Integrating Irrigation and Conservation Tillage Technology

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There is an important relationship between conservation tillage practices and irrigation methods. The choice of a conservation tillage program may be limited by the existing irrigation system, or a change in irrigation systems could be necessary to implement a desired conservation tillage program. Traveling overhead irrigation systems lend themselves well to no-till or minimum-tillage farming operations while furrow irrigation would be of questionable use under high-residue conservation tillage conditions. An exception might be a furrow system irrigating moderate to steeply sloping no-tilled ground where the stubble and residue serve to reduce the rate of advance and runoff. A modified no-till or limited-till system could possibly be used in which furrow bottoms were cleaned and smoothed while leaving the tops of beds in a no-tilled condition. Surface or subsurface drip systems are an option for water distribution for conservation tillage but lack the capability of foliar chemigation afforded by the overhead systems. Surface drip systems require additional trips through the field for installation and removal of drip lines unless harvesting and planting can be accomplished with the lines in place. In general, the management of irrigated no-till or reduced tillage is greatly enhanced with overhead irrigation systems.

One of the primary advantages of moving overhead irrigation systems in a conservation tillage operation is the ability to apply chemicals through the system (chemigation), thus decreasing ground operations or eliminating the expense of aerial applications. Research at the Texas Agricultural Experiment Station, Halfway, is directed toward efficient chemical application through moving irrigation systems to both conservation tillage and conventionally tilled plots. Other research is focused at determining the effects of various conservation tillage treatments and crop rotations on yield and soil moisture storage under both irrigated and dryland conditions. The following is an overview of this research.

Rotation/Tillage Studies

Methods. A replicated irrigated/dryland rotation test, initiated in 1982, was expanded in 1985 to include tillage treatments in a split plot factorial experimental design. The main plots are either irrigated or dryland with irrigation being by LEPA methods. The rotation subplots consist of continuous cotton and a cotton-wheat rotation in which wheat in the rotation treatment is sown in the stalks immediately after cotton harvest. Wheat plots remain fallow during the summer until cotton is planted the next spring.

The conventional tillage treatment in the sub-subplots includes chiseling, sweeping, disking, bedding, rod weeding, and cultivation as needed. All operations are not necessarily performed each year. The alternate tillage method in the sub-subplot is no-tillage with the exception of fertilizer placement. Nitrogen and phosphorus fertilizer is placed through the side of the bed with a swept-wing applicator that bands the fertilizer about 15 cm under and 20 cm to the side of the cotton plants. This type fertilizer treatment results in minimum disturbance to the soil.

Sub-sub-subplots consist of either diked or non-diked treatments. The no-till diked treatment is referred to as a limited-till treatment with diking and dike removal being the only tillage operation other than fertilizing. The diking is confined to the bottom of the furrows with the top of the beds left undisturbed.

Results. The 1986 growing season was the first in which results were available from the added tillage treatments. Very positive response to rotation before 1986 had been observed in both irrigated and dryland tests. These data are summarized in Table 1.

The 1984 irrigated rotation cotton lint yield was 42 kg/ha greater than continuous cotton. This rotation treatment also started the year with about 4 cm more soil moisture in the soil profile than did continuous cotton. Dryland yields were increased 63 kg/ha because of the wheat rotation and had about 3 cm more water in the root zone at the beginning of the season.

The 1985 irrigated rotation treatment out-yielded the continuous treatment by only 23 kg/ha, which may have been due to similar beginning soil moisture. A large increase was measured due to the rotation in the dryland tests (114 kglha), although beginning profile moisture was only 1.6 cm higher in the rotation treatment.

The 1986 yields shown in Table 2 depict the additional subplot treatments of tillage and diking. Rotation again had a positive effect under irrigation, increasing lint yields averaged over all tillage treatments by 43 kg/ha. Rotation in 1986, however, had a detrimental effect on dryland yields, which were decreased an average of 48 kg/ha because of the wheat rotation. These yield differences were not significant at the 0.05 level. Diking also decreased yields for the first time since it was reintroduced in 1976. This was attributed to higher than normal rainfall during the growing season, which caused flooded conditions at times.

There was no difference in irrigated yields because of tillage. However, the no-till dryland treatments out-yielded the conventional tillage treatments by an average of 75 kg/ha and were significantly different (0.05).

Both rotation and no-till treatments increased the moisture content in the soil profile at the beginning of the growing season (Table 3). These values are given for

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TABLE 1. CROP ROTATION RESULTS AT THE TEXAS AGRICULTURAL EXPERIMENT STATION, HALFWAY, TEXAS, 1984-85

Year	Irrigated		Dryland	
	Cotton Yield (kg/ha)	Beginning Soil Moisture' (cm)	Cotton Yield (kg/ha)	Beginning Soil Moisture (cm)
1984				
Cotton-Wheat Rotation	**453.3**	**48.8**	359.7*	**48.5**
Continuous Cotton	**411.6**	**44.7**	**296.4**	**45.2**
1985				
Cotton-Wheat Rotation	**463.0**	**47.8**	354.2*	**48.8**
Continuous Cotton	**440.5**	**47.5**	**239.9**	**47.2**

'Soil moisture in 1.5 m soil profile at beginning of season.
***Significantly different at 0.05 level.**

TABLE 2. EFFECT OF CROP ROTATION AND TILLAGE ON COTTON YIELD (KG LINT/HA) AT THE TEXAS AGRICULTURAL EXPERIMENT STATION, HALFWAY, TEXAS, 1986

Tillage	Irrigated			Dryland			
	Con-tinous Cotton	Cotton -Wheat Rotation	Irrigated Averages	Con-tinous Cotton	Cotton -Wheat Rotation	Dryland Averages	Overall Averages
Conventional	**924.1**	**983.1**	**953.6** a*	**622.1**	**606.3**	**614.2** bc	**783.9** ab
			920.1			**595.8**	**757.9**
Conv./Diked	**869.3**	**903.9**	**886.6** a	**612.0**	**542.8**	**577.4 c**	**732.0** b
No-Ell	940.1	**941.8**	**941.0a**	**678.0**	**694.5**	**686.3** a	**813.6** a
			926.8			**670.9**	**798.3**
Min-Till/Diked	**860.8**	**959.6**	**910.1** a	**674.5**	**636.6**	**655.6ab**	**782.9** ab
Averages	**898.6**	**947.1**	**922.8**	**645.8**	**597.6**	**633.4**	

***Numbers with the same letter behind them are not significantly different at the 0.05 probability level.**

both the 1.5-m soil profile and the top 0.6-m depth. Rotation increased beginning soil moisture by more than 2.5 cm in both irrigated and dryland treatments. No-till irrigated treatments had 2.1 cm more stored soil moisture than did the irrigated conventional, and the dryland no-till stored 3.3 cm more water than did the conventional tilled treatments.

Measured water extracted from the root zone as determined by neutron methods taken throughout the growing season is given in Table 4. There was little difference because of rotation but substantial differences because of tillage. The no-tilllnon-diked treatment stands out as superior in moisture extraction to all other treatments. This corresponds to the highest yield average also achieved by the no-till treatment.

Chemigation Research

Methods. Chemigation research is being carried out with an experimental multiple-use LEPA system that was developed for very precise chemical application through a separate nozzle system. The multifunction irrigation system (MFIS) is a linear-move irrigation system that was developed to use automated, programmable, dynamic nozzle movement and uniform constant forward movement to achieve precise and efficient water and chemical application (Lyle and Bordovsky, 1986). The system uses two independent nozzle systems (one each for water and chemical application), which are both capable of dynamic horizontal and vertical movement. The amplitude and oscillation period of the vertical dynamic nozzles are controlled by a programmable microprocessor along with the spray period and choice of independent or simultaneous span operation capability. Constant uniform movement is achieved by variable frequency A.C. control of the tower motors. A primary objective in the development of the systems was to facilitate a total no-till system.

Extensive spraying tests were initially conducted to evaluate chemical application with the MFIS using lithium salt solutions as tracers and analysis with atomic

TABLE 3. BEGINNING SOIL MOISTURE (CM), APRIL 9, IN THE 1.5-M SOIL PROFILE AND IN THE TOP (0.6 M) OF THE ROOT ZONE AT THE TEXAS AGRICULTURAL EXPERIMENT STATION, HALFWAY, TEXAS, 1986

Tillage	Irrigated				Dryland					
	Con-tinous Cotton	Cotton -Wheat Rotation	Irrigated Averages		Con-tinous Cotton	Cotton -Wheat Rotation	Dryland Averages		Overall Averages	
Conventional	52.3 (23.1)*	52.8 (21.8)	52.6 (22.6)		46.5 (20.1)	47.5 (20.3)	47.0 (20.2)		49.8 (21.6)	
				52.3 (22.1)				48.3 (20.1)		50.3 (21.3)
Conv./Diked	51.8 (22.4)	52.3 (21.3)	52.1 (21.8)		48.5 (19.8)	49.8 (19.6)	49.3 (19.7)		50.8 (20.8)	
No-Till	48.8 (20.6)	56.4 (23.4)	52.6 (22.1)		49.3 (20.8)	54.1 (23.6)	51.8 (22.4)		52.3 (22.4)	
				54.4 (23.1)				51.6 (22.4)		53.1 (22.8)
Min-Till/Diked	53.6 (22.9)	58.4 (24.9)	56.1 (23.9)		49.5 (21.3)	52.8 (22.9)	51.3 (22.1)		53.8 (23.1)	
Averages	51.6 (22.4)	55.1 (22.9)	53.3 (22.6)		48.5 (20.6)	51.1 (21.6)	49.8 (21.1)			

*( )—Top 0.6-m of **the** root **zone.**

TABLE 4. MEASURED WATER EXTRACTED (CM) FROM THE 1.5-M SOIL PROFILE DURING THE GROWING SEASON AT THE TEXAS AGRICULTURAL EXPERIMENT STATION, HALFWAY, TEXAS, 1986

Tillage	Irrigated				Dryland					
	Con-tinous Cotton	Cotton -Wheat Rotation	Irrigated Averages		Con-tinous Cotton	Cotton -Wheat Rotation	Dryland Averages		Overall Averages	
Conventional	13.5	12.4	13.0		14.5	13.0	13.7		13.5	
				13.0				13.3		13.2
Conv./Diked	11.7	15.2	13.0		12.4	13.2	12.9		13.0	
No-Till	16.8	17.5	17.2		14.7	16.5	15.6		16.5	
				16.8				13.7		15.4
Min-Till/Diked	16.8	16.0	16.4		11.7	11.7	11.7		14.2	
Averages	14.7	15.0	14.9		13.3	13.6	13.5			

absorption spectrophotometry. Analyses included measurement of quantity and uniformity of the chemical application by various available dynamic and stationary modes along with nozzle orientation and nozzle output. Aerial application was analyzed for comparative purposes. Data averaged over four crops (corn, cotton, sorghum, and soybeans) revealed a twofold coverage improvement for the dynamic nozzle movement over stationary application and fourfold better coverage than that obtained with aerial application.

Since initial uniformity and coverage testing, two years have been devoted to applying specific chemicals to numerous crops by both the stationary and dynamic modes. The stationary mode closely duplicates traditional chemigation from low-pressure spray nozzles.

Herbicides were applied by the MFIS to corn, sorghum, soybeans, and cotton under both minimum tillage and conventional tillage conditions. These treatments were compared to conventional spray applications with a ground rig. Water quantity with which the herbicides were applied varied between herbicides and the crop but ranged between 1.3 and 2.6 cm.

Numerous chemical and biological insecticides have been applied to corn, sorghum, and cotton by the MFIS. Replicated aerial applications were also made for comparative purposes.

Foliar fertilizer (29-7-10-4) was applied to soybeans in four and five applications during the pod-filling stages by both stationary and dynamic spraying modes. However, there was no significant response to the foliar fertilizer treatments from either spraying mode.

Other applications have included tallow applied as an antitranspirant to cotton, corn, and grain sorghum. Tallow was also applied to the soil surface as an evapora-

TABLE 5. WEED CONTROL FROM HERBICIDE APPLICATION BY CHEMIGATION AND GROUND APPLICATION (ABERNATHY ET AL., 1985; KEELING ET AL., 1986)

				Pigweed Control (Percent)			
				Chemigation		Ground Application	
Year	Crop	Herbicide	Rate (kg AI/ha)	Conventional	Min-Till	Conventional	Min-Till
1985	Corn	Dual + Propazine	1.96 + .12	100	100	100	100
		Propazine	1.12	100	100	100	100
	Sorghum	Dual + Propazine	1.96 + .12	100	100	100	100
		Propazine	1.12	100	100	100	100
	Soybeans	Dual + Lorox	2.22 + .46	95	70	100	70
		Prowl	0.78	85	65	70	55
	Cotton	Dual + Caparol	1.96 + .68	100	65	90	70
		Prowl	0.84	85	65	85	75
1986	Corn	Dual + Propazine	1.96 + 1.12	100	100	100	95
		Propazine	1.12	100	100	100	100
	Sorghum	Dual + Propazine	1.96 + 1.12	100	85	100	85
		Propazine	1.12	100	90	95	85
	Cotton	Dual + Caparol	1.96 + 1.68	100	87	100	45
		Prowl	1.40	50	80	95	90

tion suppressant. There were no significant differences in yield due to the tallow, although the trend was a yield reduction from its application to the plant as an antitranspirant.

Chemigation Results. Results of 1985 and 1986 herbicides application by chemigation and ground methods are given in Table 5. Pigweed control by chemigation was at least as effective as ground application in almost all treatments. Minimum-tillage pigweed control in cotton and soybeans, however, was not as effective as that in conventional tillage.

Pydrin insecticide was applied by various modes through the MFIS to corn for southwestern corn borer control (Bynum et al., 1986). Excellent results were obtained with three applications using a dynamic 2X spraying mode. Azodrin and Comite miticides were applied at two rates by both the dynamic and stationary spraying modes to corn. Both full and half rates gave excellent mite control when applied with dynamic nozzle movement. However, stationary overhead application that simulated traditional chemigation failed to provide control with either chemical.

A biological insecticide, Dipel, was applied to cotton along with other treatments of Dipel + Chlordimeform and Capture for bollworm control without any significant results. The bollworm infestation was late, nonuniform and not severe enough to actually warrant a control application.

Fairly extensive greenbug control tests on grain sorghum were carried out to verify the earlier results obtained with the lithium tracer tests. The data are reported in Table 6. These data verify the superiority of dynamic in-canopy chemical application over traditional chemigation and aerial application methods. Aerial application required the maximum labeled rate of Lorsban® 4E (0.57 kg [AI]/ha) to maintain effective control for two weeks. Aerial greenbug control dropped to 63 percent and 55 percent after 14 days with half and quarter the maximum labeled rate, respectively. Rates lower than these were not applied aerially. Stationary overhead chemigation remained effective at 3, 7, and 14 days following treatment with rates down to quarter the maximum registered rate (0.14 kg [AI]/ha), but effectiveness dropped drastically at rates below this. Rates of 1/16 the maximum recommended were totally ineffective. On the other hand, the MFIS dynamic treatments produced 75 percent or greater control through the two-week post-treatment period at a chemical rate of 1/16 the maximum labeled rate for Lorsban® (0.035 kg [AI]/ha).

The success of dynamic in-canopy insecticide application has led to preliminary testing of both stationary and manually adjustable in-canopy chemigation nozzles for center pivots. Three different rates of Comite were applied to corn with prototype nozzles in both every row and alternate row treatments from a continuously moving one-tower center pivot. This was compared to above-canopy traditional chemigation. Comite in previous tests had never demonstrated the ability to control mites by overhead chemigation, and this test was no exception. However, the in-canopy nozzle application gave 86 percent to 94 percent control with the recommended rate of Comite.

Summary

Conservation tillage and crop rotations are showing advantages over continuous cotton and conventional tillage in both dryland and irrigated tests. The implementation and management of irrigated no-till or conventional tillage methods is greatly facilitated by

TABLE 6. GREENBUG CONTROL ON SORGHUM WITH LORSBAN® 4E insecticide (Bynum et al., 1985; Smith et al., 1985)

		Percent control		
		MFIS		
Days post-treatment	Rate, kg[AI]ha	Dynamic nozzle movement	Stationary nozzle (overhead chemigation)	Aerial application
3	0.57*	—	—	99
	0.28†	99	97	78
	0.14	99	97	83
	0.07	99	55	—
	0.035	75	−7	—
7	0.57	—	—	99
	0.28	99	99	80
	0.14	97	99	85
	0.07	96	67	—
	0.035	80	21	—
14	0.57	—	—	99
	0.28	97	98	63
	0.14	84	96	55
	0.07	81	75	—
	0.035	78	−5	—

***Maximum labeled rate of Lorsban recommended for greenbug control. Rate normally used in aerial application**

†Minimum registered rate of Lorsban for greenbug control

moving overhead irrigation systems capable of foliar chemigation. Irrigation systems that also incorporate in-canopy chemigation nozzles are being developed specifically to enhance no-till or conservation tillage irrigation and management. These systems are demonstrating distinct advantages over existing ground, aerial, and conventional chemigation techniques and look extremely promising for enhancing irrigated conservation tillage practices.

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