FINAL REPORT

BASIN OR RESERVOIR TILLAGE FOR RUNOFF CONTROL IN LOW PRESSURE IRRIGATED AREAS

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by

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SUMMARY

The effects of reservoir tillage on runoff losses, soil moisture content and crop yields were examined. Replicated plots were established on eight different low pressure center-pivot sprinkler irrigated fields, covering a range of soils slopes and crop conditions.

Results showed that reservoir tillage substantially reduces or eliminates runoff and could increase irrigation efficiencies by as much as 26%. Soil moisture contents under reservoir tillage were increased in each study field, and some yield increases were documented also. In no case were yields significantly decreased.

The reduction in runoff can be directly translated to a reduction in the energy requirement for irrigation. Under severe runoff conditions (steep slopes, fine soils), potential energy savings of up to 30% could be realized using reservoir tillage.

INTRODUCTION

Runoff from agricultural lands has always been a problem. Before the advent of modern farming techniques, the adverse effects of runoff were mostly limited to the erosion of top soil, and in some areas of limited rainfall, water lost to runoff has resulted in insufficient soil water reserves to support healthy plant growth. The development of sprinkler irrigation systems has made it possible to irrigate much steeper terrain than had previously been irrigated with gravity methods, and irrigating steeper lands has intensified the problems associated with runoff. Not only did the rapid increase in sprinkler irrigated acreage bring a corresponding increase in soil erosion in many areas, but other problems began to be apparent as well. Pollution of surface water sources through suspended sediment and dissolved agricultural chemicals has become increasingly annoying. Also, due to the high energy requirement of pumping for sprinkler irrigation systems, the loss of water to runoff can be directly translated to an unnecessary increase in crop production costs and a waste of energy.

In an effort to defray energy costs, sprinkler equipment has been developed to adequately distribute water at much lower pressures than previously possible. Some of these devices have been developed for use with hand-line and side-roll sprinkler systems, but the most popular application has been with continuously moving, self-propelled center-pivot and lateral-move systems. Although these low pressure sprinkler systems do, in most cases, cut down considerably on the energy requirements for irrigation pumping, their use can greatly increase the potential for runoff. Since the sprinkler pattern diameter of low pressure sprinklers is necessarily less than that of high pressure sprinklers, the instantaneous application rate per unit of applied water is higher as the same amount of water is applied over a smaller area.

In areas with high crop water requirements, it is usually not possible to design low pressure center-pivot sprinkler irrigation systems to supply sufficient amounts of water to the soil without exceeding the soil's infiltration rate. Water applied at rates greater than the infiltration rate can be lost from the area as surface runoff. Consequently, engineers and other members of the agricultural community have been challenged to devise methods to prevent runoff.

A viable method for reducing or eliminating runoff that has gained renewed interest in recent years has been the concept of basin tillage. The idea behind basin tillage is to create small reservoirs that retain ponded water in the immediate area in which it is applied until it has a chance to infiltrate into the soil. These reservoirs are usually small depressions in the soil surface that are large enough to retain applications in excess of the infiltration capacity of the soil.

The concept of basin tillage itself is not new. Performance studies on machines that dig series of depressions in the soil surface were reported as early as 1931 (Knight and Hyde, 1931). Numerous other studies were conducted up through the early 1950's, but soon thereafter, interest in the concept seemed to taper off due to lack of significant yield increases (Lyle and Dixon, 1977). Nearly twenty years later, Aarstad (1973) examined the effectiveness of small basins between row crops as a means of reducing runoff under center-pivot sprinklers. He measured the runoff reductions and found runoff in areas without basin tillage to be about 40 percent of the applied water, and in areas with basin tillage runoff was only about one percent of applied water. He also measured yield increases in potatoes and sugarbeets. Other studies examined the use of basin tillage in dryland cotton and grain sorghum production in Texas (Clark and Hudspeth, 1976). Yield increases of 12 percent for grain sorghum and 25 percent for cotton lint were reported.

Several different types of tillage implements have been developed to form basins in row-crops and small grains. These machines use one of two basic methods for creating the basins. One method uses a shovel type implement to drag a volume of soil a short distance and then deposit it in a pile to alternately create dams and basins. The other method uses spades mounted on freely turning wheels to punch depressions into the soil surface. Longley (1984) distinguished the difference between the two methods. The first one he referred to as basin tillage and the second as reservoir tillage.

Longley (1981, 1982, 1984) has examined the performance of several different machines of both types in several types of crops. He has found that all of the machines tested resulted in reduced runoff and, in most cases, increased crop yields. According to Longley (1984), the most promising machine was a reservoir tillage machine that had spades mounted on freely turning wheels and used positive pressure from the tractor to push the spades below the ground surface to create subsurface reservoirs.

Although research has been conducted to evaluate machine performance and the effects of reservoir tillage on irrigation efficiency and crop production, it is limited in extent. A need for further documentation of the effects of reservoir tillage under a wide variety of farming conditions still exists.

OBJECTIVES

The objectives of this study were to determine the effects of the practice of reservoir tillage has on crop production under center-pivot sprinkler irrigation. The specific objectives were:

1) To determine the most effective solution for afterseeding to prevent a stand reduction in small grains.
2) To determine the runoff reduction associated with the use of reservoir tillage under center-pivot irrigation over a variety of cropping conditions.
3) To determine the energy savings which could be recognized when using reservoir tillage as a means of runoff control.
4) To further substantiate yield and quality increases found in reservoir tilled plots in 1984 (Longley, 1984), and to determine the economic consequences of using this practice on the crop production budget.

EXPERIMENTAL PROCEDURES

The procedures used to accomplish the stated objectives were to establish sets of replicated plots on several different fields that were being irrigated by center-pivot sprinklers and to document the effects of reservoir tillage practices. The fields were owned and operated by private farming operations, and covered a range of slope, soil type and crop conditions.

Experimental Design

Two basic types of experimental designs, split plot factorial and completely randomized, were used to analyze the effects of reservoir tillage. The first was used on several fields where the performance characteristics of different types of sprinkler equipment were being analyzed. On these fields, the outermost two or three center-pivot spans were outfitted with different sprinkler treatments. Plots were established to give several replications of both conventional tillage and reservoir tillage treatments within each span. This plot set-up resulted in the classical split-plot factorial statistical experimental design. This design allowed an efficient analysis of the effects of both the different tillage treatments and the different sprinkler treatments. The second design was used on fields where only one type of sprinkler equipment was being used. Since the sprinkler equipment was identical between spans, plots were established to give several replications of both conventional and reservoir tillage in the outermost span only as the highest application rate occurred under this span. This latter plot set-up resulted in a completely randomized statistical experimental design, and was used to analyze the tillage effects only. Diagrams of plot layouts are contained in the Appendix.

Plot Preparation

Plots were established on eight different center-pivot irrigated fields in the southern portion of the Columbia River Basin and Eastern Oregon. The farming operations cooperating with this project were:

David Childs,
Chateau Ste Michelle,
Eastern Oregon Farming Co.,
LPC Partnership,
Sunheaven Farms, and
UI Group, Inc.

On each field, plots were set up so that slope, soil type and crops were identical for all treatment repetitions. The exact methods of imposing the tillage treatments varied with each type of crop and with each cooperator. The reservoir tillage treatments were put in using several different configurations of the Dammer-Diker,[1] manufactured by the Agricultural Engineering and Development Company of Richland, Washington.

For the two row crops (corn and potatoes), plots were established in a portion of the field where the slope was fairly uniform and where the rows ran up and down the slope. Each plot was twelve rows wide by 30 feet long. (Potato row width was 34 inches, and corn row width was 30 inches.) Immediately prior to the final cultivation operation, the plot sites were surveyed to measure slope, and the corners were marked.

The reservoir tillage operations on all plots were performed with an implement similar to that shown in Figure 1. The subsurface reservoirs were punched in to a depth of 8 to 10 inches and were spaced approximately 24 inches in the direction of travel. Reservoirs were placed between each row of corn and potatoes, and at 36 inches in grain. Figure 2 is a picture of reservoirs in a potato field that shows their effectiveness in retaining water. It was observed that some reservoirs did erode during the irrigation season, especially under very high instantaneous irrigation application rates. Erosion was generally more of a problem on non-cohesive soils such as silt loams.

On the potato fields, the reservoir tillage machines were designed to combine the final hilling operation and the reservoir tillage operation. The reservoir tillage implement could be raised independently from the hilling implements. During the final cultivation, whenever a plot that was to have the conventional tillage treatment was encountered, the reservoir tillage implement was raised so that the final hilling operation could be performed

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[1] The use of trade names does not constitute endorsement of manufacturer's products by the author or the University of Idaho. Trade names are used to identify style and design of equipment only.

Figure 1. Machine used for reservoir tillage.

Figure 2. Reservoir tillage in potatoes showing water in reservoirs.

without putting reservoirs in the conventionally tilled plots. When a plot that was to have the reservoir tillage treatment was encountered, both the hilling implement and the reservoir tillage implement were lowered to perform both of these operations.

On the corn fields, the final cultivation operation and reservoir tillage operation could not be performed independently of each other. In this case, both operations were performed on all plots, and then the reservoirs were smoothed over by hand in the conventional tillage plots. The resulting soil conditions were identical to soil conditions in a conventionally tilled plot.

The small grain plots had been established prior to the start of this project by the private cooperators. The grain rows were spaced at 8 inches. Reservoirs were put in on 36-inch spacings parallel to the grain rows. Two grain fields were used for this study. One was planted to spring barley, and the other was planted to winter wheat. On the spring barley field, the tillage operation was performed after planting, and an afterseeding device was attached to the Dammer-Diker to provide afterseeding at a rate of 40 pounds per acre in the rows where basins had been placed. On the winter wheat field, the basins were placed after the seeding operation also, but no afterseeding was used. A third set of plots were placed in a non-irrigated section of winter wheat, but due to the abnormally dry conditions of early summer in 1985, there was insufficient soil moisture in both the conventional and reservoir tillage plots, and the plants died.

DATA COLLECTION

Afterseeding and Crop Stand--

The effects of reservoir tillage and afterseeding on crop stand were evaluated. Stand counts were taken in all irrigated plots in grain fields. Different tillage and afterseeding practices that were evaluated were conventional tillage, reservoir tillage at the time of planting and reservoir tillage with 40 pound per acre afterseeding shortly after planting. All counts were taken after tillering occurred in order determine the cumulative effects of reservoir tillage on stand and tillering and to obtain the final stand count that would affect yield.

Application Depth--

To determine the application depth and the average instantaneous application rate, it was necessary to know the flow rate through each nozzle, nozzle spacing, the pattern diameter of the sprinkler spray at the ground surface, and the ground speed of the center-pivot over each set of plots. The flow rate through each nozzle was determined by noting nozzle size and measuring nozzle pressure. The ground speed of the center-pivot was determined by timing the outermost tower of the system over a known distance.

Runoff--

Runoff data were measured using graduated furrow flumes placed at the low end of each plot. Data were collected by recording the time and flow depth in the flumes at short time intervals as the sprinkler system passed over the plots. These measurements were made frequently enough to construct a runoff hydrograph for each flume.

The method used for flume placement varied with the type of crop. On the small-grain plots, interception trenches were dug around the plots to prevent external runoff from entering the plots and to route the runoff from the plots through the flumes. In the row crops, runoff from above the plots was diverted around the outside of the plot by ditches. To measure the runoff from the plot, flumes were placed directly in the furrows at the low end.

Soil Moisture

The soil moisture in the plots was measured periodically throughout the season with gravimetric samples and a neutron probe. With both methods, measurements were taken at six-inch intervals below the soil surface to a depth of three feet. Soil bulk densities in each field were also measured. From these measurements, the moisture content could be calculated and expressed as a depth of water in a given depth of soil.

Yield--

Yield samples were collected from the plots immediately prior to the harvesting operation of the host field. The yield samples for the small grains consisted of samples collected from a 10-foot length of each of four rows. The samples were harvested with hand sickles, threshed, dried to equilibrium moisture content (12 - 14 percent moisture) and weighed. For the corn, the ears were hand picked from a ten foot section of row from each plot. These ears were threshed, and the grain was weighed. The moisture content of each sample was determined so that the yields could be adjusted to account for differences in moisture content between the treatments. Potato yields were determined by digging 7.5 feet of row from each plot and weighing all tubers over 2 inches in diameter.

DATA ANALYSIS

Runoff--

Representative hydrographs were constructed for each field where runoff was measured. Runoff data were analyzed by performing numerical integrations of the hydrograph data. To perform the integrations, a straight line interpolation between the data points for each hydrograph was assumed. The results gave a total volume of runoff through each flume for each application event. This volume was then divided by the area supplying runoff to each flume to obtain the runoff depth.

Soil Moisture--

Gravimetric sample data were analyzed by first determining the moisture content on a dry weight basis and converting that moisture content to a depth of moisture per foot of soil using the measured bulk densities. The neutron probe data were directly measured on a volumetric basis and needed no adjustment to be able to express the moisture contents as a depth of water per foot of soil. Graphs were constructed to compare the soil moisture contents between the tillage treatments for the length of the growing season of each set of plots.

Potential Energy Savings--

The energy requirement of a sprinkler irrigation system can be calculated by the relationship

$$PE = \frac{0.085\ ADH}{E \cdot E_p}$$

where PE = energy requirement for pumping (kwh),
A = area irrigated (acres),
D = net depth of irrigation (inches),
H = total dynamic pumping head (feet)
E = irrigation efficiency (decimal), and
E_p = pumping plant efficiency (decimal).

From this equation, it can be seen that the energy requirement is inversely proportional to the irrigation efficiency.[2/] Therefore, if irrigation efficiency can be increased by reducing runoff with reservoir tillage, the percent potential energy savings can be expressed as:

$$PES = (1 - \frac{E_c}{E_R}) \times 100\%$$

where PES = potential energy savings (%)
E_c = irrigation efficiency in conventional tillage, and
E_R = irrigation efficiency in reservoir tillage.

Irrigation efficiency is dependent on climatic conditions, physical characteristics of the crop canopy, crop water requirement, soil conditions, irrigation management and irrigation system design. All of these factors are widely site specific and can also vary over the course of an irrigation

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[2/] The term "Irrigation Efficiency" as used in this report refers to irrigation application efficiency -- the ratio of water stored in the root zone to that applied by the irrigation system.

season. The causes of sprinkler inefficiency include evaporation and wind drift, equipment leakage, crop canopy interception, deep percolation and/or runoff. For this analysis, a conservative estimate of 85% efficiency is assumed when accounting for all factors except runoff. When accounting for the water lost to runoff, the final irrigation efficiency is expressed as

$$E = .85 - \frac{D_R}{D_A}$$

where E = irrigation efficiency (decimal),
D_R = runoff depth, and
D_A = application depth at the nozzles.

By calculating the irrigation efficiency for each tillage treatment and inserting those values into the potential energy savings equation, an estimate of the percent potential energy savings from using reservoir tillage can be computed.

Yield

Yield data were analyzed using a statistical analysis of variance and a means comparison procedure. These analyses examined the statistical significance of the effects of the different tillage treatments on yield and calculated the yield sample means and least significant difference of the means between the tillage treatments.

RESULTS

Results from this study indicate that reservoir tillage is a very positive means of runoff control. In all of the fields that were tested, soil moisture was found to be highest in the reservoir tillage plots. In most cases, yields were also increased.

Since field conditions varied widely between the study fields, the results that were obtained from each field were unique. Therefore, for the purposes of discussion, the results from each field will be described separately. Summaries of runoff, potential energy savings and yield data are contained in Tables 1 through 4. Graphical representations of the hydrograph data and soil moisture data are contained in the appendix.

The runoff data listed in Table 1 indicate that in most fields the use of reservoir tillage essentially eliminated runoff. The only fields in which runoff was measured from reservoir tillage plots was under corn and winter wheat, and the values were quite low. Although the runoff amounts from conventional tilled plots may appear to be quite low, they are a sizeable percentage of the applied water in most cases.

The potential energy savings values shown in Table 1 were computed assuming a conservative estimate irrigation application efficiency of 85 percent excluding surface runoff as described in the Data Analysis section. If this application efficiency were higher, the potential energy savings of reservoir tillage would be greater also. As shown, the potential energy savings exceeded 20% in many instances.

Yield results for potatoes, corn and small grain are shown in Tables 2, 3, and 4, respectively. Increases in yield were found for all potato fields with a statistically significant increase for the UI 103 field. For the corn fields, increases in yield were noted for both UI fields while there was a slight decrease in the Chateau Ste Michelle site. Winter wheat yields at

Sunheaven Farms were significantly increased using reservoir tillage whereas there was a slight decrease for spring barley.

The potential energy savings and yield data must be considered together in determining the net effects on costs and returns. Net effects on costs and/or returns can be determined using appropriate energy costs, crop commodity prices and other pertinent production cost data.

The following descriptions for each site give more details regarding site-specific conditions and their effects on yield and runoff data.

UI Group, Inc., Field #103 (Potatoes)--

UI 103 was a field with very mild slopes (approximately 2%) on a coarse sand. The soil layer was approximately 18-inches deep and was underlain by a consolidated layer. Because of these soil conditions, irrigations were frequent (every 12 hours) and of low intensity (approximately 0.23 inches). As expected, runoff losses in the conventional tillage plots were low (5% - 10% of the applied water), and in the reservoir tillage plots, runoff was eliminated entirely. Differences in soil moisture of up to 2 inches in the top three feet were found between the treatments. Unusually high moisture contents for a coarse sand soil were noted near the middle of July up through the first part of August in the reservoir tillage treatments. These high levels were due to a perched condition of excess soil water above the consolidated layer. Yield increases of over 25% in the reservoir tillage plots were found. This yield increase was highly statistically significant.

LPC Partnership (Potatoes)--

Soil conditions on the LPC Partnership field were sandy, but not nearly as coarse as the soil on the UI Group, Inc. field #103. Slopes here were medium (approximately 4.5%). Throughout the majority of the growing season, the field was irrigated every 18 hours with approximately 0.38 inches of water. Runoff losses were low (5% - 7% of applied water) in the conventional tillage plots and were eliminated entirely in the reservoir tillage plots. Soil moisture was higher in the reservoir tillage plots by about 1 inch in the top 3 feet. Although yield differences were not statistically significant, due to a large amount of within-treatments variation, an increase in yield of approximately 7% was found in the reservoir tillage plots.

Eastern Oregon Farms (Potatoes)--

Soil conditions of the Eastern Oregon Farms field were very similar to the conditions at the UI 103 field. The soil was a coarse sand, but there was no consolidated layer underneath. The irrigation frequency was every 28 - 36 hours with applied depths ranging from .44 to .64 inches. Slopes were very steep also, with an average of approximately 7.7%. Because of the high application depth and steep slopes, it was expected that runoff losses would be high in the conventional tillage plots. In these plots, runoff losses were found to be approximately 26% of the applied water, but runoff was eliminated entirely from the reservoir tillage plots. Soil moisture increases in the reservoir tillage were about 1.5 inches in the top 3 feet of soil.

Near the end of the growing season, irrigations were less frequent (approximately 40 hours) with application depths of about 0.33 inches. During this period, runoff losses in the conventional tillage plots were reduced to about 5% of the applied water and the soil moisture content in the conventional tillage plots approached that in the reservoir tillage plots. No differences in yield were found.

UI Group, Inc., Field #237 (Corn)--

The soil in UI 237 was a loamy sand with steep slopes (approximately 6.4%). Irrigation frequency varied from 18 to 30 hours with an application depth was usually about 0.4 inches. Runoff losses of 19.5% and 7.8% of the applied water were measured in the conventional tillage plots. In the reservoir tillage plots, runoff losses of 2.5% and 3.4% of the applied water were measured. The reason for the occurrence of runoff in the reservoir tillage plots for corn whereas there was none in the potato plots was due to the nature of water movement through the corn canopy. Most of the intercepted water in the corn canopy was converted to stem-flow and ran down the corn stalks into the row depressions where it was free to move relatively unobstructed.

A slight yield increase of 3.4% was found in the reservoir tillage plots. This increase, however, was not statistically significant at the 10% level.

UI Group, Inc., Field #235 (Corn)--

UI 235 was adjacent to UI 237, and conditions were almost identical. In UI 235, however, there was a malfunction with the irrigation system in the middle of the growing season, and during that period, the reservoir tillage plots were washed out. As a result, no runoff comparisons were possible. Moisture differences in the two plots were observed, however, up through the end of the growing season. Soil moisture was higher in the reservoir tillage plots by up to 1.5 inches in the top 3 feet. Yield increases of 16.6% were found in the reservoir tillage plots.

Chateau Ste Michelle (corn)--

The soils at Chateau Ste Michelle were very similar to the soils found in the UI 235 and UI 237 fields. Slopes were approximately 5.7%. The irrigation frequency was approximately every 30 hours and depths of between 0.25 and 0.30 inches were applied. Runoff losses were relatively high for the field conditions. In the conventional tillage plots, up to 26.4% of the applied water was lost to runoff. In the reservoir tillage plots, runoff losses were reduced to 5.2% of the applied water. In spite of this occurrence however, differences in yield were negligible.

David Childs Farm (Spring Barley)--

The soil on the David Childs Farm was a silt loam with a very low infiltration rate. The slopes in the plots were mild (approximately 2%). Irrigations were done approximately every 24 hours with an application depth of 0.2 inches. No measurable runoff occurred in either the conventional tillage or reservoir tillage plots. Soil moisture contents were slightly higher in the reservoir tillage plots near the end of the growing season by approximately 0.5 inches in the top 3 feet. Yield differences were negligible.

Sunheaven Farms (Winter Wheat)--

The soils on Sunheaven Farms were very similar to the soils on the David Childs Farm. Slopes were medium (approximately 5.5%). Irrigation frequencies ranged from 12 to 24 hours and the application depth was approximately 0.25 inches. As was expected, runoff losses in the conventional tillage plots were high (approximately 33% of the applied water). In the reservoir tillage plots, runoff was reduced to 9% of the applied water. Soil moisture increases of over 1 inch in the top 3 feet of soil were found in the reservoir tillage plots. It was noted throughout the growing season that the wheat in the conventional tillage plots was visibly stressed, whereas the wheat in the reservoir tillage plots was quite healthy. Yields were higher in the reservoir tillage plots by approximately 20%.

Afterseeding and Crop Stand--

Stand count data showing the effects of reservoir tillage and afterseeding are listed in Table 5. There was a stand reduction of 11.5 percent for the spring barley even with 40 pounds per acre afterseeding. This difference is statistically significant at the 5 percent level. The slight decrease in yield for spring barley with reservoir tillage was much less than the difference in stand count indicating that factors other than stand affect yield such as tillering and the number of grains produced on each stem.

For the winter wheat, there was an insignificant decrease in stem count of less than 6 percent. There was no afterseeding on this crop. It was noted that there was substantial tillering in both the conventional and reservoir tilled plots, a factor that would help compensate for possible stand reduction due to the reservoir tillage. Even with a slightly lower stem count, the wheat under reservoir tillage had a significantly higher yield indicating that applied water was used more effectively.

General Discussion--

As a general observation, it was noted that the greatest differences in yield for corn and grain occurred under conditions where the crops appeared to be stressed. This condition was noted at UI Group, Inc., Field #235 and at Sunheaven farms.

Also noted was a much higher tendency for reservoir failure to occur in the finer textured soils on moderate to steep slopes. This condition was observed at Sunheaven Farms and in all the corn fields. The nature of the failure was approximately the same in all cases. At the top of the hill, the failure started with a piping condition at the base of the dikes. As the runoff gained momentum, dikes at the lower end were washed out entirely. In the corn fields, the condition was aggravated by the fact that the water running down the row depressions already had sufficient momentum to damage the dikes. As a result, dike failures on the corn fields were found in up to 30% of the rows.

Table 1. Runoff and potential energy savings

Date	Application Depth (inches)	Runoff from Conventional Tillage (inches)	Runoff from Reservoir Tillage (inches)	Potential Energy Savings (%)
		Potatoes		
UI Group, Inc.	#103			
7-03-85	0.23	0.023	0	11.76
7-23-85	0.23	0.012	0	6.14
LPC Partnership				
6-11-85	0.38	0.025	0	7.74
7-26-85	0.38	0.019	0	5.58
Eastern Oregon Farming Co.				
6-10-85	0.47	0.128	0	32.04
7-26-85	0.47	0.106	0	26.53
8-01085	0.49	0.124	0	29.77
8-28-85	0.33	0.016	0	5.70
		Corn		
UI Group, Inc. #237				
8-13-85	0.41	0.080	0.014	19.73
8-22-85	0.41	0.032	0.010	6.50
Chateau Ste Michelle				
7-19-85	0.25	0.060	0	28.23
8-08-85	0.25	0.066	0.013	26.57
		Winter Wheat		
Sunheaven Farms				
6-21-85	0.25	0.055	0.011	21.84
6-28-85	0.25	0.078	0.024	28.65

Table 2. Yield results--Potatoes

UI Group, Inc. Field #103

	Grouping [1]	Yield (Tons/A)
Reservoir Tillage	A	21.73
Conventional Tillage	B	17.34
LSD 5% = 2.49 10% = 2.06		Δ% [2] = 25.3%

LPC Partnership

	Grouping	Yield (Tons/A)
Reservoir Tillage	A	23.61
Conventional Tillage	A	22.02
LSD 5% = 5.93 10% = 4.78		Δ% = 7.22%

Eastern Oregon Farming Co.

	Grouping	Yield (Tons/A)
Reservoir Tillage	A	29.81
Conventional Tillage	A	29.23
LSD 5% = 5.31 10% = 4.32		Δ% = 1.98%

[1] Yield means with same grouping identification letter are not significantly different.

[2] Δ% designates the increase in yield in reservoir tillage plots.

Table 3. Yield results--Corn

UI Group, Inc. Field #237

	Grouping [1]	Yield (Tons/A)
Reservoir Tillage	A	4.55
Conventional Tillage	A	4.40
LSD 5% = 0.49		Δ% = 3.41% [2]
10% = 0.41		

UI Group, Inc. Field #235

	Grouping	Yield (Tons/A)
Reservoir Tillage	A	3.94
Conventional Tillage	A	3.38
LSD 5% = 1.10		Δ% = 16.57%
10% = 0.89		

Chateau Ste Michelle

	Grouping	Yield (Tons/A)
Reservoir Tillage	A	5.28
Conventional Tillage	A	5.34
LSD 5% =		Δ% = -1.12%
10% =		

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[1] Yield means with same grouping identification letter are not significantly different.

[2] Δ% designates the increase in yield in reservoir tillage plots.

Table 4. Yield results--Small Grain

Spring Barley

David Childs Farm

	Grouping [1]	Yield (Bu/A)
Reservoir Tillage	A	150.72
Conventional Tillage	A	156.65
LSD 5% = 18.48 10% = 14.90		Δ% = -3.78% [2]

Winter Wheat

Sunheaven Farms

	Grouping	Yield (Bu/A)
Reservoir Tillage	A	92.00
Conventional Tillage	B	76.58
LSD 5% = 18.49 10% = 14.20		Δ% = 20.13%

[1] Yield means with same grouping identification letter are not significantly different.

[2] Δ% designates the increase in yield in reservoir tillage plots.

Table 5. Small grain stand counts

Spring Barley

David Childs Farm--40 lb/acre Afterseeding

	Grouping [1]	Stems/acre
Reservoir Tillage	A	511,467
Conventional Tillage	B	577,896
LSD 5% = 56,069 10% = 43,487		Δ% = -11.50% [2]

Winter Wheat

Sunheaven Farms--No Afterseeding

	Grouping	Stems/acre
Reservoir Tillage	A	418,176
Conventional Tillage	A	444,312
LSD 5% = 220,652 10% = 142,517		Δ% = -5.887%

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[1] Yield means with same grouping identification letter are not significantly different.

[2] Δ% designates the increase in stand count in reservoir tillage plots.

CONCLUSIONS

From the results of this study, it can be said that reservoir tillage is an effective means of controlling runoff and lowering energy requirements and crop production costs. With the exception of the spring barley results, substantial savings in runoff losses were noted which could be directly translated into a substantial savings in the energy requirement for irrigation.

Results of the soil moisture measurements show that the runoff reduction results directly in an increase in available soil moisture for consumption by crops. In cases where overall field moisture was quite low, the higher moisture in the basin tillage plots was enough to relieve crop stress and improve yields.

Factors other than afterseeding in small grains are important in affecting stand count and yield. Doing the reservoir tillage operation as close to planting as possible is one means of reducing detrimental effects. Other factors such as tillering and irrigation water management can greatly affect yield possibly more than afterseeding.

Yield increases were found in most cases and in no case was there any significant yield reduction. Therefore, with the energy savings resulting from the runoff reduction, it is clear that use of reservoir tillage can increase the net returns of crop production. In addition, reservoir tillage is a practice that could be used to greatly enhance irrigation management especially on soils with low water holding capacities such as in the UI 103 field.

RECOMMENDATIONS

The methods used for this research were successful in analyzing the effects of reservoir tillage on controlling runoff losses from an area. However, from observations in the field it was noted that a large part of the total runoff doesn't leave the field but moves from higher to lower areas within the field. As of this date, there have been no studies that examine the effects of reservoir tillage on overall uniformity of water within a field. Using this approach, a much clearer picture of the integrated effects of reservoir tillage on crop production could be gained.

To obtain the necessary information on overall uniformity within a field, it will be necessary to collect more complete data on both surface water movement and soil moisture status. A monitoring system for obtaining runoff data from plots throughout an irrigation needs to be set up on several fields. to precisely monitor changes throughout the irrigation season. This system will require a degree of sophistication to collect accurate data on both water applications and surface runoff at any time of the day. To better monitor soil moisture status, a more extensive network of neutron access tubes needs to be established in each field to monitor variations in soil moisture levels as affected by "short distance" runoff.

The data obtained will provide the information needed for better recommendations on the effectiveness and use of reservoir tillage as a practical and effective energy saving irrigation management practice. It will also be necessary to conduct more extensive studies regarding the effectiveness of afterseeding on small grains. As indicated in the results section, more data need to be collected showing the final effects of timing of reservoir tillage and/or afterseeding on crop yield. These results will be difficult to document as there are many additional conditions that affect stand and yield such as tillering which are influenced by factors other than reservoir tillage.

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RESULTS

Results from this study indicate that reservoir tillage is a very positive means of runoff control. In all of the fields that were tested, soil moisture was found to be highest in the reservoir tillage plots. In most cases, yields were also increased.

Since field conditions varied widely between the study fields, the results that were obtained from each field were unique. Therefore, for the purposes of discussion, the results from each field will be described separately. Summaries of runoff, potential energy savings and yield data are contained in Tables 1 through 4. Graphical representations of the hydrograph data and soil moisture data are contained in the appendix.

The runoff data listed in Table 1 indicate that in most fields the use of reservoir tillage essentially eliminated runoff. The only fields in which runoff was measured from reservoir tillage plots was under corn and winter wheat, and the values were quite low. Although the runoff amounts from conventional tilled plots may appear to be quite low, they are a sizeable percentage of the applied water in most cases.

The potential energy savings values shown in Table 1 were computed assuming a conservative estimate irrigation application efficiency of 85 percent excluding surface runoff as described in the Data Analysis section. If this application efficiency were higher, the potential energy savings of reservoir tillage would be greater also. As shown, the potential energy savings exceeded 20% in many instances.

Yield results for potatoes, corn and small grain are shown in Tables 2, 3, and 4, respectively. Increases in yield were found for all potato fields with a statistically significant increase for the UI 103 field. For the corn fields, increases in yield were noted for both UI fields while there was a slight decrease in the Chateau Ste Michelle site. Winter wheat yields at

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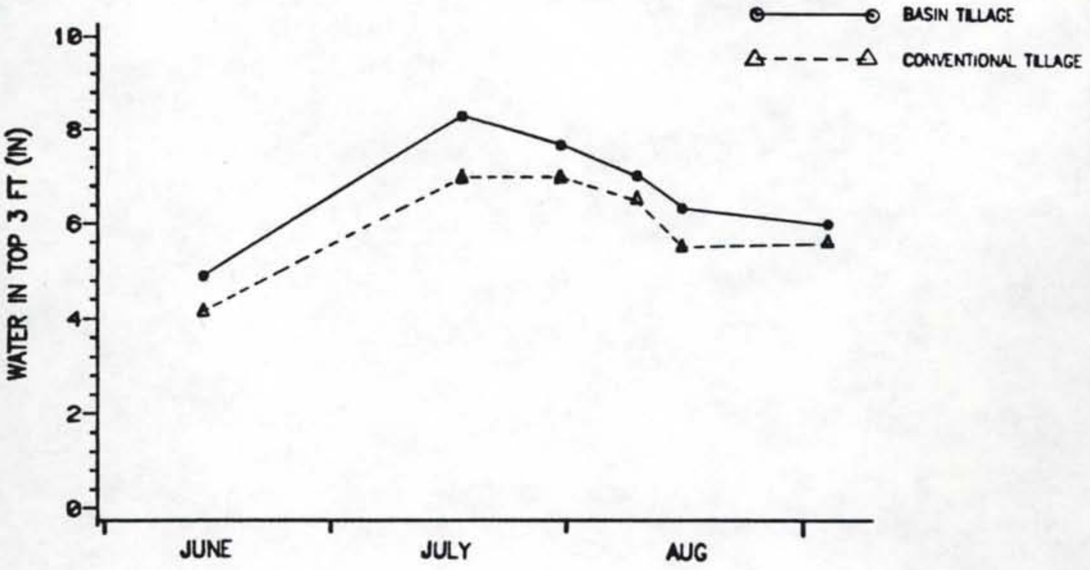
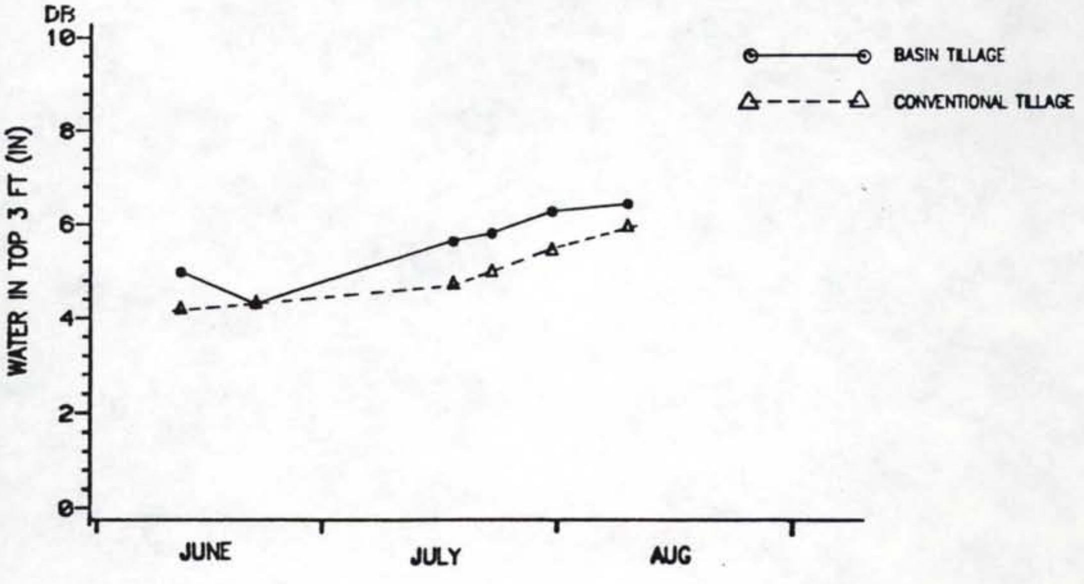
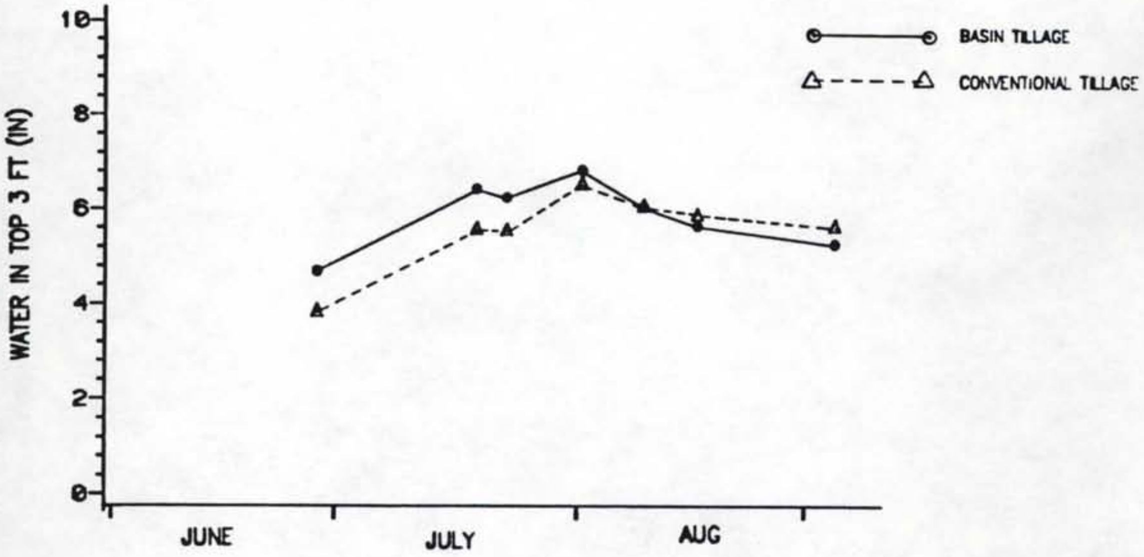
APPENDIX

SOIL MOISTURE DATA
UI 103 (POTATOES)

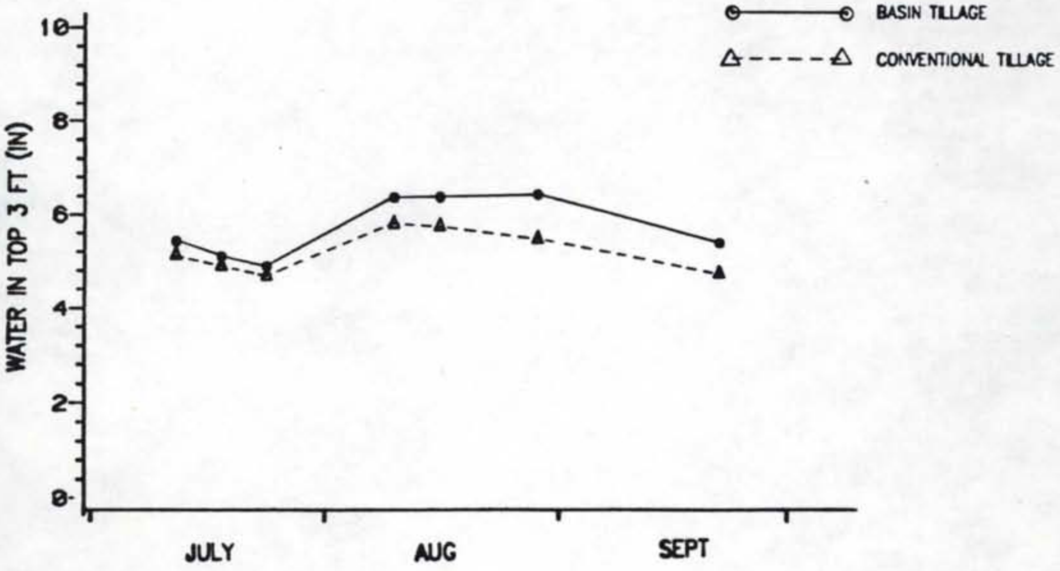


SOIL MOISTURE DATA
LPC PARTNERSHIP (POTATOES)



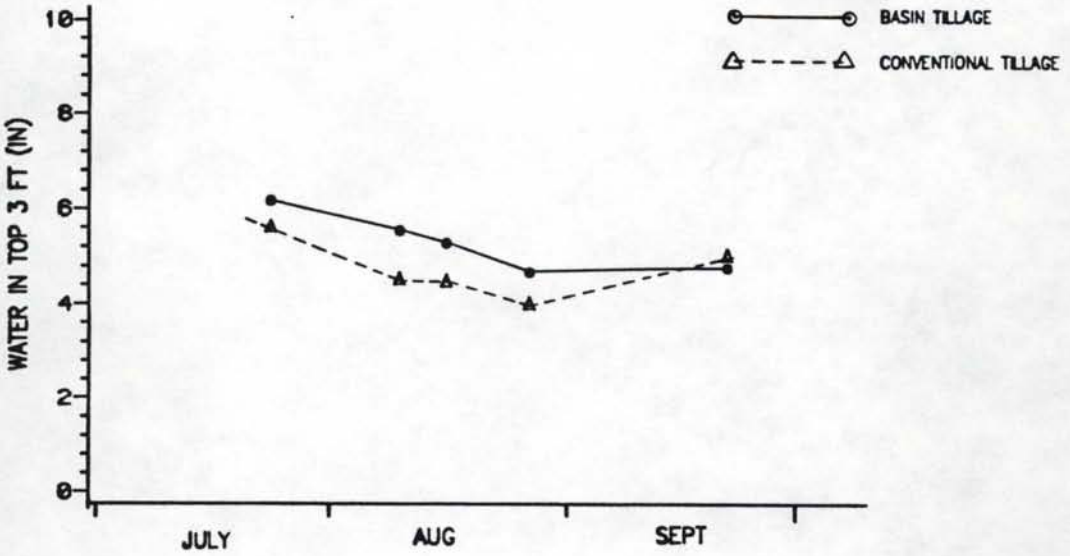


SOIL MOISTURE DATA
EASTERN OREGON FARMS (POTATOES)

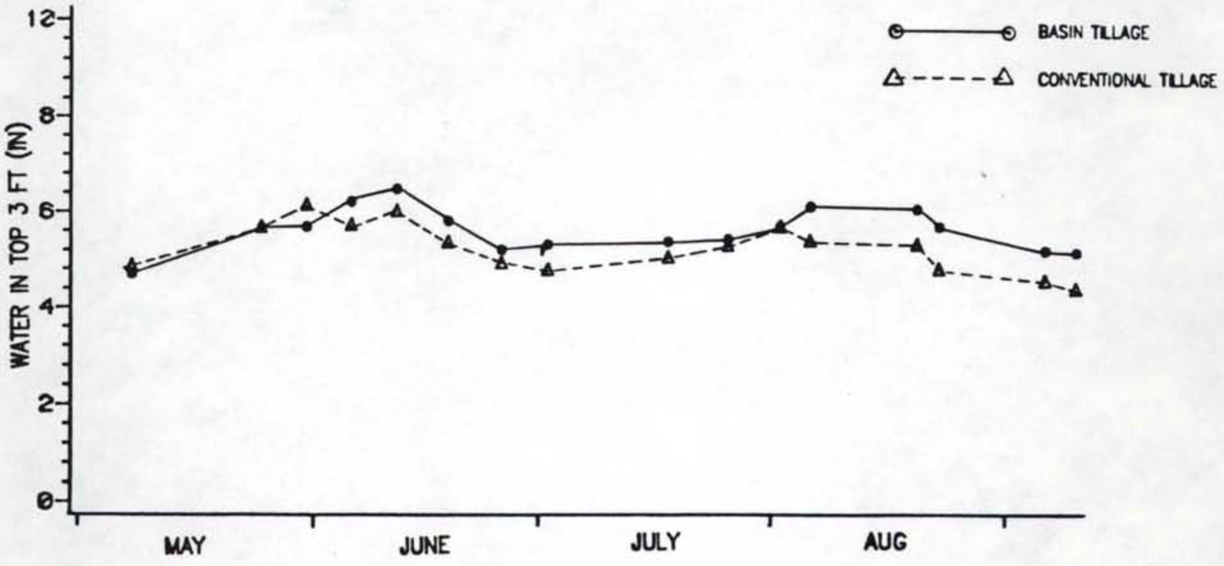


SOIL MOISTURE DATA
UI 237 (CORN)

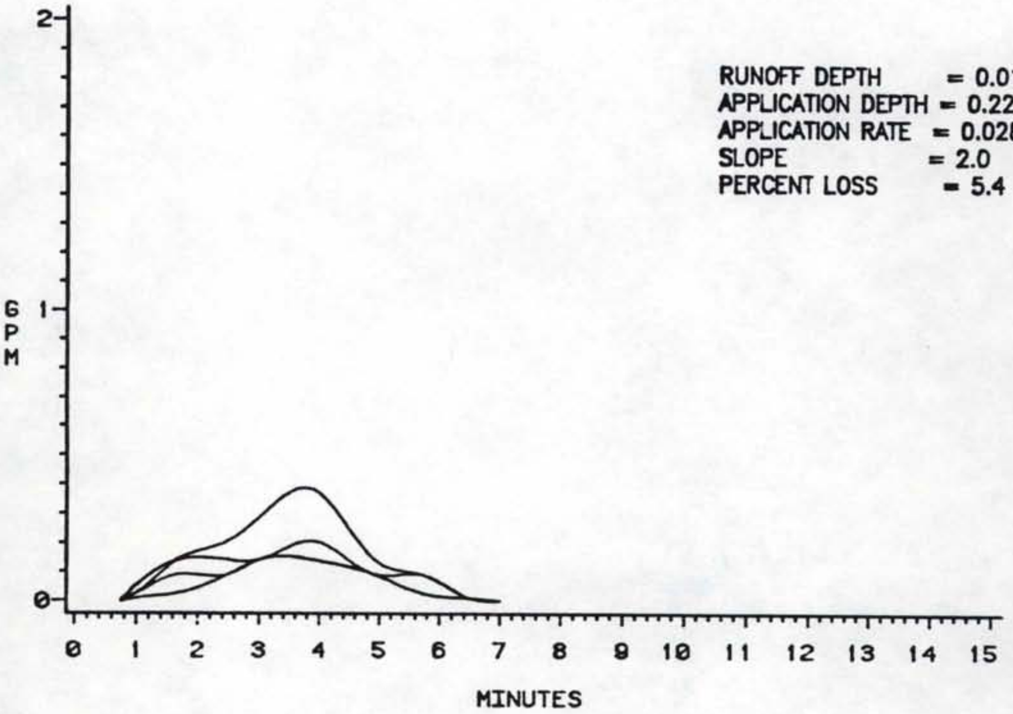
SOIL MOISTURE DATA
UI 235 (CORN)



SOIL MOISTURE DATA
CHATEAU STE MICHELLE (CORN)

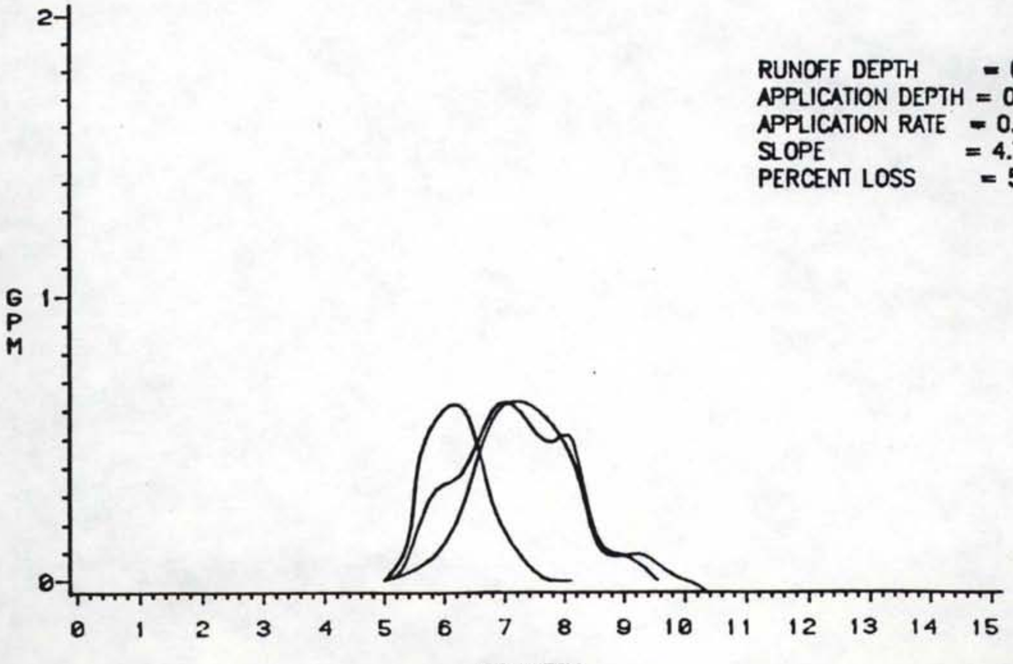


RUNOFF HYDROGRAPH
UI 103
POTATOES
CONVENTIONAL TILLAGE PLOT



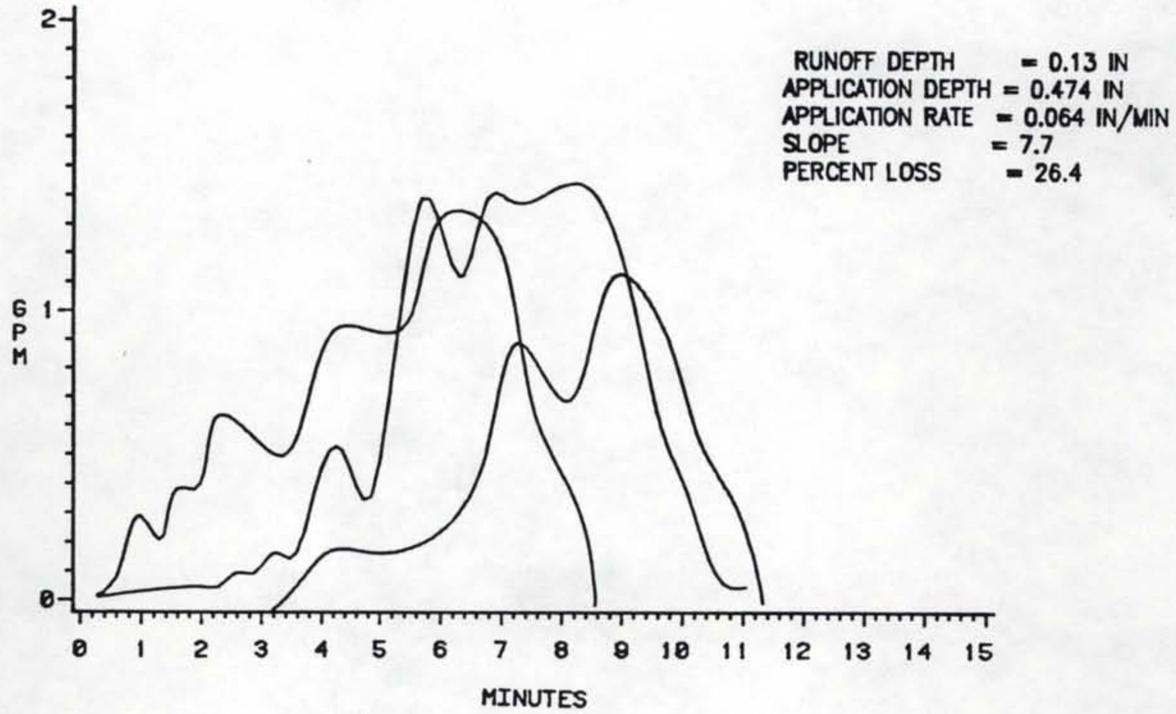
RUNOFF DEPTH = 0.012 IN
APPLICATION DEPTH = 0.22 IN
APPLICATION RATE = 0.028 IN/MIN
SLOPE = 2.0
PERCENT LOSS = 5.4

RUNOFF HYDROGRAPH
LPC PARTNERSHIP
POTATOES
CONVENTIONAL TILLAGE PLOT



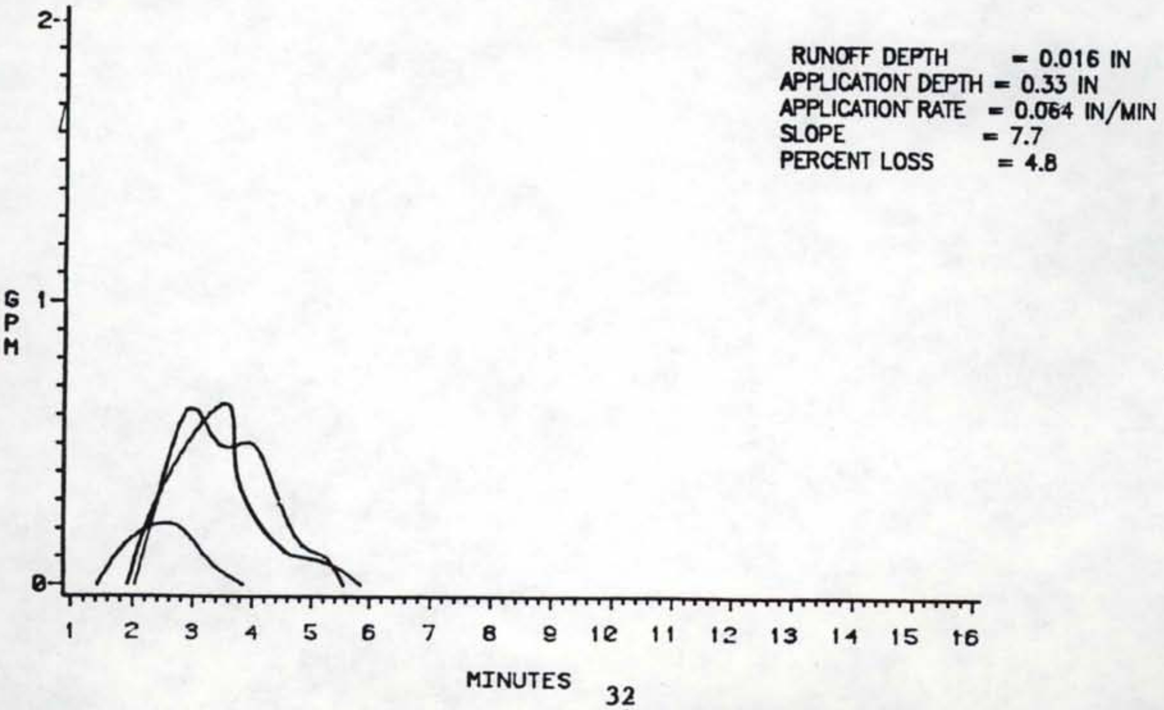
RUNOFF DEPTH = 0.022 IN
APPLICATION DEPTH = 0.38 IN
APPLICATION RATE = 0.087 IN/MIN
SLOPE = 4.7
PERCENT LOSS = 5.9

RUNOFF HYDROGRAPH
EASTERN OREGON FARMS
POTATOES
CONVENTIONAL TILLAGE PLOT



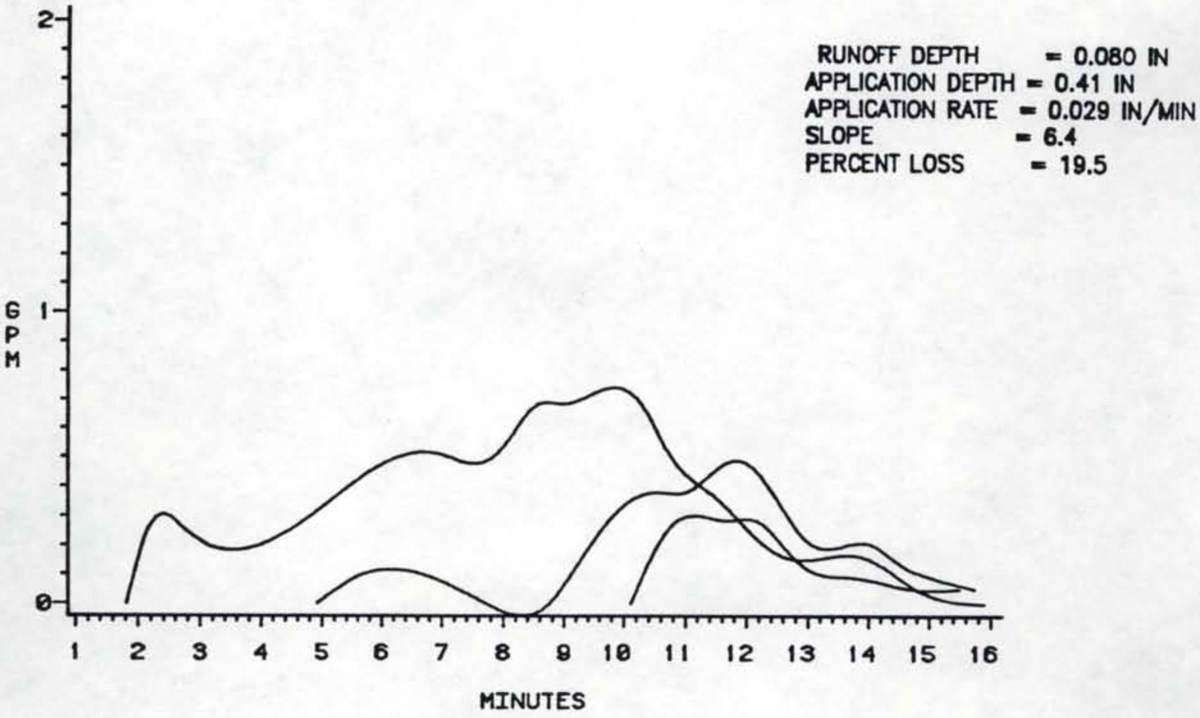
RUNOFF DEPTH = 0.13 IN
APPLICATION DEPTH = 0.474 IN
APPLICATION RATE = 0.064 IN/MIN
SLOPE = 7.7
PERCENT LOSS = 26.4

RUNOFF HYDROGRAPH
EASTERN OREGON FARMS
POTATOES
CONVENTIONAL TILLAGE PLOT

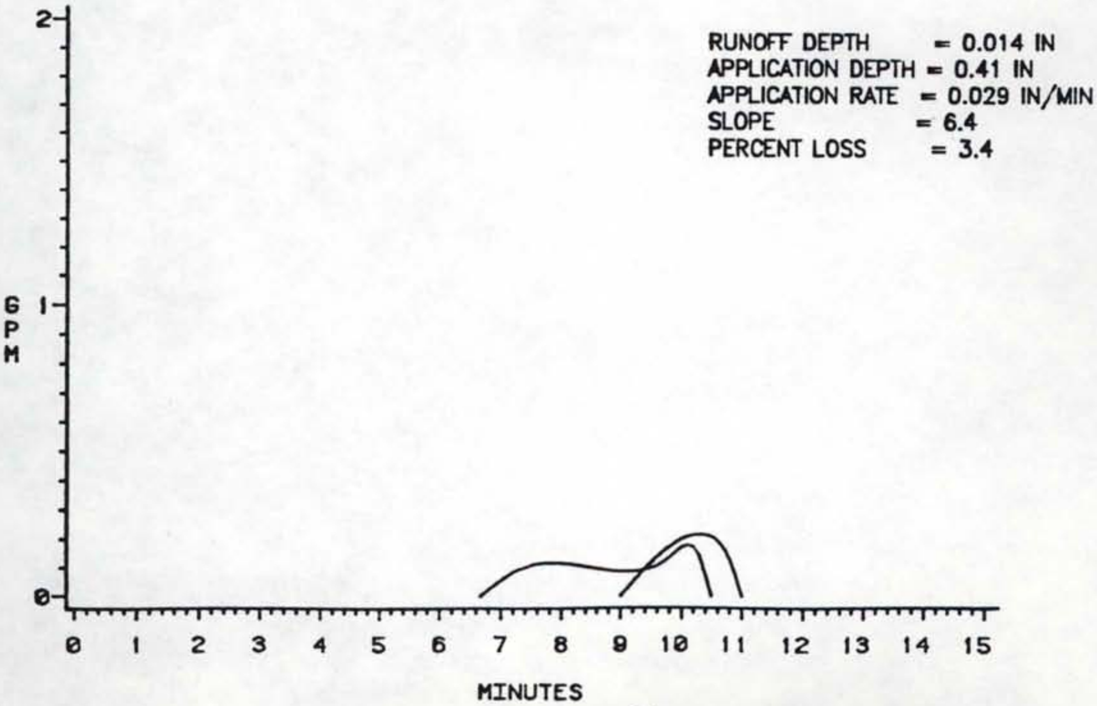


RUNOFF DEPTH = 0.016 IN
APPLICATION DEPTH = 0.33 IN
APPLICATION RATE = 0.064 IN/MIN
SLOPE = 7.7
PERCENT LOSS = 4.8

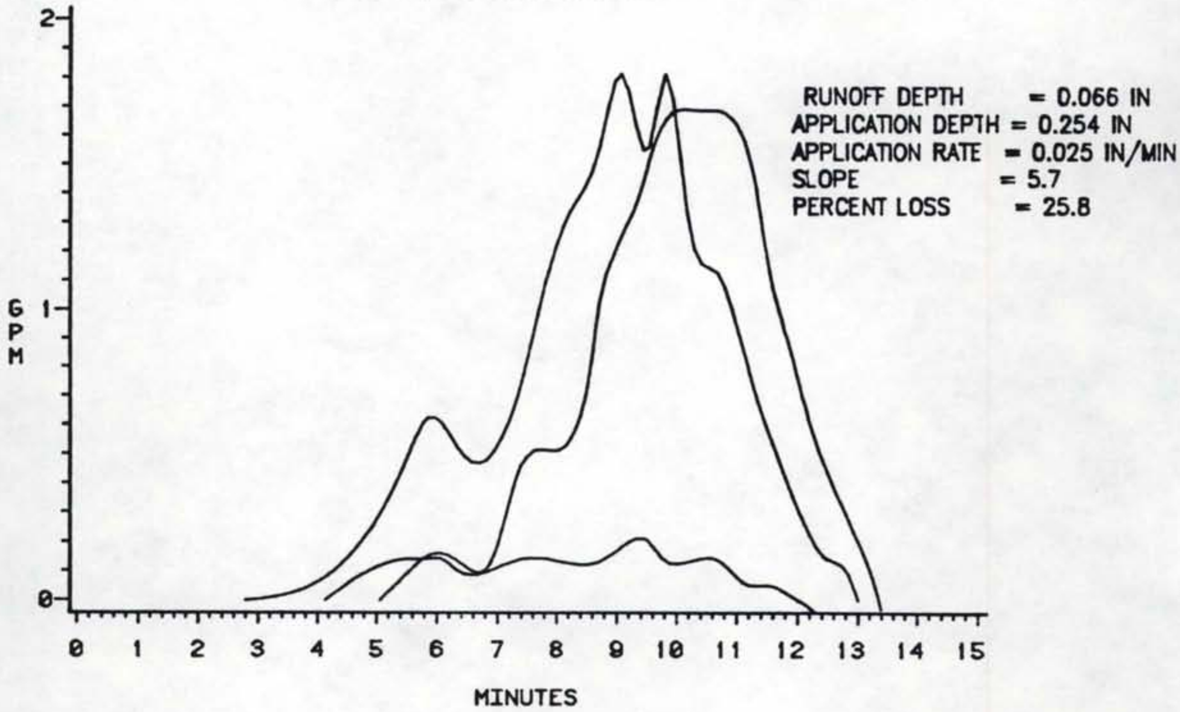
RUNOFF HYDROGRAPH
UI 237
CORN
CONVENTIONAL TILLAGE PLOT



RUNOFF HYDROGRAPH
UI 237
CORN
BASIN TILLAGE PLOT

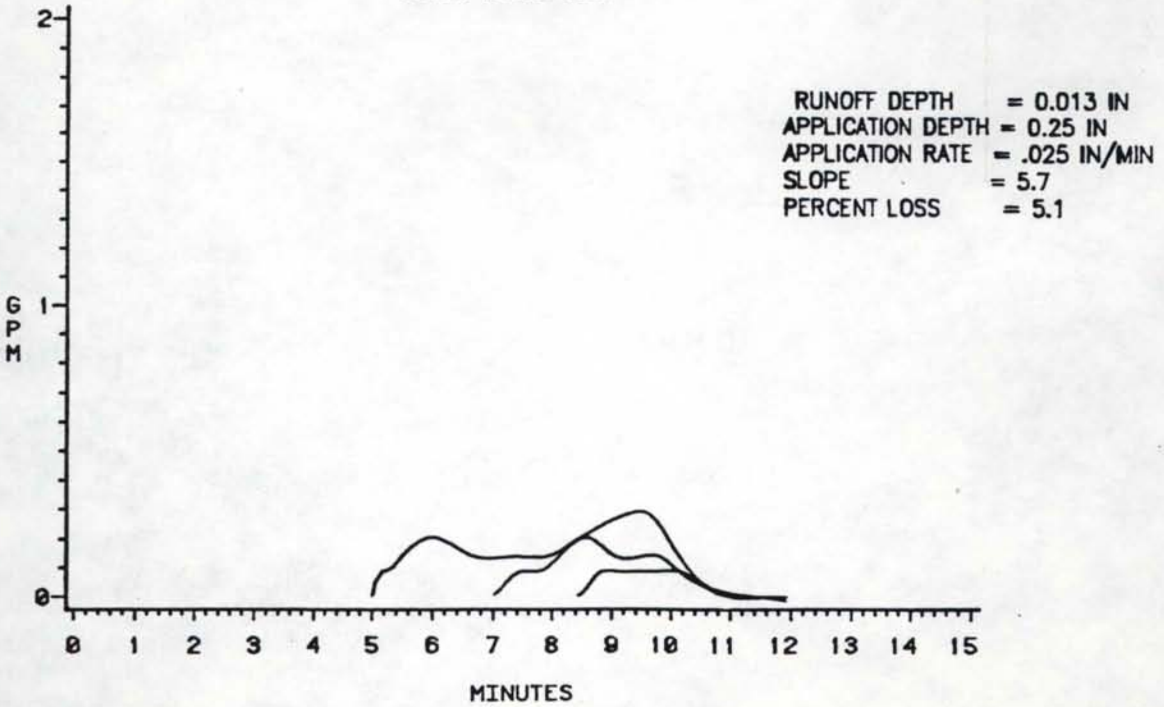


RUNOFF HYDROGRAPH
CHATEAU STE MICHELLE
CORN
CONVENTIONAL TILLAGE PLOT



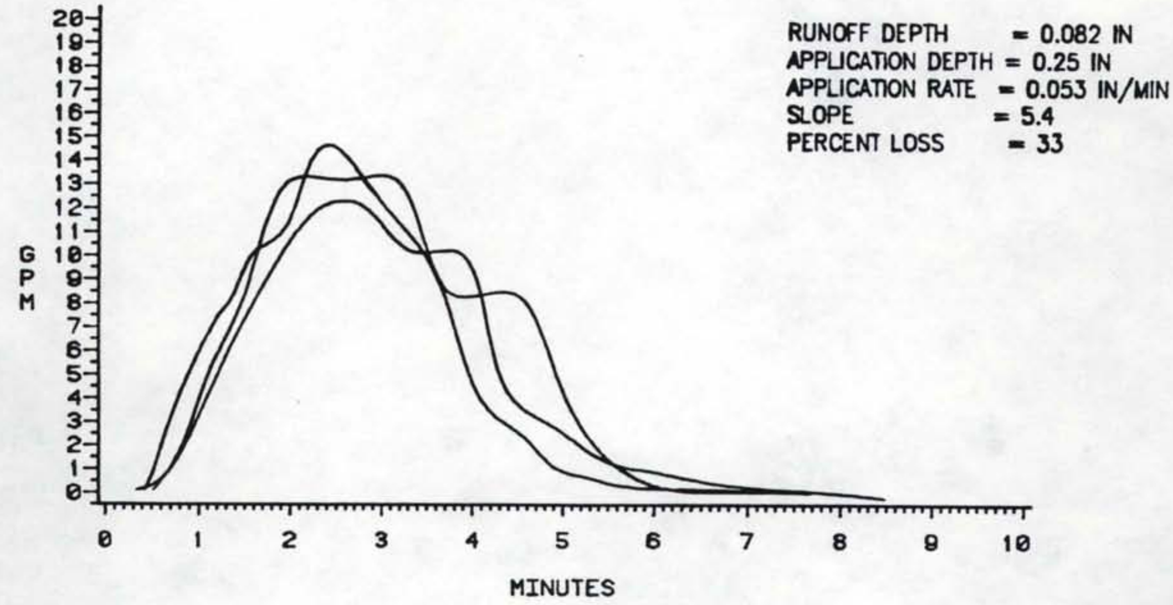
RUNOFF DEPTH = 0.066 IN
APPLICATION DEPTH = 0.254 IN
APPLICATION RATE = 0.025 IN/MIN
SLOPE = 5.7
PERCENT LOSS = 25.8

RUNOFF HYDROGRAPH
CHATEAU STE MICHELLE
CORN
BASIN TILLAGE PLOT

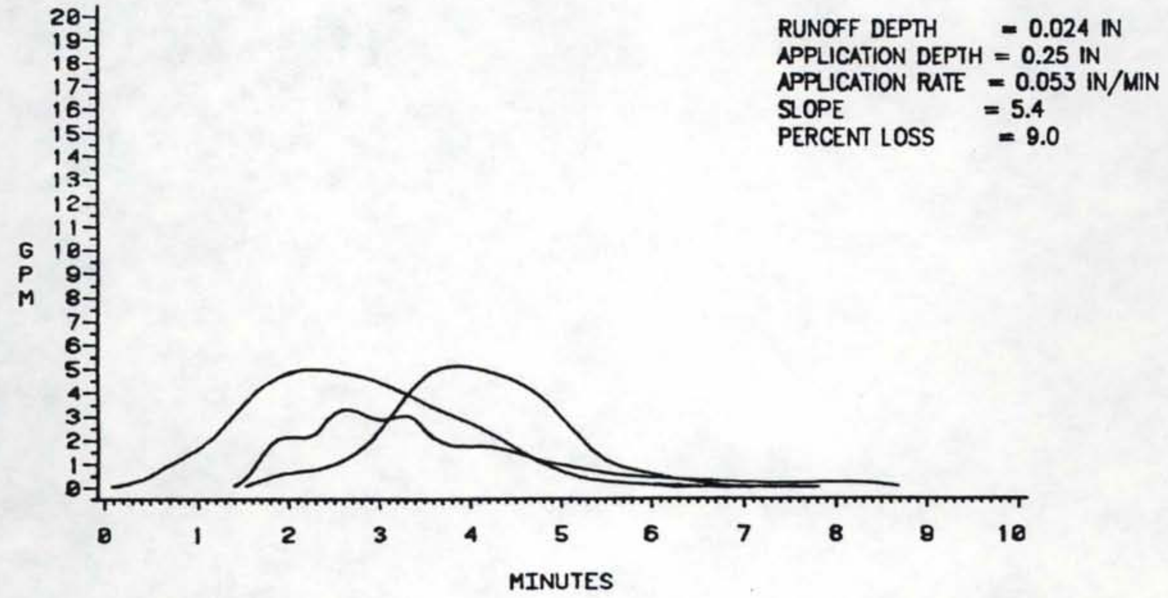


RUNOFF DEPTH = 0.013 IN
APPLICATION DEPTH = 0.25 IN
APPLICATION RATE = .025 IN/MIN
SLOPE = 5.7
PERCENT LOSS = 5.1

RUNOFF HYDROGRAPH
SUNHEAVEN FARMS
WINTER WHEAT
CONVENTIONAL TILLAGE PLOT

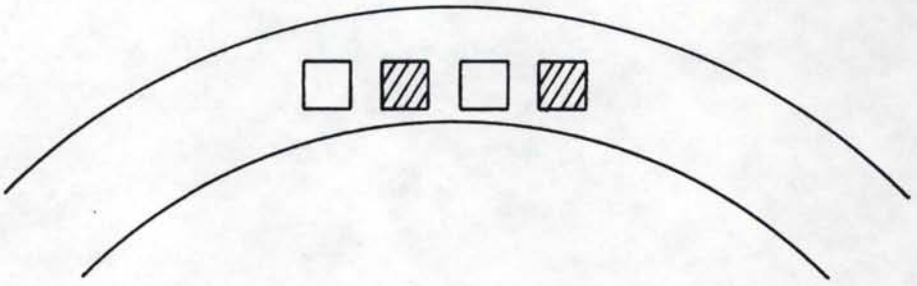

RUNOFF DEPTH = 0.082 IN
APPLICATION DEPTH = 0.25 IN
APPLICATION RATE = 0.053 IN/MIN
SLOPE = 5.4
PERCENT LOSS = 33

RUNOFF HYDROGRAPH
SUNHEAVEN FARMS
WINTER WHEAT
BASIN TILLAGE PLOT


RUNOFF DEPTH = 0.024 IN
APPLICATION DEPTH = 0.25 IN
APPLICATION RATE = 0.053 IN/MIN
SLOPE = 5.4
PERCENT LOSS = 9.0

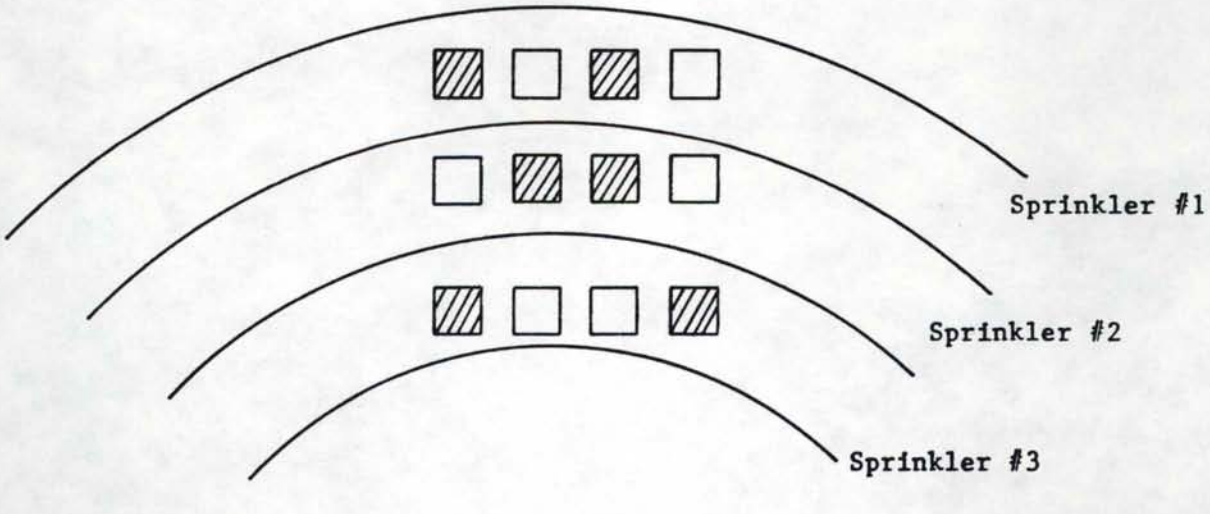
EXPERIMENTAL DESIGNS

Completely randomized design -- Used to evaluate the effects of reservoir tillage only



▨ -- Reservoir tillage
☐ -- Conventional tillage

Split plot factorial -- Used to evaluate the effects of both reservoir tillage and different sprinkler application treatments



▨ -- Reservoir tillage
☐ -- Conventional tillage