SPRINKLER APPLICATION AND EFFECTS ON CORN YIELD TILLAGE PRACTICES

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There are at least two reasons for irrigation farmers to reduce water use for irrigated crop production. One is to conserve existing supplies for future use. In many areas of Kansas and other High Plains States, groundwater aquifers are being depleted. A second reason would be to reduce irrigation energy costs associated with pumping. While progress has been make in reducing irrigation water and energy requirements through better irrigation system efficiency and better management efficiency, such as irrigation scheduling, many areas are still withdrawing groundwater faster than the sustainable yield of the aquifer.

Irrigated crop production management strategies initially did not place much priority on utilizing naturally occurring water sources such as stored soil water from off-season precipitation or in-season rainfall. Past irrigation research studies most often focused on single crop production system with various irrigation treatments. Several recent and current studies consist of crop rotation and tillage procedures which try to identify production systems which utilize natural precipitation more efficiently and minimize irrigation requirement. Dryland production studies also look at production systems that better capture, store, and utilize available precipitation. These same ideas, when applied to irrigated crop production, could result in a reduction of irrigation water requirement, if indeed more of the available annual rainfall is captured. Norwood (1994A), for example, showed in a dryland study using a combination of wheat, sorghum and fallow which had conventional and no-tillage treatment imposed on the rotations, that the no-tillage system was more efficient in storage of precipitation. Norwood (1994B) compared various limited irrigation and dryland cropping systems at Garden City, Kansas, and showed substantial yield increases by adding limited irrigation to wheat- grain sorghum- fallow rotation in 1991. Irrigated continuous wheat and grain sorghum were compared to a wheat-sorghum-fallow rotation where one, both or neither crop was irrigated. In the wetter 1989 and 1990 seasons, limited irrigation benefits were negligible. A conclusion from this study was that no single system is best for all conditions. In addition, producers with little water should probably irrigate fallow systems, while those with more water can crop more intensely. Schalegel and Dhuyvetter (unpublished data, Tribune Experiment Field) showed limited irrigation in wheat-sorghum-fallow rotation have yield increases of 9 and 38 bu/acre for wheat and sorghum respectively. The best allocation of the limited water resources was to have the amount directed to grain sorghum only rather than split between wheat and grain sorghum or wheat only. Lamm (1989) showed the possibilities of dryland corn production in a wheat-corn-fallow production system. Their tillage systems were used with a no-tillage system resulting in slightly higher average yields. Average no-till yields were 72 bu/acre. Year to year yield variability was quite high. Stability to the production system could be obtained with the addition of a limited amount of irrigation water such as the production system discussed by Norwood (1994B). The increasing popularity of early planted early corn for some Kansas producers, indicate a willingness to try to closely match production systems with natural precipitation cycles.

Seasonal water needs of High Plains crops are largely known and discussed beginning with first presentation in 1989 of this Central Plains Short Course (Shawcroft 1989). Others, including Martin et al. (1991, 1992), Wenstrum (1993), Clark, Klocke, and Kizer (1995) all addressed crop water needs. Rogers et al. (1992), showed a crop water use chart, based on western Kansas research plots, for western Kansas corn production (Figure 1). Figure 1 indicates that on average about 26 to 27 inches of water use is needed to reach the yield potential of full season corn. This typically required about 14 to 16 inches of net irrigation water. Net irrigation requirement quantities from the NRCS irrigation guide are also typically around 14 inches. On the deep silt loam soils of western Kansas, around 10 inches of available soil water can be stored of which 5 to 6 inches is to be readily available. With net irrigation requirements established at around 14 inches, this suggests more of the in-season precipitation might be better utilized in fully irrigated fields, although capture of intense summer thunderstorm precipitation is difficult. This also suggests good scheduling procedures to minimize loss of irrigation or precipitation water while maintaining productivity has merit but also increased capture of in-season could reduce irrigation requirements for fully irrigated crops or enhance yields for limited irrigated crops. Practices to increase capture of precipitation may also have the additional benefit of reducing irrigation water movement within a center pivot irrigated field or runoff from the field.

Runoff from center pivots can occur anytime the rate of application exceeds the infiltration rate of the soil, although it can be held in place by soil surface with increases with roughness, residue, impeding structures. Numerous studies have documented runoff. Addink (1975) reported runoff of up to 65% of the total water applied by irrigation and rainfall on field areas irrigated by low pressure spray sprinklers and up to 22% of the field areas under high pressure sprinklers. Kincaid et al. (1969) also measured 22% applied water runoff for the field conditions under high pressure center pivot system.

Aarstad and Miller (1973) recorded runoff rates of 40% and relatively flat slopes. Gilley and Mielke (1980) measured runoff rates of 25%, 9% and 28% for high pressure impacts, low pressure impacts, and spray nozzle systems, respectively. Plant population difference could account for some of the high runoff for the high pressure system. Buchleiter (1991) showed no runoff with an in-canopy sprinkler for a 1% slope but had 30% runoff when slope increased to 3%.

Irrigators have a wide choice of sprinklers packages including the combination of actors such as type of nozzle, discharge rate, pressure, spacing and managing height. They also can select from a variety of cultural practices including residue management and soil surface modification. The latter could include implanted reservoirs or dammer dikers. The LEPA concept of sprinkler irrigation developed in Texas has influenced sprinkler package selection preferences in Kansas but in a modified form. A common sprinkler configuration is an in-canopy nozzle placement.

Many irrigators want to conserve water resources and select in-canopy systems to try to increase irrigation efficiency. While application efficiency may increase, over- all efficiency may decrease if runoff from the field or water movement within the field occurs. Personal conversation with various crop consultants, irrigators, and agency personal indicate this is an increasing problem.

Kranz (1989 , 1994) and Spurgeon et al. (1993) have previously discussed interaction of sprinkler management and tillage systems. Spurgeon et al. (1995) gives guidelines for sprinkler package selection for runoff control. These, as well as other Central Plain Short Course presentations, have discussed details of sprinkler management for runoff control. The remainder of this paper will review recent sprinkler/tillage work from Kansas.

A LEPA frequency of irrigation study was conducted at Garden City, Kansas from 1989 to 1991 (Spurgeon and Makens 1992). The study also included reduced or limited irrigation water treatment. Irrigation frequencies were an application applied every 3.5, 7, or 10.5 days. The amount applied was 0.4, 0.7, 1.0 or 1.3 times a base irrigation (BI) amount as determined crop water use. Results are summarized in Figures 2 and 3 and Tables 1 and 2.

Figure 2 shows that frequency did not have a major influence on yield. The 7-day frequency had the highest yield but not significantly better than the 3-day frequency. The 10.5-day frequency had the highest yield but not significantly less than 3-day. The deep silt loams of the study site have high available water holding capacity which help buffer the crop from water stress during the long irrigation intervals. The high frequency allows a smaller application amount that reduces likelihood of runoff losses, although runoff losses should not have been a factor in this study.

The application amount resulted in increasing yield with increasing water use until the 1.0 treatment which was full irrigation. No additional yield benefit was apparent for the additional water applied by the 1.3 BI irrigation treatment. In 1991, a 0.0 BI irrigation treatment was added, however it received 2.5 inches of irrigation. This yield was 106.4 bu/acre.

A runoff/tillage study conducted in 1990 and 1991 (Spurgeon and Makens 1992) compared the effects of LEPA bubble mode to flat spray on sloped soils. Tillage treatments were control, dike, rip, and dike and rip. The effectiveness of the sprinkler mode and tillage treatment were measured by yield response (Table 3). Runoff control on the sloped soils (up to 6%) was a problem. The flat spray had less runoff as indicated by the higher yield. (222 bu/ac versus 166.8 bu/ac). Yield also improved with more tillage induced surface storage with the dike/drip combination having the highest yield for either sprinkler mode. Some observation of erosion of rip channels was noted as reported also in Nebraska by Kranz (1989).

The effect of slope is shown in Figures 4 and 5. Yields decreased under both sprinkler modes and all tillage systems with increasing slope, although flat spray out-performed bubble mode. The more aggressive tillage systems resulted in better yield with increasing slope. However, dependance on tillage treatments to control runoff also come with a price (equipment, energy and time) and risk, such as wet conditions preventing installation of a treatment.

In 1993 and 1994, the effect of two irrigation frequency (daily and 3-day) and from application mode (5-ft flat spray, 10-ft flat spray, bubble, and sock) on corn yield and implanted reservoirs were investigated (Vela et al. 1995). (Tables 3-8). Regardless of slope or frequency the 5 and 10 foot spray modes performed better than bubble and sock modes. Yields were best when field slopes were small. Implanted reservoirs volume were reduced to zero (100% degradation) in the nozzle row by early August for sock and bubble mode treatments. Reservoir volume in the nozzle row for flat sprays were reduced to about 65% by the end of August. Rainfall degradation effects were about 44%, based on results of measurements in non-nozzle runs for such treatments.

Water conservation is an important consideration for irrigators, especially for irrigators in declining groundwater areas. There are many options available to the irrigator in terms of irrigation systems, cultural practices and other management decisions. Adaption of new technology and practices from one area to another is an important method of improving productivity and economic well being. However, careful consideration of the effect of changes on over-all farm productivity, efficiency or economic well-being must be made. Adoption of in-canopy sprinkler nozzles for fields on relatively uniform slope and low-capacity wells often increases irrigation efficiency but may be unsuitable on undulating or steep fields. Tillage practices can also increase over-all irrigation efficiency but may not be energy cost effective.

Table 1

Effect of Irrigation Frequency and Amount on Corn Yield (bu/ac), Southwest Research-Extension Center, 1989-1991.

Fraction of BI	Irrig. Inches	Irrigation Frequency, Days 3.5	7	10.5	AVG
1991					
0.0		85.7	127.7	105.8	106.4
0.4		166.6	153.3	155.8	158.6
0.7		194.5	209.7	184.4	196.2
1.0		228.1	218.2	217.8	221.4
1.3		219.9	228.5	204.5	217.7
AVG		179.0	187.5	173.7	
3-year average					
0.4		155.7	154.2	157.7	155.9
0.7		180.4	194.3	175.3	183.3
1.0		209.8	203.1	200.3	204.4
1.3		206.7	214.4	194.4	205.2
AVG		188.1	191.5	181.9	

Table 2

Irrigation Amounts, In Inches, for 1991.

Fraction of BI	Irrigation Frequency, Days 3.5	7	10.5
0.0*	2.5	2.5	2.5
0.4	9.5	8.9	8.0
0.7	14.8	13.6	12.2
1.0	20.0	18.4	16.3
1.3	25.3	23.1	20.5

* All plots received a small amount of irrigation until modifications were made to the irrigation system.

Table 3

Average Corn Yield for an Irrigation Application Frequency and Application Mode at Garden City, KS (1993-94)

Application Treatment	Frequency: Daily Ave Slope + 2.36%	3-day Ave slope = 2.5%	Frequency Average
5-ft	168.7	172.7	170.7
10-ft	170.3	177.4	173.8
Bubble	163.9	142.9	153.4
Sock	147.2	143.3	145.3

Table 4

1993-1994 Average Percent cumulative Reservoir Volume Reduction For 3-Day Irrigation Frequency Treatments

Average slope = 2.81%

	Bubble		Sock		5 ft		10 Ft		
	Nz	Near	Nz	Near	Nz	Near	Nz	Near	Far
1st Reading	88.84	41.10	80.37	28.04	46.16	41.56	49.74	32.28	38.14
2nd Reading	95.63	59.80	95.08	38.75	62.78	52.19	66.45	52.20	53.13
3rd Reading	99.02	66.56	96.80	46.26	69.95	60.40	66.47	58.04	59.45

Table 5

1993-1994 Average Percent cumulative Reservoir Volume Reduction
For Daily Irrigation Frequency Treatments

Average slope = 2.36%

	Bubble		Sock		5 Ft Spray		10 Ft Spray		
	Nz	Near	Nz	Near	Nz	Near	Nz	Near	Far
1st Reading	77.58	30.79	76.64	23.76	35.60	20.13	34.09	33.31	26.05
2nd Reading	96.42	45.65	94.71	32.26	48.68	34.19	57.88	49.04	37.39
3rd Reading	98.37	54.41	95.41	40.99	62.01	44.74	54.95	50.74	40.93

Table 6

1993-1994 Average percent cumulative Reservoir Volume Reduction

Average Slope = 2.58%

	Bubble		Sock		5 Ft		10 Ft		
	Nz	Near	Nz	Near	Nz	Near	Nz	Near	Far
1st Reading	83.21	35.95	78.50	25.90	40.88	30.84	41.92	32.80	32.09
2nd Reading	96.03	52.72	94.90	35.50	55.73	43.19	62.16	51.09	44.80
3rd Reading	98.70	60.49	96.10	43.62	65.98	52.57	60.71	54.39	50.19

Figure 1. Corn Water Use and Irrigation vs. Yield from Western Ks. Research Plots

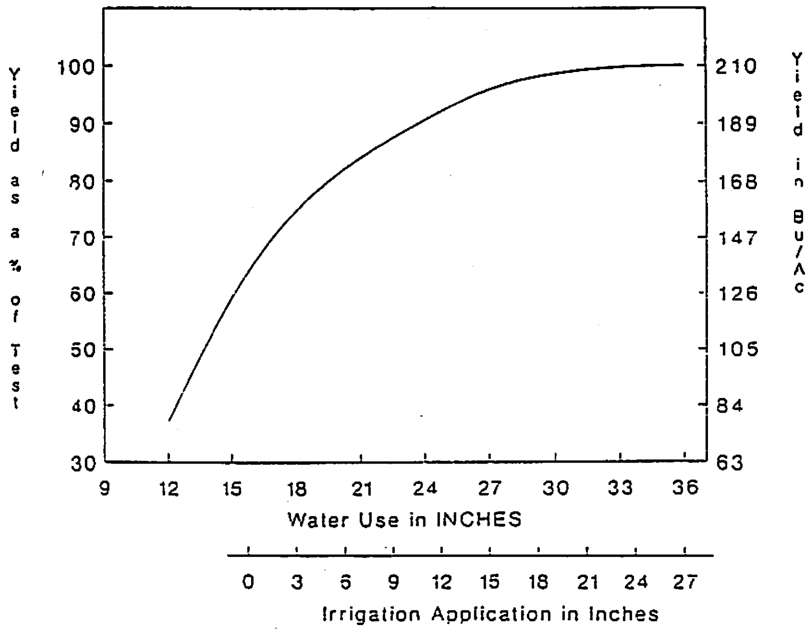
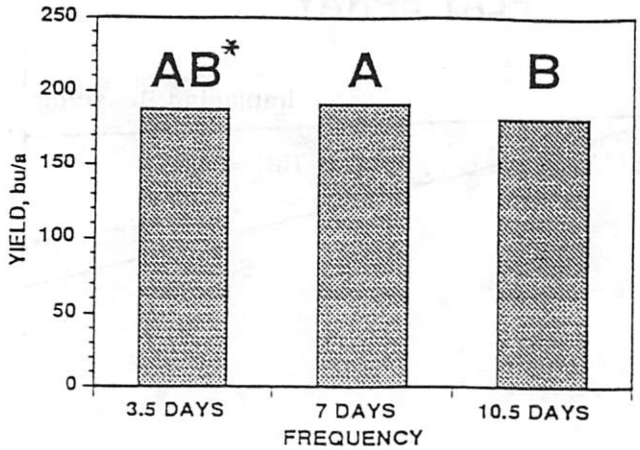
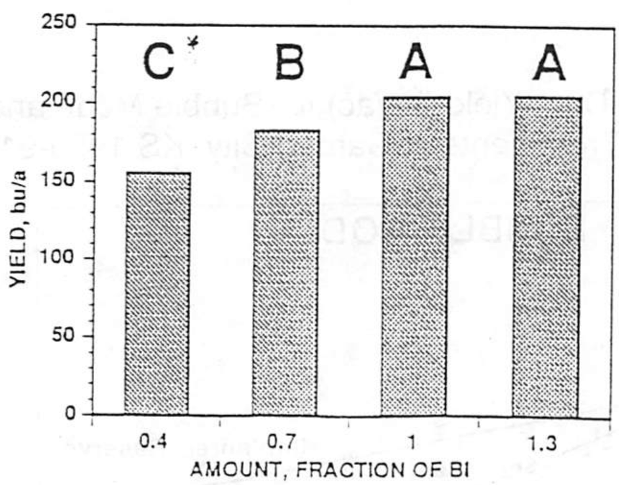


Figure 2. Three-year average corn yield for frequency treatments.



* Columns with the same letters are not statistically different.

Figure 3. Three-year average yield for amount treatments.



* Columns with the same letters are not statistically different.

Figure 4. Predicted Corn Yield (bu/ac) for Spray Mode and Tillage Treatments at Garden City, KS 1990-91

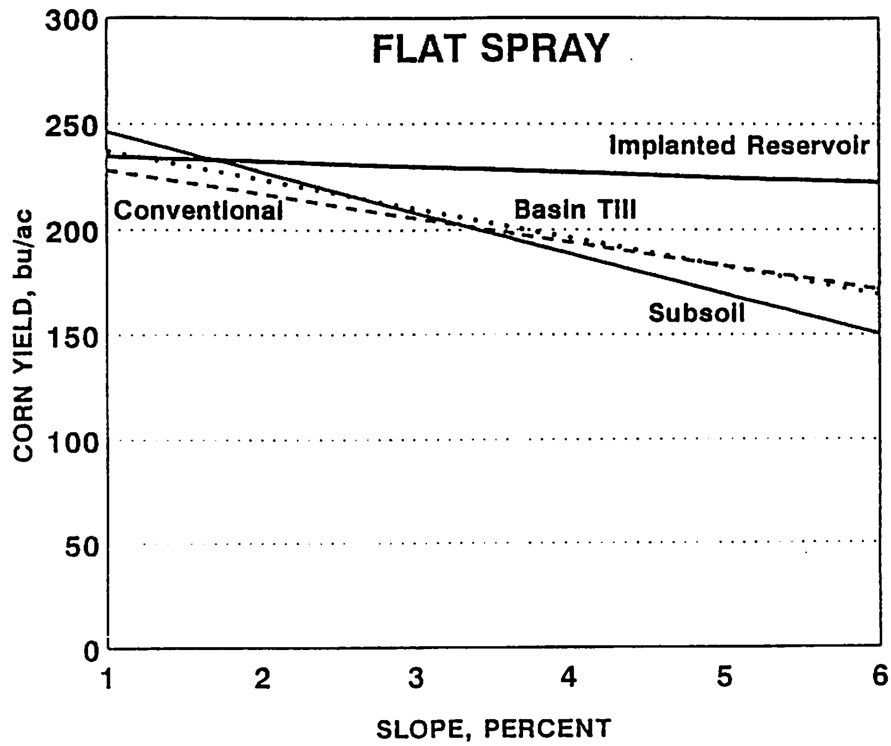
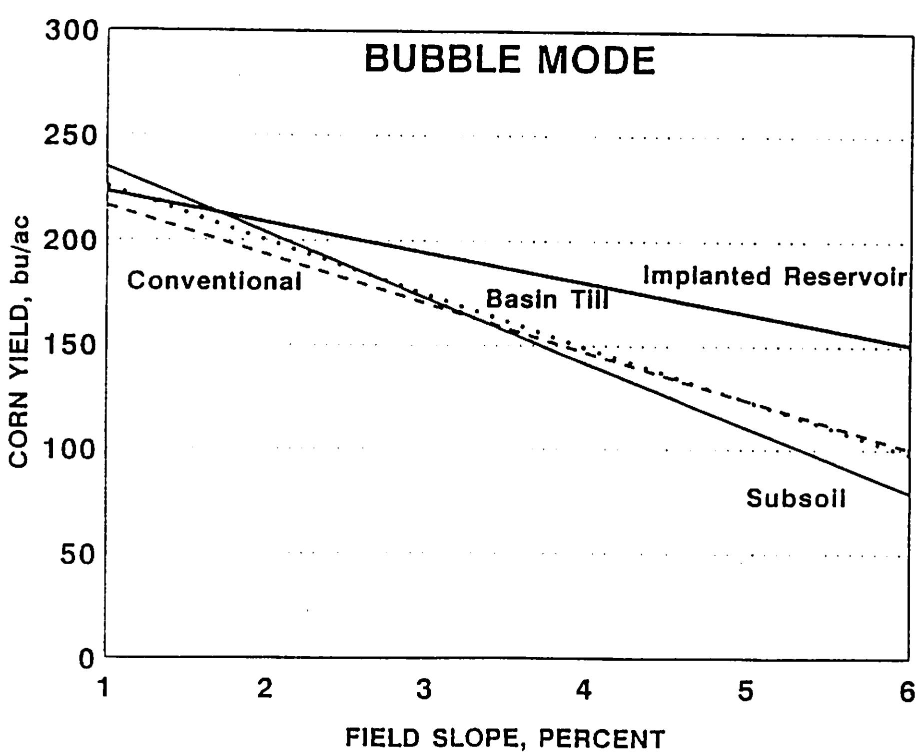


Figure 5. Predicted Corn Yield (bu/ac) for Bubble Mode and Various Tillage Treatments at Garden City, KS 1990-91



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