of grasshopper damage.

ever, when wheat is seeded against a sorghum strip the danger of grasshopper damage is reduced. Therefore, in those sections where alternate crop and fallow is practiced the danger from grasshoppers can be reduced by strip fallowing for wheat with growing sorghums in one field and fallow for sorghum with wheat in another field. By following such a system sorghum would occupy the same strip every second year. Likewise wheat would be planted on the same strips every two years.

Influence of Fallow on Soil Fertility Losses

It has been contended by some that fallowing is more destructive of soil fertility than is continuous wheat, but experimental results do not substantiate this contention.

The effect of summer fallow on soil fertility has been studied at the Hays, Colby and Garden City Branch Experiment Stations over a period of 22 years. The change in the total nitrogen content of the soil was taken as a measure of fertility loss. The nitrogen content of a soil is a part of the soil organic matter and bears a rather definite relationship to it. The percentage losses of nitrogen at the several stations for two cropping systems are shown in Table 17.

TABLE 17. *Influence of fallow on the nitrogen change in dry land soils.*

Cropping System.	Percentage loss 1916–1938.		
	Hays.	Colby.	Garden City.
Continuous small grain	12.8	12.8	9.9
Alternate small grain and fallow	13.4	13.7	9.8

The plots on which the alternate small grain and fallow cropping plan has been used have shown practically the same to only slightly greater losses of nitrogen than those on which small grains have been grown continuously. A study of the results from a large number of other cropping systems shows that continuous small grain production is the least destructive method of cropping that can be practiced on the dry land farms of western Kansas. Therefore, it appears that a good system of fallow used with the cereal crops will not result in a marked acceleration in fertility loss.

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