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An Economic Analysis of Soybean Yield Response to Irrigation of Mississippi River Delta

SUMMARY AND CONCLUSIONS

This study addressed the economic aspects of several factors that can affect the yield response of soybeans to irrigation in the Delta of Mississippi. Two irrigation systems were used in this analysis as a basis for estimating irrigation costs. These systems included a center-pivot system irrigating 130 acres on one pivot point and a gated-pipe system irrigating 160 acres. Data on the yield response of irrigated soybeans associated with alternative production patterns and irrigation applications were obtained from research conducted at the MAFES Delta Branch.

Soybeans planted in mid-May and irrigated regularly from the beginning of bloom to the end of podfill generally resulted in higher returns above estimated direct and total costs of irrigation than from soybeans planted in late May or early June and irrigated by the same guidelines. Returns above estimated direct and total costs of irrigation for common furrow-irrigation systems averaged approximately $30.00 per acre higher on soybeans planted in mid-May versus later-planted soybeans.

Irrigation of soybeans appears to be more economical if started during early reproductive stages of the plant if drought occurs at this stage. Returns above estimated direct and total costs of irrigation were generally greatest when irrigation was initiated just before or at the beginning of bloom. Returns from irrigation initiated at podset were generally positive but somewhat lower than returns from irrigation started earlier. Irrigation started at the beginning of podfill almost always resulted in very low or negative returns above irrigation costs per acre.

Both furrow and sprinkler systems were generally shown to increase yields, but the amount of water applied will determine which type of system is more economical. Fixed costs per acre were shown to be significantly higher for a center-pivot system than for a gated-pipe system. However, operating costs were higher for the furrow system than for the center-pivot system.

Irrigation of soybeans planted in narrow rows rather than wide rows on Sharkey clay soils may increase yields and returns in a very dry year. However, no consistent differences in returns to irrigation of soybeans planted in narrow versus wide rows were observed over the time period covered by this study.

Irrigating a clay soil according to the soil water potential (SWP) at the 24-inch soil depth required less water and resulted in lower costs per acre than did irrigating according to the SWP at the 12-inch depth. However, in two-thirds of the cases, returns above estimated direct and total irrigation costs were greater when irrigation applications were based on the SWP at the 12-inch depth.

Soybean yields are influenced directly by both the amount and distribution of rainfall. The crop must have adequate soil moisture throughout the growing season for proper plant growth and development. It has been estimated that 18 to 26 inches of water per acre are necessary for soybeans to reach their yield potential. During years of low rainfall, insufficient soil moisture can result in plant stress and reduction in yield unless irrigation is available for applying water to the crop when needed.

The rate of water use by soybeans averages about 0.15 inch per day over the entire growing season. Demand for water by soybeans peaks during the reproductive stage of plant development when water use may be up to 0.4 inch per day (Heatherly, et al). This high moisture requirement period for soybeans usually occurs during the months of July, August and September. In the Delta of Mississippi this time period is representative of a period of high temperatures combined with relatively low and/or poorly distributed rainfall. Adequate soil moisture during this period is critical for proper reproductive development of the soybean plant. Irrigation during this time can be beneficial in supplying sufficient moisture to the soybean plant and may serve to reduce the year-to-year variation in soybean yields often associated with non-irrigated soybean fields.

A four-year study of soybean irrigation was completed recently at the MAFES Delta Branch (Heatherly). Factors such as planting date and row spacing, in conjunction with alternative methods and timing of irrigation, were evaluated to determine their impact on soybean yields. This report presents an economic analysis of these factors in relation to estimated costs and returns of soybean irrigation.

OBJECTIVES

The objectives of this study were:

1. To update the direct and total costs per acre of representative irrigation systems used to irrigate soybeans in the Mississippi Delta.

2. To evaluate the feasibility of alternative irrigation applications and timing on soybean production with alternative production patterns, such as planting date and row spacing.

3. To determine break-even yield requirements for selected methods and timing of irrigation.

SOURCES OF DATA

Costs of irrigation systems included in this report were obtained from a study of soybean irrigation performed by the Department of Agricultural Economics at Mississippi State University (Rebsamen). The basic investment data were obtained from well-drilling firms and irrigation-equipment dealers located in the study area in 1979 and 1980. Investment and operating costs were obtained by interviewing 52 farmers who irrigated soybeans in the Delta during 1979 and 1980. In addition, 50 farmers kept irrigation records that provided other information for the study conducted by Rebsamen.

Data on the agronomic response of soybeans to irrigation were obtained from experiments conducted at the MAFES Delta Branch (Heatherly). The data included yields of soybeans grown with similar production practices and different row spacings with and without irrigation. Soybeans were irrigated by alternative methods and at different stages of development.

METHODS OF ANALYSIS

The costs of representative irrigation systems included in this report were based on estimates obtained from Rebsamen's study and were updated for 1983. Costs were estimated for a center-pivot system irrigating 130 acres and a gated-pipe system irrigating 160 acres. Fixed and direct irrigation costs for these systems were estimated in accordance with published agricultural production cost data for the Delta of Mississippi (Cooke, et al.). All other production costs were assumed to be the same because the same production practices were followed for the irrigated and non-irrigated plots.

Calculated direct costs of irrigation were based on 1 acre-inch per application for the center-pivot system and 4 acre-inches per application for the gated-pipe system. All fixed costs were estimated on a per acre basis.

These costs were then assumed to be representative of the cost of alternative irrigation application tests performed at the MAFES Delta Branch in order to estimate the cost of applying water by different methods. Irrigation application rates were combined with estimated fixed and direct costs to estimate total irrigation costs for each test conducted. Yield of irrigated plots above yields of non-irrigated checks for each test were used as a basis for estimating returns above irrigation costs. Break-even yields also were developed for each test.

It should be noted that experimental results obtained by Heatherly were achieved utilizing a fixed-sprinkler ("rainbird") system and by furrow-or surface irrigation methods. The cost of a center-pivot irrigation system was substituted in this study for the cost of the "rainbird" fixed-sprinkler system in order to estimate the benefits of overhead irrigation of soybeans. Thus, this study assumed that results obtained from the "rainbird" fixed-sprinkler irrigation system would be representative of results obtained from a center pivot system.

DESCRIPTION OF SOILS

Most of the irrigation experiments were conducted primarily on Sharkey clay, which has about 1% organic matter, very slow internal drainage, high fertility, low bulk density, uniformity with depth and no compacted zones. This soil type shrinks and cracks when drying and swells when wet. Its relatively slow release of water to plants results in soybean vegetative growth being somewhat slower than when soybeans are grown on a silt loam or a very fine sandy loam soil.

Other tests were conducted on a Dubbs silt loam site. This soil has good internal drainage but forms a surface crust that severely inhibits water infiltration. This is an important factor to consider when watering by furrow methods because the rate of water application should not exceed the capacity of the soil to absorb it. This soil supplies water to the crop at a relatively rapid rate and this can result in the production of vegetative growth, which requires frequent application of water to maintain the plant in a nonstressed condition. Atmospheric conditions that promote transpiration from leaves can cause severe wilting of plants grown on soils of this type if water is not immediately available.

ESTIMATED COSTS OF REPRESENTATIVE IRRIGATION SYSTEMS

Center-Pivot Irrigation Systems

A quarter-mile center-pivot system irrigating 130 acres on one pivot point was considered for this analysis. Estimated fixed and direct costs of such a system are presented in Table 1. Investment costs for this system included the cost of an engine, well, pump, gearhead, generator, fuel tank and lines and the pivot system. Total investment costs for this system were $59,150. Total fixed costs consist of annual depreciation, interest on investment and insurance. Annual depreciation was calculated for each component of the system using the straight-line method with a zero salvage value. Annual interest charges were based on 14% of one half of the original investment. Insurance was estimated at 1% of the original investment. Total annual fixed costs for the system were estimated as $8,560.33 or $65.85 per acre.

Operating or direct costs of a pivot system include fuel, oil, labor and engine repair. Fuel is the major direct cost of operating a center-pivot system. Fuel requirements included in this analysis were based on an engineering formula that estimated the power requirements of pumping water from its source to the point of discharge (Johnson and Henderson).

Direct costs of operating a quarter-mile pivot system on one pivot point were estimated to be $338.10 per revolution with a 1-inch application rate. This is equivalent to $2.60 per acre-inch of water applied.

Gated-Pipe Irrigation System

The estimated fixed and direct costs of a gated-pipe system irrigating 160 acres are presented in Table 2. Investment in this system included the cost of an engine, well, pump, gearhead, fuel tank and lines and gated pipe. Total investment costs for this system were estimated to be $28,920. Annual depreciation costs were estimated using the straight-line method with a zero salvage value. Annual interest charges were estimated at 14% of one half of the original investment. Insurance was estimated at 1% of the original investment. Total annual fixed costs for the gated-pipe system were $3,910.73 or $24.44 per acre. No land-forming costs were charged to the gated-pipe system. The cost of land forming for specific situations must be included when evaluating the feasibility of using a gated-pipe system to irrigate soybeans on a field requiring land forming.

The gated-pipe system included in this study was assumed to be used to irrigate 160 acres of soybeans. Irrigation water was pumped at a flow rate of 2,000 gallons per minute and 34 PSI. Direct costs for this system included fuel, oil, labor, engine repairs and pipe replacement. Direct costs per acre for a 4-inch application of water were estimated. Diesel fuel costs for the tractor and labor costs reflect the costs of moving and setting up irrigation pipe. Total direct costs for the gated-pipe system were estimated to be $11.73 per acre or about $2.94 per acre-inch of water applied.

Although the amounts of irrigation water applied by the furrow and sprinkler systems in this study were not equal, some general conclusions can be drawn concerning the costs of different irrigation methods. The center-pivot system was estimated to have the lowest direct or operating cost of the systems included in this analysis. The estimated direct cost for this system was $2.60 per acre-inch of water applied. This was primarily due to low labor requirements for center-pivot systems. The furrow-irrigation system required greater amounts of labor for operation, thereby resulting in higher direct costs. Estimated direct costs for the gated-pipe system included in this analysis were $2.94 per acre-inch of water applied.

Investment costs of the center-pivot system, however, were much greater than investment costs for the gated-pipe system. Fixed costs for the center-pivot system included in this report were $64.85 per acre while fixed costs for the gated-pipe system were $24.44 per acre.

ANALYSIS OF FACTORS AFFECTING IRRIGATION COSTS AND RETURNS

Estimated fixed and direct costs of the two irrigation systems presented in the previous section were used to develop estimated irrigation costs, returns and break-even yield increases. Reference is made to the year in which a particular agronomic study was conducted, but all estimated costs and break-even yield increases presented in the remainder of this report were based on 1983 prices of irrigation equipment and production inputs and a soybean price of $6.00 per bushel.

Seasonal average soybean prices for an eight-year period are presented in Table 3. These prices have averaged between $6.25 per bushel for the eight-year period to $6.52 per bushel for the most recent three years. A price of $6.00 per bushel for soybeans was selected on the basis that, if irrigation of soybeans becomes a widely accepted practice, soybean supplies would be greater during dry years.

Planting Date and Irrigation

The costs and returns to furrow irrigation of soybeans planted on two dates for three years are shown in Table 4. Soybeans were planted in mid-May and in late May or early June in each year on Sharkey clay. These soybeans were furrow irrigated beginning at bloom, and irrigation was continued until the end of the growing season. Irrigation water was applied when the soil water potential dropped to between -50 and -100 centibars as measured by a tensiometer at the 12-inch soil depth.

Large amounts of irrigation water were applied in all three years. Approximately 20 inches or more were applied to soybean plots in 1980, which was a relatively dry year. Early-planted soybeans (May 12) were irrigated six to seven times while late-planted soybeans (June 3) were irrigated five times. This large number of applications produced yield increases of 20 bushels per acre or more for all three varieties tested. In 1981 and 1982, plots were irrigated three to four times and more than 10 acre-inches of water per plot were applied with one exception. Yield increases were obtained from irrigation for both planting dates. However, in almost every case, irrigated mid-May-planted soybeans produced higher yield increases per acre than did irrigated soybeans planted in late May or early June.

Estimated direct and total irrigation costs are included in Table 4 for a furrow-irrigation system. Per acre costs of the gated-pipe system were estimated based on the inches of irrigation water applied. Early-planted soybeans had higher irrigation costs than later-planted soybeans due to a larger number of irrigations.

Returns to irrigation above estimated direct and total costs were obtained for all plots during the 1980 to 1982 period. Soybeans planted in mid-May and irrigated regularly from the beginning of bloom to the end of podfill generally had higher returns above estimated direct and total costs of irrigation than did soybeans planted in late May or early June and irrigated by the same guidelines. Returns above direct and total irrigation costs for the three-year period averaged about $30.00 per acre higher for early-planted soybeans.

Yield increases required to cover furrow-irrigation costs are shown in Table 5. Yield increases necessary to cover fixed costs of irrigation were 4.1 bushels per acre for the gated-pipe system. With a direct or operating cost of $2.94 per acre-inch, yield increases necessary to cover the direct costs were about 0.[illegible] bushel per acre-inch applied.

The yield increases necessary to recover the cost of applying relatively large volumes of irrigation water are presented in Table 5. In 1980, the total volume of irrigation water applied to soybeans ranged from 18.40 to 27.15 inches. Yield increases necessary to recover the direct costs of applying this volume of water ranged from 9.0 to 15.1 bushels for the gated-pipe system. Less total water was applied in 1981 and 1982, and the yield increases required to recover direct irrigation costs in these years ranged from 3.8 to 7.[illegible] bushels per acre.

Timing of Irrigation

Timing of irrigation is very important in obtaining a maximum soybean yield response to irrigation. Soybean yield increases from irrigating at different stages of plant maturity were measured for three varieties grown on Sharkey clay. Four irrigation treatments were included in the test---irrigation started before bloom (PB), irrigation started at the beginning of bloom (BL), irrigation started at the beginning of podset (PS) and irrigation started at the beginning of podfill (PF). The irrigation costs and increased returns of these treatments are shown in Table 6.

Two irrigation treatments were conducted in 1979 on Bedford, Tracy, and Bragg soybeans. Irrigation was started at the beginning of podset or at the beginning of podfill and continued for the remainder of the growing season as needed. However, five of the six trials did not produce any substantial yield increase due to relatively large amounts of and more evenly distributed rainfall during the 1979 growing season. Only one treatment produced a return above irrigation costs in 1979.

In 1980, three irrigation treatments were conducted on each variety tested. Irrigation applications were started at the beginning of bloom, podset and podfill on Bedford soybeans and before bloom, at the beginning of bloom, and at the beginning of podfill on Tracy and Bragg varieties. Some of these plots were irrigated seven to eight times. Total irrigation water applied ranged from 11.55 to 27.45 acre-inches depending upon when irrigation was started. All three varieties showed a greater yield response to irrigation when applications were started at the earliest stage. As initial applications were delayed to later reproductive stages, the yield increase due to irrigation declined. Irrigation treatments started before or at the beginning of bloom increased irrigation costs over the podset and podfill treatments due to irrigating over a longer period of time, but returns above estimated direct and total costs were much greater when irrigation was started before or at bloom rather than at the beginning of podset or podfill.

Returns per acre above estimated direct costs for the gated-pipe system ranged from \$79.24 to \$118.50 per acre for the PB treatment, from \$57.53 to \$101.13 per acre for the BL treatment and were \$34.60 per acre for the PS treatment. Returns above total cost were negative for all PF treatments in 1980.

Yield increases necessary to cover estimated costs of irrigation started at different stages of plant growth are presented in Table 7. When irrigation was started at earlier plant stages and continued throughout the growing season, yield increases required to recover irrigation costs became larger as a result of the increased cost of applying more water over longer periods of time. Yield increases necessary to recover the direct cost of applying the volumes of water presented in Table 7 in 1983 with a gated-pipe system ranged from 5.7 to 13.5 bushels per acre. The total costs of applying these volumes of water required yield increases ranging from 9.7 to 17.5 bushels per acre to recover the total costs of the gated-pipe system based on a soybean price of \$6.00 per bushel.

The effect of irrigation timing on yield response of soybeans grown on a silt loam soil is shown in Table 8. 'Forrest' soybeans were grown on Dubbs silt loam and irrigated by a sprinkler system. As indicated earlier, due to the amount and distribution of rainfall during the growing season, application of irrigation water resulted in only a minor yield increase in 1979.

The effect of beginning irrigation early during a dry year or during periods of inadequate soil moisture was evident in 1980. A yield response to irrigation of 27.6 bushels per acre was recorded when irrigation was started at the beginning of bloom. Yield response decreased to 20.2 bushels when irrigation was delayed until podset and to 19.7 bushels when irrigation was delayed until podfill. Returns above estimated direct and total costs of a center-pivot system were more than \$30.00 per acre higher when irrigation was started at the beginning of bloom as compared to later initial applications. Break-even yield increases for these tests are included in Table 9.

Method of Irrigation

The two basic types of irrigation systems used on row crops are surface and overhead. The gated-pipe system is one of the major types of surface systems used to irrigate soybeans in the Delta. Center-pivot systems are the most common type of overhead system found on farms in the Delta. This section presents economic aspects of using these systems to irrigate soybeans.

Tests were conducted using the 'Tracy-M' and 'Centennial' varieties at the MAFES Delta Branch in 1981 and 1982. These varieties were irrigated by both furrow and sprinkler methods to determine the yield increase associated with using these different methods of irrigation. Two irrigation treatments were used in this study. One treatment consisted of irrigation water being applied using each irrigation method whenever the soil water potential at the 12-inch soil depth dropped to between -50 and -100 centibars as measured by a tensiometer (T12). Another group of soybeans was irrigated using each method according to the soil water potential at the 24-inch soil depth (T24). Results of these tests, along with the associated estimated costs and returns of the different irrigation methods, are presented in Table 10.

Soybean yield response to irrigation was positive for both methods of irrigation. Yield increases from irrigation were higher on the furrow-irrigated plots than on the sprinkler-irrigated plots for both the T12 and T24 treatments in 1981 and on furrow-irrigated plots for the T12 treatment in 1982. The T24 treatment resulted in approximately the same yield response for both the furrow and sprinkler methods in 1982. Break-even yield increases associated with these treatments are included in Table 11.

Row Spacing and Irrigation

Tracy soybeans were planted in 20-inch and 40-inch rows on Sharkey clay in 1980. Three irrigation treatments and a non-irrigated check were included in this study. Irrigation was started just before bloom (PB) as one treatment and continued throughout the season as needed. Irrigation applications for the other treatments were started at the beginning of bloom (BL) and at the beginning of podfill (PF). Soybeans receiving the PB and BL treatments were irrigated six to eight times. The PF treatment received two applications of irrigation water.

Yield response data (Table 12) indicate higher yield increases for irrigated soybeans planted in 20-inch rows than for soybeans planted in 40-inch rows when irrigation was started at the late vegetative (PB) and early reproductive (BL) stages. Estimated direct and total irrigation costs of the gated-pipe system on narrow rows is approximately equal to or greater than irrigation costs on wide rows, but returns above estimated direct and total costs were greater for soybeans planted on narrow rows as opposed to wide rows in 1980, which was a relatively dry year. Yield increases required to recover estimated costs are presented in Table 13.

The effect of row spacing on irrigated soybeans grown on a silt loam soil is presented in Tables 14 and 15. Forrest soybeans were planted in 20-inch and 40-inch rows on Dubbs silt loam. Irrigation water was applied by the sprinkler method. Yield increases for irrigated soybeans versus the non-irrigated check were recorded for both row spacings. The yield of soybeans planted in narrow rows was 10.0 bushels greater than that for soybeans planted in coventional (40-inch) rows in 1981. Yields observed in 1982 did not indicate any major yield increase due to row spacing. Hence, based on 1981 and 1982 results for Forrest soybeans planted on Dubbs silt loam, row spacing results were not consistent.

The economic feasibility of applying relatively large amounts of irrigation water with a sprinkler system is illustrated in Table 15. In 1981, soybeans planted on wide rows were irrigated seven times with a total of 10.75 inches of water. Soybeans planted on narrow rows were irrigated eight times with a total of 12.80 inches of water. Estimated direct irrigation costs for a center-pivot system were $27.95 and $33.28 per acre, respectively. Yield increases required to cover these direct costs were 4.7 bushels per acre on wide rows and 5.5 bushels per acre on narrow rows. In 1982, both row spacings were irrigated six times with a total of 7 inches. Direct costs for these applications were $18.20 per acre, resulting in a required break-even yield increase of about 3.0 bushels per acre. The required yield increase to recover estimated total cost of a center-pivot system ranged from 14.0 to 16.5 bushels per acre over the two year period.

In 1981 and 1982, Bedford, Tracy-M and Braxton varieties were planted in 20-inch and 40-inch rows on Sharkey clay. These soybeans were irrigated two to four times according to the soil water potential at the 12-inch (T12) and the 24-inch (T24) soil depth. Estimated irrigation costs, returns and yield increases for these tests are shown in Table 16. Although yield increases were recorded for all plots, no consistent differences in returns to irrigation of soybeans planted in narrow rows versus wide rows were observed during 1981 and 1982.

A larger total volume of irrigation water was applied with the T12 treatment than with the T24 treatment. Total irrigation water applied by the furrow method with the T12 treatment ranged from 10 to 20 inches. Furrow applications of water for the T24 treatment were somewhat less. As a result, estimated direct and total irrigation costs were greater when irrigation was based on the soil water potential at the 12-inch depth. However, yield increases were consistently higher and, in two-thirds of the cases, returns above estimated direct and total costs were greater for soybeans receiving the T12 irrigation treatment than for soybeans receiving the T24 irrigation treatment. The low yield response (7.4 and 5.4 bushels) and negative returns shown for the T24 treatment and both row spacings of Tracy-M in 1982 (Table 16) were the result of this treatment being inadvertently skipped on an August 27 watering and then being watered with 7.90 inches on September 9 to try to compensate for the omitted irrigation. This result reinforces the need for timely irrigation of soybeans.

LIMITATIONS OF THE STUDY

Results of this study are based upon yield response of soybeans to irrigation on experimental plots, but they should be transferable to actual large field conditions. Production practices, other than irrigation practices, within the plots were the same as generally followed by better producers. In addition, a full-scale center-pivot irrigation system was not used in the irrigation tests on which this study was based. However, these results should be indicative of relative soybean yield response when irrigation practices are performed in a timely manner and based upon soil moisture potential.

Table 1. Estimated costs of a center-pivot system irrigating 130 acres on one pivot point, Mississippi Delta, 1983.

Item	Investment	Est. life	Annual costs
Fixed costs			
Engine	$ 6,000	15	$ 400.00
Well, pump, gearhead	12,000	20	600.00
Generator	2,150	10	215.00
Fuel tank and lines	1,000	15	80.00
Pivot system (1/4 mile)	38,000	15	2,533.33
Total investment	$59,150		
Average annual interest			4,140.50
Insurance			591.50
Total annual fixed costs			$8,560.33
Annual fixed cost per acre			$ 65.85
Direct costs		Per revolution	Per acre - inch
Engine repairs at 70% of new cost		$ 26.00	$ .20
Diesel fuel at $1.15/gal.		297.57	2.29
Oil at $4.00/gal.		3.46	.03
Maintenance labor at $4.40/hr.		11.07	.08
Total direct costs		$338.10	$2.60

Table 2. Estimated costs of a gated-pipe system irrigating 160 acres, Mississippi Delta, 1983.

Item	Investment	Est. life	Annual costs
Fixed costs			
Engine	$ 6,500	15	$ 433.33
Well, pump, gearhead	13,500	20	675.00
Fuel tank and lines	1,000	20	50.00
8" Gated pipe at $3.00/ft.	7,920	15	528.00
Total investment	$28,920		
Average annual interest			2,024.40
Insurance			200.00
Total annual fixed costs			$3,910.73
Annual fixed cost per acre			$ 24.44

Direct costs	4 inches per acre	Approximate costs per acre-inch
Engine repairs at 70% of new cost	$ .50	$ .13
Diesel fuel at $1.15/gal.	6.98	1.75
Oil at $4.00/gal.	.04	.01
Tractor fuel at $1.15/gal. (25 hrs. of operation)	.36	.09
Labor at $4.40/hr.	2.85	.71
Pipe replacement (2% of original pipe investment)	.99	.25
Total direct costs	$11.73	$2.94

Table 3. Seasonal yearly average price received per bushel of soybeans in Mississippi, 1975-82[1/].

Year	Seasonal price
	dollars/bushel
1975	4.81
1976	6.42
1977	6.18
1978	6.63
1979	6.37
1980	7.75
1981	6.25
1982	5.55
8-year average[2/]	6.25
Most recent 3-year average[3/]	6.52

1/ Source: Mississippi Crop and Livestock Reporting Service, Mississippi Agricultural Statistics, selected issues.

2/ Average of seasonal average price over the period.

3/ Average of seasonal average price for 1980, 1981 and 1982.

Table 4. Yield increase, estimated direct and total furrow-irrigation costs and estimated returns above direct and total irrigation costs of irrigated soybeans planted on two dates on Sharkey clay at the MAFES Delta Branch, 1980-1982.

Year	Planting date	Variety	Amount[1/] of water applied	Yield[2/] increase	Direct cost[3/] per acre	Total cost[3/] per acre	Returns above[4/] direct cost	Returns above[4/] total cost
			inches	bushels	dollars			
1980	May 12	Bedford	20.90	25.9	61.45	85.89	93.95	69.51
		Tracy	24.70	27.0	72.62	97.06	89.38	64.94
		Bragg	27.15	32.5	79.82	104.26	115.18	90.74
	June 3	Bedford	19.10	29.7	56.15	80.59	122.05	97.61
		Tracy	21.25	20.2	62.48	86.92	58.72	34.28
		Bragg	18.40	21.8	54.10	78.54	76.70	52.26
1981	May 13	Bedford	12.65	26.7	37.19	61.63	123.01	98.57
		Braxton	16.55	33.4	48.66	73.10	151.74	127.30
	June 4	Bedford	7.70	19.7	22.64	47.08	95.56	71.12
		Braxton	11.55	18.5	33.96	58.40	77.04	52.60
1982	May 12	Bedford	11.55	18.9	33.96	58.40	79.44	55.00
		Braxton	15.40	25.4	45.28	69.72	107.12	82.68
	May 28	Bedford	11.55	11.7	33.96	58.40	36.24	11.80
		Braxton	11.55	17.3	33.96	58.40	69.84	45.40

1/ Irrigation water was applied when the soil water potential at the 12-inch depth dropped between -50 and -100 centibars.

2/ Yield increase equals yield of irrigated soybeans minus yield of soybeans for the non-irrigated check.

3/ Direct and total costs of irrigation were estimated based on 1983 prices and costs of using a gated-pipe system.

4/ Returns above direct and total costs were computed using a soybean price of $6.00 per bushel and estimated costs of applying the amount of water indicated by a gated-pipe system.

Table 5. Yield increase and estimated yield increase required to recover irrigation costs for furrow-irrigated soybeans planted on two dates on Sharkey clay at the MAFES Delta Branch, 1980-1982.

Year	Planting date	Variety	Amount of water applied[1/]	Yield increase[2/]	Yield increase required to recover[3/]: Direct cost	Total cost
			inches	bushels	-----bushels------	
1980	May 12	Bedford	20.90	25.9	10.2	14.3
		Tracy	24.70	27.0	15.1	16.2
		Bragg	27.15	32.5	13.3	17.4
	June 3	Bedford	19.10	29.7	9.4	13.7
		Tracy	21.25	20.2	10.4	14.5
		Bragg	18.40	21.8	9.0	13.1
1981	May 13	Bedford	12.65	26.7	6.2	10.3
		Braxton	16.55	33.4	8.1	12.2
	June 4	Bedford	7.70	19.7	3.8	7.8
		Braxton	11.55	18.5	5.7	9.7
1982	May 12	Bedford	11.55	18.9	5.7	9.7
		Braxton	15.40	24.4	7.5	11.6
	May 28	Bedford	11.55	11.7	5.7	9.7
		Braxton	11.55	17.3	5.7	9.7

1/ Irrigation water was applied whenever the soil water potential at the 12-inch soil depth dropped between -50 and -100 centibars.

2/ Yield increase equals yield of irrigated soybeans minus the yield of soybeans for the non-irrigated check.

3/ Break-even yield increases were based on a soybean price of $6.00 per bushel and estimated costs of applying the amount of water indicated by a gated-pipe system are presented in Table 4.

Table 6. Yield increase, estimated direct and total irrigation costs and estimated returns above direct and total irrigation costs of furrow-irrigated soybeans grown on Sharkey clay at the MAFES Delta Branch, 1979-1980.

Year	Variety	Irrigation treatment[1/]	Amount of water applied	Yield increase[2/]	Direct cost per acre[3/]	Total cost per acre[3/]	Returns above direct cost[4/]	Returns above total cost
			inches	bushels	----------	---dollars---	----------	----------
1979	Bedford	PS	6.00	0.0	17.64	42.08	(17.64)	(42.08)
		PF	3.40	0.0	10.00	34.44	(10.00)	(34.44)
	Tracy	PS	6.85	0.2	20.14	44.58	(18.94)	(43.38)
		PF	5.80	0.0	17.05	41.49	(17.05)	(41.49)
	Bragg	PS	3.45	0.6	10.14	34.58	(6.54)	(30.98)
		PF	3.55	6.8	10.44	34.88	30.36	5.92
1980	Bedford	BL	18.80	18.8	55.27	79.71	57.53	33.09
		PS	19.25	15.2	56.60	81.04	34.60	10.16
		PF	13.90	5.6	40.87	65.31	(7.27)	(31.71)
	Tracy	PB	25.70	25.8	75.56	100.00	79.24	54.80
		BL	25.90	24.7	76.15	100.59	72.05	47.61
		PF	11.55	4.7	33.96	58.40	(5.76)	(30.20)
	Bragg	PB	27.45	33.2	80.70	105.14	118.50	94.06
		BL	22.95	28.1	67.47	91.91	101.13	76.69
		PF	11.55	6.9	33.96	58.40	7.44	(17.00)

1/ Application of irrigation water started prior to bloom (PB), beginning of bloom (BL), beginning of podset (PS) and beginning of podfill (PF).

2/ Yield increase equals the yield of irrigated soybeans minus the yield of soybeans for the non-irrigated check.

3/ Direct and total costs of irrigation were estimated based on 1983 prices and estimated costs of applying the amount of water indicated by a gated-pipe system.

4/ Returns above direct and total costs were computed using a soybean price of $6.00 per bushel and estimated cost of applying the amount of water indicated by a gated-pipe system. Items enclosed in parentheses represent negative returns or loss.

able 7. Yield increase and estimated yield increase required to recover irrigation osts for furrow-irrigated soybeans planted on Sharkey clay at the MAFES Delta Branch, 979-1980.

ear	Variety	treatment	Amount of water applied[1/]	Yield increase[2/]	Yield increase[3/] required to recover Direct cost	Total cost
			inches	bushels	------bushels------	
1979	Bedford	PS	6.00	0.0	2.9	7.0
		PF	3.40	0.0	1.7	5.7
	Tracy	PS	6.85	0.2	3.4	7.4
		PF	5.80	0.0	2.8	6.9
	Bragg	PS	3.45	0.6	1.7	5.8
		PF	3.55	6.8	1.7	5.8
1980	Bedford	BL	18.80	18.8	9.2	13.3
		PS	19.25	15.2	9.4	13.5
		PF	13.90	5.6	6.8	10.9
	Tracy	PB	25.70	25.8	12.6	16.7
		BL	25.90	24.7	12.7	16.8
		PF	11.55	4.7	5.7	9.7
	Bragg	PB	27.45	33.2	13.5	17.5
		BL	22.95	28.1	11.2	15.3
		PF	11.55	6.9	5.7	9.7

1/ Application of irrigation water started prior to bloom (PB), beginning of bloom (BL), beginning of podset (PS) and beginning of podfill (PF).

2/ Yield increase equals the yield of irrigated soybeans minus the yield of soybeans for the non-irrigated check.

3/ Break-even yield increases were based on a soybean price of $6.00 per bushel and estimated costs of applying the amount of water indicated by a gated-pipe system presented in Table 6.

Table 8. Yield increase, estimated direct and total center-pivot irrigation cost and estimated returns above direct and total cost of irrigated Forrest soybeans grown on Dubbs silt loam at the MAFES Delta Branch, 1979-1980.

Year	Irrigation[1/] treatment	Amount of water applied	Yield[2/] increase	Direct cost[3/] per acre of a center pivot system	Total cost[3/] per acre of a center pivot system	Returns above[4/] direct cost	Returns above[4/] total cost
		inches	bushels	---------dollars---------			
1979	PF	3.00	1.7	7.80	73.65	2.40	(63.45)
1980	BL	12.15	27.6	31.59	97.44	134.01	68.16
	PS	9.05	20.2	23.53	89.38	97.67	31.82
	PF	6.75	19.7	17.55	83.40	100.65	34.80

1/ Application of irrigation water started at beginning of bloom (BL), beginning of podset (PS) and beginning of podfill (PF).

2/ Yield increase equals yield of irrigated plots minus the yield of non-irrigated check.

3/ Direct and total costs were estimated based on 1983 prices and costs of applying the amount of water indicated.

4/ Returns above direct and total costs were computed using a soybean price of $6.00 per bushel. Items enclosed in parentheses represent negative returns or loss.

NOTE: Tests were conducted using a fixed sprinkler system.

Table 9. Yield response and estimated yield increase required to recover center-pivot irrigation costs for Forrest soybeans grown on Dubbs silt loam at the MAFES Delta Branch, 1979-1980.

Year	Irrigation treatment[1/]	Amount of water applied	Yield[2/] increase	Yield increase required to recover[3/]	
				Direct cost	Total cost
		inches	bushels	------bushels-	----
1979	PF	3.00	1.7	1.3	12.3
1980	BL	12.15	27.6	5.3	16.2
	PS	9.05	20.2	3.9	14.9
	PF	6.75	19.7	2.9	13.9

1/ Application of irrigation water started at beginning of bloom (BL), beginning of podset (PS) and beginning of podfill (PF).

2/ Yield increase equals yield of irrigated plot minus yield of non-irrigated check.

3/ Break-even yield increases were based on a soybean price of $6.00 per bushel and the cost of applying the amount of water indicated by a center-pivot system presented in Table 8.

NOTE: Tests were conducted using a fixed sprinkler system.

Table 10. Irrigation application, yield increase, direct and total irrigation cost and returns above direct and total irrigation cost of soybeans irrigated by different methods on Sharkey clay at the MAFES Delta Branch, 1981-1982.1/

Year	Irrigation treatment[1/]	Amount of water applied		Yield[2/] increase		Direct cost[3/] per acre		Total cost[3/] per acre		Returns[4/] above direct cost		Returns[4/] above total cost	
		Sprinkler	Furrow	Sprinkler	Furrow	Center pivot	Gated pipe	Center pivot	Gated pipe	Center pivot	Gated pipe	Center pivot	Gated pipe
		----inches----		---bushels---		---------------		-------------dollars		---------------		---------------	
1981	T12	6.70	12.75	24.5	26.3	17.42	37.49	83.27	61.93	129.58	120.31	63.73	95.87
	T24	4.80	7.75	17.5	23.4	12.48	22.79	78.33	47.23	95.52	117.61	26.67	93.17
1982	T12	3.15	4.60	3.5	11.0	8.19	13.52	74.04	32.96	12.81	52.48	(53.04)	28.04
	T24	1.75	2.75	3.8	3.3	4.55	8.09	70.40	32.53	18.25	11.71	(47.60)	(12.73

1/ Irrigation water was applied whenever the soil water potential at the 12-inch (T12) and 24-inch (T24) soil depth dropped between -50 and -100 centibars.

2/ Varieties tested were Tracy-M and Centennial. Yield increase equals irrigated yield minus non-irrigated yield.

3/ Direct and total costs of irrigation were estimated based on 1983 prices and costs of applying the amount of water indicated.

4/ Returns above direct and total costs were computed using a soybean price of $6.00 per bushel. Items enclosed in parentheses represent negative returns or loss.

NOTE: Tests were conducted using a fixed sprinkler system and a gated-pipe system.

Table 11. Irrigation application, yield increase and yield increase required to recover irrigation costs of soybeans irrigated by different methods on Sharkey clay at the MAFES Delta Branch, 1981-1982.

Year	Irrigation Treatment 1/	Amount of water applied		Yield increase 2/		Yield increase required to recover 3/			
						Direct cost		Total cost	
		Sprinkler	Furrow	Sprinkler	Furrow	Center pivot	Gated pipe	Center pivot	Gated pipe
		-----inches-----		----bushels-----		------------bushels------------			
1981	T12	6.70	12.75	24.5	26.3	2.9	6.2	13.9	10.3
	T24	4.80	7.75	17.5	23.4	2.1	3.8	13.1	7.9
1982	T12	3.15	4.60	3.5	11.0	1.4	2.3	12.3	6.3
	T24	1.75	2.75	3.8	3.3	0.8	1.3	11.7	5.4

1/ Irrigation water was applied whenever the soil water potential at the 12-inch (T12) and the 24-inch (T24) soil depth dropped between -50 and -100 centibars.

2/ Varieties tested were Tracy-M and Centennial. Yield increase equals irrigated yield minus non-irrigated yield.

3/ Break-even yield increases were based on a soybean price of $6.00 per bushel and the cost of applying the amount of water indicated by the appropriate system presented in Table 10.

NOTE: Tests were conducted using a fixed sprinkler system and a gated-pipe system.

Table 12. Irrigation application, yield increase, estimated direct and total furrow-irrigation cost and estimated returns above direct and total irrigation cost for irrigated Tracy soybeans grown in two row spacings on Sharkey clay at the MAFES Delta Branch, 1980.

Year	Irrigation treatment 1/	Row spacing	Amount of water applied	Yield increase 2/	Direct cost 3/ per acre	Total cost 3/ per acre	Returns above 4/ direct cost	Returns above 4/ total cost
		inches	inches	bushels	---------dollars---------			
1980	PB	40	24.55	26.4	72.18	96.62	86.22	61.78
		20	28.95	36.5	85.11	109.55	133.89	109.45
	BL	40	22.35	22.5	65.71	90.15	69.29	44.85
		20	23.35	29.5	68.65	93.09	108.35	83.91
	PF	40	11.65	6.1	34.25	58.69	2.35	(22.09)
		20	11.55	7.4	33.96	58.40	10.44	(14.00)

1/ Application of irrigation water began prior to bloom (PB), beginning of bloom (BL), and beginning of podfill (PF).

2/ Yield increase equals irrigated yield minus non-irrigated yield.

3/ Direct and total irrigation costs were estimated based on 1983 prices and costs of applying the amount of water indicated.

4/ Returns above direct and total costs were computed using a soybean price of $6.00 per bushel and costs of applying the amount of water indicated by a gated-pipe system. Items enclosed in parentheses represent negative returns or loss.

Table 13. Irrigation application, yield increase and yield increase required to recover irrigation costs for furrow-irrigated Tracy soybeans grown in two row spacings on Sharkey clay at the MAFES Delta Branch, 1980.

Year	Irrigation treatment [1]	Row spacing	Amount of water applied	Yield increase [2]	Yield increase required to recover [3]: Direct Cost	Total Cost
		inches	inches	bushels	-----bushels------	
1980	PB	40	24.25	24.6	12.0	16.1
		20	28.95	36.5	14.2	18.3
	BL	40	22.35	22.5	11.0	15.0
		20	23.35	29.5	11.4	15.5
	PF	40	11.65	6.1	5.7	9.8
		20	11.35	7.4	5.7	9.7

1/ Application of irrigation water started prior to bloom (PB), beginning of bloom (BL), and beginning of Podfill (PF).

2/ Yield increase equals irrigated yield minus yield of the non-irrigated check.

3/ Break-even yield increases were based on a soybean price of $6.00 per bushel and costs of applying the amount of water indicated by a gated-pipe system.

Table 14. Irrigation application, yield increase, estimated direct and total center-pivot irrigation cost and estimated returns above direct and total cost of irrigated Forrest soybeans grown in two row spacings on Dubbs silt loam at the MAFES Delta Branch, Station, 1981-1982.

Year	Row spacing	Amount of water applied [1]	Yield increase [2]	Direct cost per acre of a center pivot system [3]	Total cost per acre of a center pivot system [3]	Returns above direct cost [4]	Returns above total cost [4]
	inches	inches	bushels	---dollars---			
1981	40	10.75	4.6	27.95	93.80	(0.35)	(66.20)
	20	12.80	14.6	33.28	99.13	54.32	(11.53)
1982	40	7.00	17.5	18.20	84.05	86.80	20.95
	20	7.00	16.1	18.20	84.05	78.40	12.55

1/ Irrigation water was applied whenever the soil water potential of the 12-inch soil depth dropped between -50 and -100 centibars.

2/ Yield increase equals irrigated yield minus non-irrigated yield.

3/ Direct and total costs of irrigation were estimated based on 1983 prices and the costs of applying the amount of water indicated.

4/ Returns above direct and total cost were computed using a soybean price of $6.00 per bushel. Items enclosed in parentheses represent negative returns or loss.

NOTE: Tests were conducted using a fixed sprinkler system.

Table 15. Irrigation application, yield increase and yield increase required to recover center-pivot costs of irrigated Forrest soybeans grown in two row spacings on Dubbs silt loam at the MAFES Delta Branch, 1981-1982.

Year	Row Spacing	Amount of water applied[1/]	Yield Response[2/]	Yield increase required to recover[3/] Direct cost	Total cost
	inches	inches	bushels	------bushels-------	
1981	40	10.75	4.6	4.7	15.6
	20	12.80	14.6	5.5	16.5
1982	40	7.00	17.5	3.0	14.0
	20	7.00	16.1	3.0	14.0

1/ Irrigation water was applied whenever the soil water potential at the 12-inch soil depth dropped between -50 and -100 centibars.

2/ Yield increase equals irrigated yield minus non-irrigated yield.

3/ Break-even yield increases were based on a soybean price of $6.00 per bushel and costs of applying the amounts of water indicated by a center-pivot system.

NOTE: Tests were conducted using a fixed sprinkler system.

Table 16. Irrigation application, yield increase, estimated direct and total furrow-irrigation cost and estimated returns above direct and total irrigation cost of irrigated soybeans grown in two-row spacings on Sharkey clay at the MAFES Delta Branch, 1981-1982.

Year	Irrigation treatment[1/]	Row spacing	Variety	Amount of water applied	Yield increase[2/]	Direct cost per acre[3/]	Total cost per acre[3/]	Returns above direct cost[4/]	Returns above total cost[4/]
		inches		inches	bushels	----------dollars----------			
1981	T12	40	Bedford	14.60	24.8	42.92	67.36	105.88	81.44
			Tracy-M	15.60	23.7	45.86	70.30	96.34	71.90
			Braxton	16.15	20.3	47.48	71.92	74.32	49.88
		20	Bedford	17.15	23.3	50.42	74.86	89.38	64.94
			Tracy-M	17.20	23.2	50.57	75.01	88.63	64.19
			Braxton	17.45	17.9	51.30	75.74	56.10	31.66
	T24	40	Bedford	11.70	19.0	34.40	58.84	79.60	55.16
			Tracy-M	8.00	19.9	23.52	47.96	95.88	71.44
			Braxton	8.95	15.4	26.31	50.75	66.09	41.65
		20	Bedford	14.50	23.7	42.63	67.07	99.57	75.13
			Tracy-M	10.25	22.0	30.14	54.58	101.86	77.42
			Braxton	10.45	15.8	30.72	55.16	64.08	39.64
1982	T12	40	Bedford	11.55	16.1	33.96	58.40	62.64	38.20
			Tracy-M	15.40	14.3	45.28	69.72	40.52	16.08
			Braxton	16.65	20.2	48.95	73.39	72.25	47.81
		20	Bedford	16.55	16.0	33.96	58.40	62.04	37.60
			Tracy-M	16.75	22.2	49.25	73.69	83.95	59.51
			Braxton	19.25	19.2	56.60	81.04	58.60	34.16
	T24	40	Bedford	7.70	10.0	22.64	47.08	37.36	12.92
			Tracy-M	7.70	7.4	22.64	47.08	21.76	(2.68)
			Braxton	7.70	13.9	22.64	47.08	60.76	36.32
		20	Bedford	9.90	13.3	29.11	53.55	50.69	26.25
			Tracy-M	13.70	5.4	40.28	64.72	(7.88)	(32.32)
			Braxton	9.85	13.5	28.96	53.40	52.04	27.60

1/ Irrigation water was applied whenever the soil water potential at the 12-inch (T12) and 24-inch (T24) soil depth dropped between -50 and -100 centibars.
2/ Yield increase equals irrigated yield minus non-irrigated yield.
3/ Direct and total costs were estimated based on 1983 prices and costs of applying the amount of water indicated by a gated-pipe system.
4/ Returns above direct and total costs were computed using a soybean price of $6.00 per bushel. Items enclosed in parentheses represent negative returns or loss.

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