FURROW DAMS FOR CONSERVING RAINWATER IN A SEMIARID CLIMATE

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ABSTRACT

A tillage technique of using furrow dams during the crop growing seasons has significantly increased dryland crop yields. Small earth dams are constructed in the furrows after crops are planted to hold excess rainfall and prevent runoff. Results from 5 years of research indicate that furrow dams increased yields of dryland sorghum from 1,420 kg/ha for normal sloping areas to 1,650 kg/ha for areas with furrow dams. Not only are yields increased, but erosion has been reduced and soil water storage increased. Rainstorms of up to 15 cm have been retained on a 10% slope with no erosion or water loss.

INTRODUCTION

Yields of dryland crops in semiarid climates are extremely dependent on available water. Many water conservation practices have been used through the years in attempts to increase crop production in the semiarid Southern Great Plains. The only practice that has substantially increased crop production is the use of supplemental water through irrigation. However, many areas do not have water available for irrigation and must rely solely on rainfall.

Several million acres in dryland wheat, sorghum, and cotton are grown in the Southern Great Plains. In Texas, about 3.5 million hectares of these crops are grown without irrigation each year. Even a modest increase in dryland crop yields could have a tremendous effect on total production for the region and nation because of the large area involved.

Many of the crop production practices used today were developed in the late 1930's and early 1940's in response to "dustbowl" conditions. These practices were designed primarily for wind erosion control. Moisture conservation was not the primary concern at that time. Conservation tillage practices such as stubble mulching were encouraged because they provided protection from both wind and water erosion.

Frequently, precipitation during crop growing seasons plus water stored in the soil does not provide adequate water to sustain the crops. To increase soil water available for crop production, a fallow period between crops has been used. In the Central and Northern Great Plains, wheat yields on fallow areas are more than double those on annually-cropped areas, thus grain yields on a total area basis are increased by fallowing. However, in the Southern Great Plains, wheat yields after fallow are about 1.5 times those on annually-cropped areas. Hence, on a total area basis, wheat yields are lowered by fallowing.

Level terraces and contour planting have been used in the Southern Great Plains to control water erosion as well as to hold and trap runoff for increased soil water storage. However, with level terraces runoff water is concentrated on a small percentage of the terrace interval and crops are often drowned.

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Data from areas that have been leveled to prevent storm runoff show the benefit of keeping rainwater where it falls. Cotton yields at Spur, Texas, were increased from 134 kg/ha to 211 kg/ha when all runoff was held in place on closed level areas (Fisher and Burnett, 1953). Average grain sorghum yields for 14 yr were increased from 1,240 kg/ha for 1% sloping plots to 1,780 kg/ha for level plots at Bushland, Texas (Jones, 1975). However, leveling large areas is expensive and sometimes not practical because of shallow soils or steep slopes.

Another approach to conserving water from rainstorms was to construct small basins in lister furrows to trap and hold water. A device which made small dams in the lister furrow was built to go behind the lister as early as 1937 (Chilcott, 1937). They were called basin listers (Cole and Morgan, 1938). From 1937 to 1951 the basin lister was compared with the ordinary lister for fallowing and preparing wheat stubble land for wheat after wheat at Colby, Kansas. Wheat yields differed less than 0.5 kg/ha for the treatments (Kuska and Mathews, 1956). Using the basin lister during fallow after wheat resulted in little increase in stored soil water. After 14 yr of research at Hays, Kansas and 9 yr at Cherokee, Oklahoma, little difference was found in wheat yields from one-way plowed, listed, and basin-listed tillage treatments (Luebs, 1962 and Daniel, 1950). During this period, lister plowing was used mainly for controlling wind erosion and weeds during the noncropped period.

The basin-lister practice was abandoned in most areas by 1950. Reasons given for abandonment were slow operating speed, poor weed control, difficulty with seedbed preparation and subsequent tillage, and increased erosion when dams washed out (Erhart, 1976). Also, little benefit in yield resulted from use of basin-listers. Stubble mulch tillage, terracing, and other conservation practices had gained in popularity and were easier to manage.

We feel that the early basin-lister concept, failed primarily because they were used during the fallow season rather than when a growing crop could readily benefit from additional soil water. Runoff data from dryland wheat-fallow-sorghum-fallow plots at Bushland, Texas, show when furrow blocking might be most effective (Fig. 1). Little runoff occurs from sloping plots during the wheat growing period and during the 11-mo fallow period after wheat harvest. The largest amount of runoff occurs near the time when sorghum is planted and during the earlier part of the growing season (June and July). Similar results for cotton have been observed. These data indicate the dammed furrows should be used during the growing season for summer crops instead of during the fallow period after wheat, which was the practice in most of the earlier studies. By using the dams while a crop is growing, conserved runoff can be used immediately and evaporation losses will be minimized.

Today weeds are usually controlled with herbicides instead of tillage. Most herbicides used for dryland sorghum and cotton are applied either preplant or at planting time and many fields are not cultivated after stand establishment. Therefore, when dams are used during the growing season, herbicides reduce the need to travel through the dammed furrows. However, if cultivation is necessary, sweeps or lister bottoms would need to be mounted ahead of the front wheels of the tractor to remove the dams. After cultivation, the dams could be re-established. Equipment to perform this tillage in a single operation is commercially available.

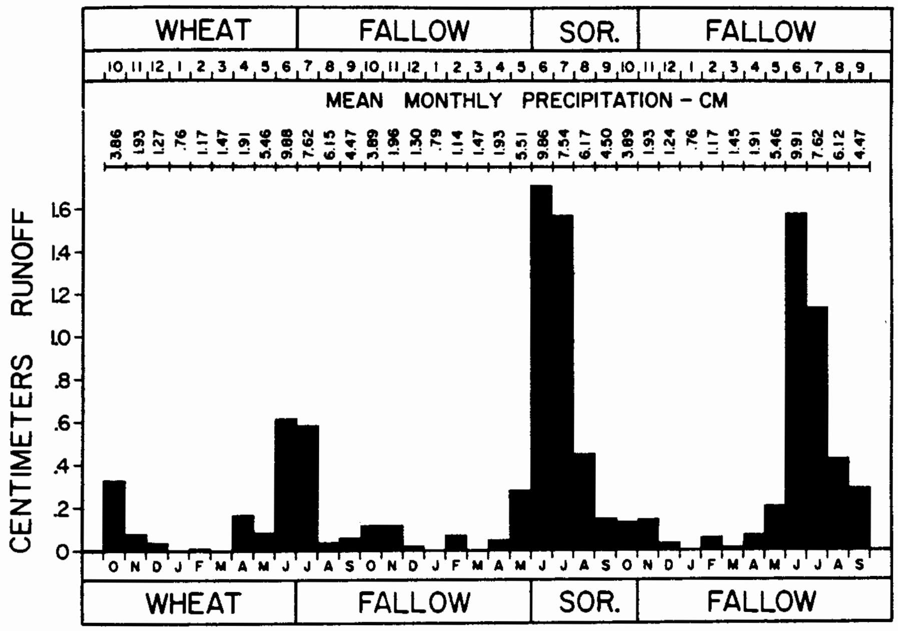

Fig. 1. Fourteen-year (1959-1972) mean monthly precipitation and runoff from three graded terraces cropped in a 3-yr wheat-fallow-sorghum-fallow sequence. One terrace was in each phase of the sequence every year (Jones, 1975)

Overtopping of dams and subsequent erosion were observed by many who studied the concept in earlier years. By using the concept during the growing season, this should be reduced to a minimum because the growing crop will utilize the stored soil water, and increase soil water intake, thus reducing pond water. Also, in earlier years many of the dams were used in furrows that were up and down the slope. Furrows on the contour should reduce the problem of overtopping.

DESCRIPTION OF EXPERIMENTS

A replicated study began in 1975 with open (not dammed) furrows, dammed furrows, and flat planting was used to evaluate the damming technique at the USDA Conservation and Production Research Laboratory. All plots were on Pullman clay loam which has a low basic infiltration rate (0.15 cm/hr) and a slope of 0.2%. Furrows were made with a conventional 75-cm lister or a tri-level lister allowing for two 75-cm rows of grain sorghum within the furrow. The flat planted treatment was included for the first 3 yr (1975-1977).

In 1975 and 1976, furrow dams were first made every 15 m with a blade-like scoop designed at the Laboratory. In 1977, a hydraulic tripping dammer was built after the design of Lyle and Dixon (1977). In 1979 a commercial dammer was used which spaced dams 3.5 m apart.

Grain sorghum was planted between June 5 and 15 and harvested in October. The plant population was approximately 18,000 plants/ha. All plots were treated each year with Propazine at the rate of 3.7 kg/ha (AI) applied preemergence. Initially dams were constructed in a separate operation immediately after herbicide application. Later, herbicide was applied as an integral part of the damming operation. Grain yields were obtained by combine harvesting 0.67 ha plots. Storm runoff from the open furrow treatment was measured with 30-cm "H" flumes equipped with water stage recorders. Soil water content was monitored with the neutron method.

Additional experiments and studies have been conducted by Laboratory staff using furrow dams. Some of these studies have been on producers fields where treatments were not replicated and only observational data was collected.

RESULTS AND DISCUSSION

Precipitation and Runoff

The effectiveness of furrow dams for increasing grain yields depends on the seasonal precipitation and the potential for storm runoff. Seasonal (June 1 to October 31) precipitation and runoff are shown in Table 1. Yield increases due to furrow dams were observed only in years with above average runoff. In 1975, only one significant runoff event occurred to produce a seasonal runoff total of 2.1 cm. Four events occurred in August, 1977 resulting in a runoff total of 8.5 cm. The 3.8 cm of runoff measured in 1978 came on September 19, too late to affect the 1978 sorghum crop; however, all water from the 11.5 cm rainstorm was retained by the furrow-dammed treatments. Only 0.2 cm of runoff was measured in 1979.

Table 1. Seasonal rainfall and runoff from open furrows (1 June - 31 Oct.)

Year	Rainfall total	Runoff		
		Total	Dates	
	cm	cm		cm
1975	21.8	2.1	8 June	0.1
			11 July	0.1
			23 July	1.8
			2 Aug.	0.1
1976	21.9	0	---	
1977	27.5	8.5	11 Aug.	4.1
			21 Aug.	3.1
			22 Aug.	0.9
			23 Aug.	0.4
1978	35.8	3.8	19 Sept.	3.8
1979	29.2	0.2	2 Aug.	0.2
20 yr Avg.	29.4	3.8	---	

The effectiveness of furrow dams in retaining potential storm runoff and preventing erosion from large storms is affected by land slope and "pre-conditioning". In Ochiltree County, Texas, 7.0 cm of rainfall in 30 min overtopped newly constructed furrow dams and caused moderate erosion on a 3% sloping clay loam soil. However, in Hutchinson County, Texas, 14.5 cm of rainfall fell in less than 24 hr. Furrow dams on a 0.5% sloping clay loam overtopped, but did not erode because the dams had been settled or "preconditioned" by 2.5 cm of rainfall that occurred 2 wk prior to the large storm. Experience with the 11.5 cm storm at Bushland and the 14.5 cm storm in Hutchinson County show that furrow dams on gentle slopes and clay loam soils can effectively control or prevent erosion from large storms.

Grain Yields

Grain yields have been variable, ranging from 0 to 2,900 kg/ha during the 5 yr test (Table 2). High yields were produced in 1975 and 1979 because of high levels of soil water stored at planting followed by timely precipitation (Figs. 2-5). Although seasonal precipitation was much below average in 1975, rainfall was adequate during July to maintain a high soil water content into early August. August rainfall was limited, but plants were brought to maturity on stored soil water. Grain yields on the furrow-dammed treatment were increased 340 kg/ha by conserving 2.1 cm of potential runoff in 1975.

Plot areas for the 1975 and 1979 crops had been fallowed the previous year which resulted in high soil water contents at planting and high grain yields. Plot areas for the 1976, 1977, and 1978 crops had been planted in sorghum the previous year and less soil moisture was available at planting time, which lowered yields. In 1976 sorghum on all treatments was destroyed by hail. Although seasonal precipitation in 1977 was near average, low soil water content and precipitation during June and July resulted in small, severely stressed that were not able to efficiently utilize the ample August rainfall. Even though 1977 sorghum yields were low, furrow damming increased yields 650 and 870 kg/ha, respectively, over the flat and open-furrow treatments.

Table 2. Yield of grain sorghum planted in 75-cm rows

	Treatments		
Years	Dammed	Open	Flat
	--kg/ha--		
1975	2,920	2,580	2,470
1976	0	0	0
1977	1,380	510	730
1978	1,050	1,120	--
1979	2,890	2,870	--
Avg.	1,650	1,420	--

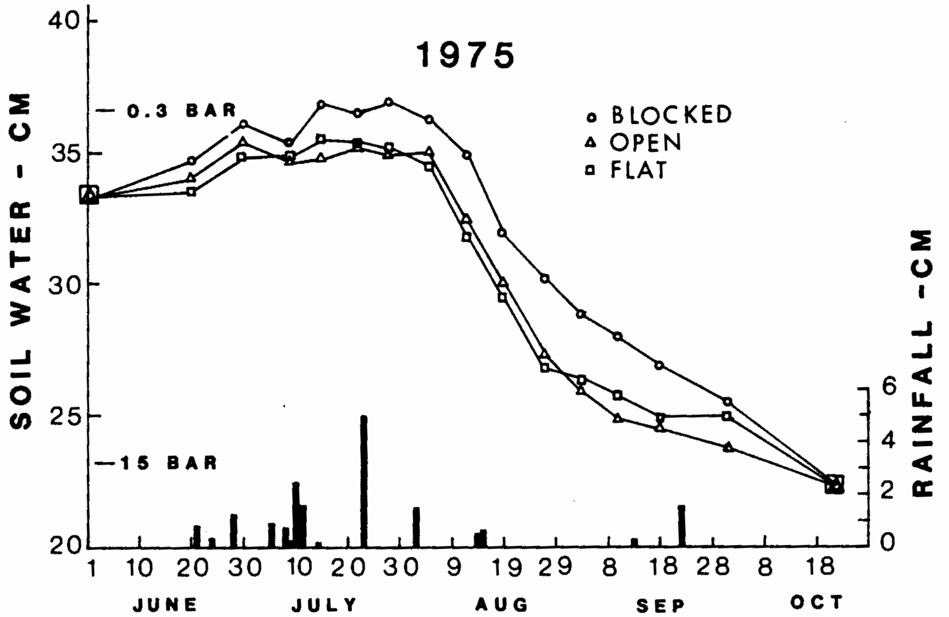

Fig. 2. Soil water content (0-120 cm) and seasonal precipitation for grain sorghum grown on the furrow dammed (blocked), open furrow, and flat tillage treatments at Bushland, TX, 1975.

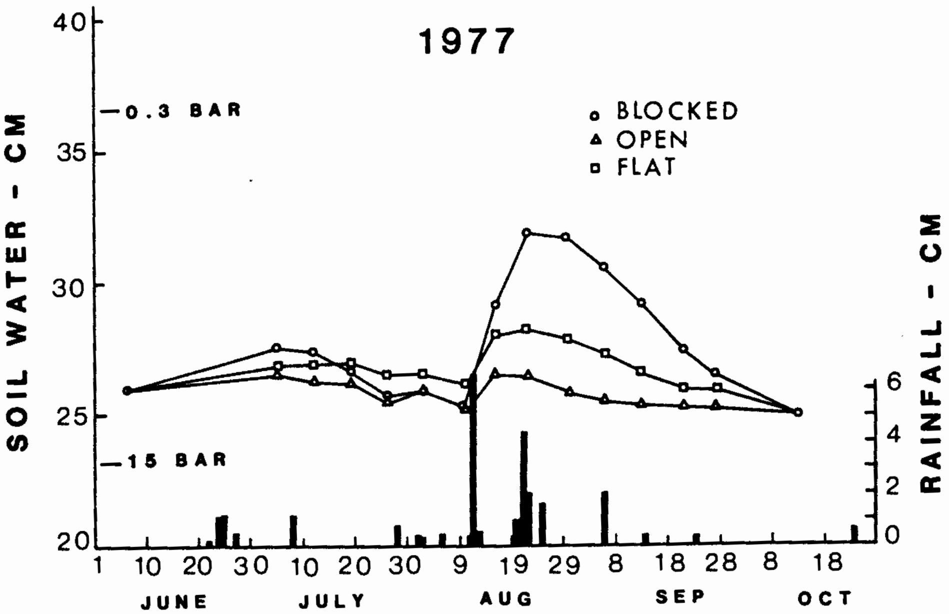

Fig. 3. Soil water content (0-120 cm) and seasonal precipitation for grain sorghum grown on the furrow dammed (blocked), open furrow, and flat tillage treatments at Bushland, TX, 1977.

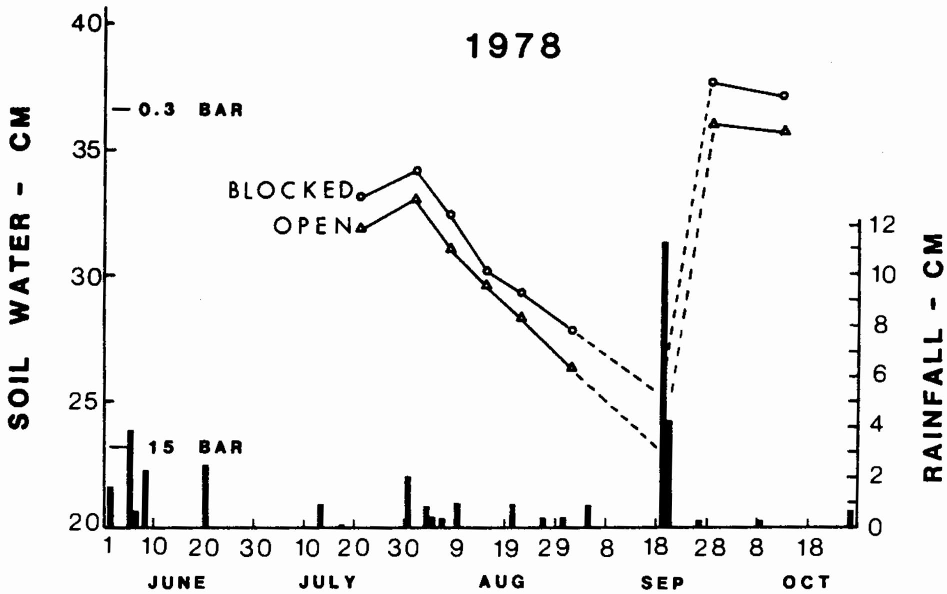

Fig. 4. Soil water content (0-120 cm) and seasonal precipitation for grain sorghum grown on the furrow dammed (blocked), and open furrow treatments at Bushland, TX, 1978.

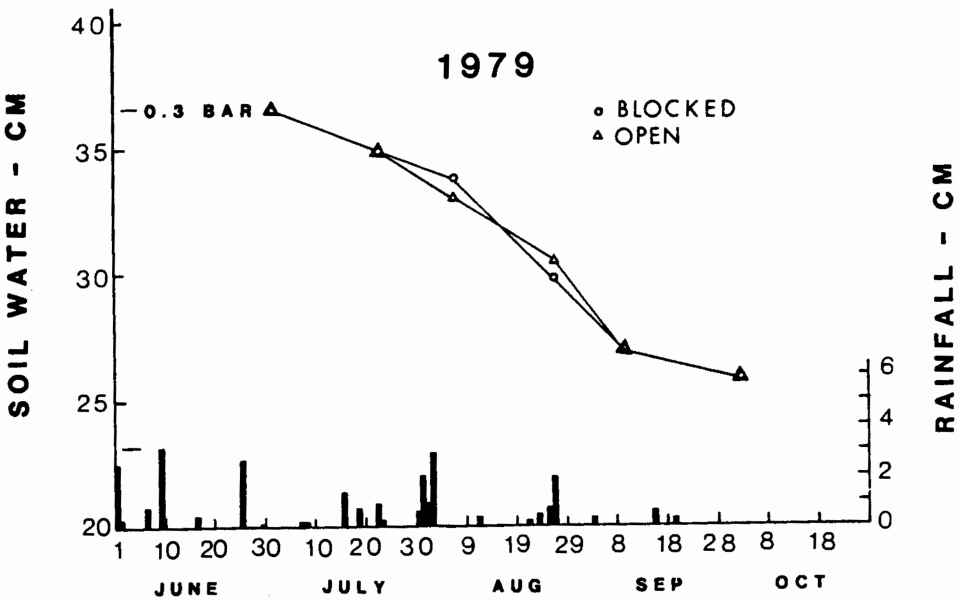

Fig. 5. Soil water content (0-120 cm) and seasonal precipitation for grain sorghum grown on the furrow dammed (blocked), and open furrow treatments at Bushland, TX, 1979.

Seasonal precipitation in 1978 was above average, however, drought stress resulting from much below average precipitation during July and August caused low yields. Runoff from the record breaking storm on September 19, 1978 occurred too late in the season to benefit the 1978 crop and possibly the excess soil water resulting from conserved runoff on the furrow-damming treatment reduced sorghum yields in comparison to the open treatment (Table 2). However, the additional water conserved by furrow damming in 1978 increased sorghum yields 660 kg/ha for the sorghum grown in 1979 on the 1978 experimental area.

Research results show that little difference in sorghum yield occurs between the furrow-dammed and open treatment in years when adequate moisture is available. However, in dry years, damming can prevent a crop failure as in 1977. In each of the years where runoff was caught in the dammed furrows before August 15, yields were increased. Long-term records show that each additional 1 cm of stored soil water at planting increases yields about 275 kg/ha (Unger, 1972).

Soil Moisture

Treatment effects on soil water content are shown in Figs. 2-5. All treatments had similar soil water contents at planting in 1975 (Fig. 2) and only small differences in content were observed until July 10. Runoff caught from rainfall on July 10 and 11 increased the soil water content in the dammed furrow treatment by 1.3 cm. This difference continued until late in the season when all treatments eventually reached a similar dry condition at harvest. A similar condition existed in 1977 (Fig. 3), except all treatments were much drier at planting and remained dry until the large rain on August 11. The dammed treatment increased in soil water after the rainfall on August 11 and August 22, reaching a maximum difference of 5.6 cm by August 24. Again, this difference continued until late in the season. In 1978, the dammed treatment had about 1 cm more soil water through most of the season until the large rain in September when the soil water content reached field capacity in both treatments (Fig. 4.). This soil moisture was retained through the winter and was still available at sorghum planting in 1979 (data not shown). In 1979 soil water contents were similar throughout the season since little runoff occurred (Fig. 5).

When runoff retained in July and early August resulted in significant soil water differences between treatments, the growing plants were able to utilize the extra water, drying the soil to the same soil water content as other treatments.

APPLICATION OF RESEARCH RESULTS

Dryland crop yields in the Southern Great Plains are normally controlled by the available soil water. Grain sorghum is highly responsive to water and even 1 cm of additional stored water can produce significant yield increases. Most rainfall occurs from May through September. Rainfall during this time is from thunderstorms which have high intensities and short durations. These storms frequently have intensities greater than the intake rate, thereby causing water to pond and leave the field as storm runoff. Even on soils that have good infiltration rates, the raindrops may seal the surface soil, reduce intake, and result in runoff. The furrow-damming technique is a management practice to hold runoff water in place and allow it to infiltrate without the cost and problems of land leveling. Also, furrow damming can eliminate the problems of point rows that are encountered with terraces or contouring and low production on terrace ridges. On steeper slopes, furrow dams should be used in conjunction with terracing to prevent severe soil erosion that may occur when furrow dams overtop. On gentle slopes (2% or less) furrow dams can control runoff from large storms without severe erosion.

The furrow-damming technique must be correlated with the time of greatest potential runoff and crop water use. For example with sorghum in the Texas High Plains, dams should be established by June 1 or earlier to capture the potential runoff. Establishing the dams at other times will have little benefit because normally there is little runoff to be caught (Fig. 1).

The use of furrow damming on wheat would have minimum benefit because little runoff occurs during the wheat growing season. This has been clearly shown by previous research (Fig. 1).

In years when rainfall is normal or above, enough runoff should occur to significantly increase summer row crop yields. In dry years, this practice may not increase yields but should not reduce them, as long as stand establishment is not affected.

REFERENCES

1. Cole, J. S., and G. W. Morgan. 1938. Implements and methods of tillage to control soil blowing on the Northern Great Plains. USDA Farmers Bull. No. 1797.

2. Chilcott, E. F. 1937. Preventing soil blowing on the Southern Great Plains. USDA Farmers Bull. No. 1771.

3. Daniel, H. A. 1950. Water conservation for wheat production in Oklahoma. Soil Sci. Soc. Proc. 15: 408-412.

4. Erhart, A. B. 1976. (Personal communication, Superintendent, Garden City Branch, Kansas Agric. Exp. Sta.).

5. Fisher, C. E., and E. Burnett. 1953. Conservation and utilization of soil moisture. Texas Agric. Exp. Sta. Bull. 767.

6. Jones, O. R. 1975. Yields and water-use efficiencies of dryland winter wheat and grain sorghum production systems in the Southern High Plains. Soil Sci. Soc. of Am. Proc. 39: 98-103.

7. Kuska, J. B., and O. R. Mathews. 1956. Dryland crop-rotation and tillage experiments at The Colby (Kansas) Branch Exp. Sta. USDA Circ. No. 979.

8. Luebs, R. E. 1962. Investigations of cropping systems, tillage methods, and cultural practices for dryland farming at Fort Hays (Kansas) Branch Experiment Station. Kansas Agric. Exp. Sta. Bull. 449.

9. Lyle, W. M., and O. R. Dixon. 1977. Basin tillage for rainfall retention. Trans. Am. Soc. Agric. Eng. 20: 1013-1017.

10. Unger, Paul W. 1972. Dryland winter wheat and grain sorghum cropping systems -- Northern High Plains of Texas. Texas Agric. Exp. Sta. Bull. 1126.

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