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Soybean Response to Irrigation of Mississippi River Delta Soils

ABSTRACT

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Four studies on both clay and silt loam soils at Stoneville, Miss., tested interactions between irrigation and variety, planting date, timing of irrigation, method of irrigation, and row spacing. Soybeans planted in mid-May and irrigated regularly from beginning of bloom to end of podfill almost always outyielded those planted in late May or early June in all years where moisture deficit conditions existed during reproductive development. Maximum yields were achieved where watering was started at or near bloom or at the onset of first stress after bloom and continued through podfill as needed. Other tested combinations of variables either produced equal yields or affected yields in ways that were inconclusive.

KEYWORDS: Dubbs silt loam, hundred-seed weight, irrigation, lodging, planting date, row spacing, seed yield, soybeans, Sharkey clay

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SOYBEAN RESPONSE TO IRRIGATION OF MISSISSIPPI RIVER DELTA SOILS

By Larry G. Heatherly[1]

INTRODUCTION

The importance of water for plant growth and development is well documented. The yield response of soybeans to water supplied by irrigation has been evaluated in several previous studies, but most of the reported results have been obtained from soils with textures ranging from silt loam to sandy loam (Ashley and Ethridge 1978, Cassel and others 1978, Doss and others 1974, Doss and Thurlow 1974, Martin and others 1979, Matson 1964, Reicosky and Deaton 1979, Scott and Batchelor 1979). Relatively few investigations have examined the response of soybeans to irrigation of clay soils. Growth and development of soybeans on clay soil are greatly different from those of the same varieties on silt loam soil, but yields may not be affected similarly (Heatherly and Russell 1979). Several reports describing the irrigation of soybeans grown on clay (Grissom and others 1955, Longer and others 1981, Scott and Batchelor 1979, Shannon and Duclos 1977) have shown maximum yields well below those obtained on coarser-textured soils.

Since there are over 9 million acres of clay-type soils in the alluvial plain of the Mississippi River, the studies reported here were conducted to determine the effect of irrigation water applied at different times on yield and related properties of soybeans grown on clay and silt loam soils. The intent of this research was to achieve maximum possible yields through full-season water management.

Four separate studies involving irrigation of soybeans were conducted at Stoneville, Miss., in 1979-82. Soil types were Dubbs silt loam (Typic Hapludalf, fine-silty, mixed, thermic) and Sharkey clay (Vertic Haplaquept, very-fine, montmorillonitic, thermic). Varieties were of Maturity Groups V ('Bedford', 'Forrest'), VI ('Tracy', 'Tracy-M', 'Centennial'), and VII ('Bragg', 'Braxton'). Other factors included in these studies were planting date, timing of application, method of application, and row spacing. Weather summaries for each of the growing seasons are presented to point out general differences in rainfall and temperature patterns.

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SUMMARY OF FINDINGS

The following conclusions can be drawn from the results presented in this report:

1. Soybeans planted in mid-May and irrigated regularly from beginning of bloom to the end of pod filling usually outyielded those planted in late May or early June and irrigated by the same guidelines. The increase in yield of irrigated beans over those not irrigated was almost always much greater with mid-May plantings. The data indicate that for optimum yield and greatest response to irrigation, soybeans planted at the generally recommended time of mid-May should be the ones irrigated for highest potential return.

2. Irrigation was never associated with yield decline in any study where soybeans were planted in May and in only one case where soybeans were planted in June (table 3, a 3-bu/acre reduction). Irrigation can increase yield of some varieties even in "wet" years (table 10, Bragg). The basic response of soybean varieties to irrigation is probably not different. In any particular environment, the growth stage of a variety at the time of moisture deficits will affect that variety's response to irrigation.

3. Results of these studies have shown that for maximum yields to be achieved, irrigation of soybeans should be started at or near beginning of bloom or at the onset of the first growth-limiting stress period. This result was true for both clay and silt loam soils.

4. Narrow rows (20-inch spacing), in an extremely dry year such as 1980, can interact with irrigation applied prior to bloom to increase yields above levels achieved with similar irrigation of wide rows (40-inch spacing). Later initiation of irrigation did not significantly increase yield from one row spacing over another. In wet or moderately dry years, row spacings used in these studies did not consistently affect yield of irrigated soybeans.

5. Overhead and furrow irrigation methods both significantly increased soybean yields by nearly identical amounts. The only difference between the two methods measured in these studies was the greater amount of water applied with the furrow method on the clay soil.

6. Watering a clay soil according to soil water potential at the 24-inch soil depth resulted in significant increases in seed yield but required much less water than watering according to soil water potential at the 12-inch depth.

Yield increase per inch of water applied to the T24 treatment always equaled or exceeded that of the T12 treatment. This suggests that the less frequent watering and subsequent lower amounts of water applied to the T24 treatment may be more economical than watering according to the 12-inch depth. Economic analyses of the data are required to verify this.

1979-80

These 2 years are grouped because of their unique differences in both temperature and rainfall patterns. Also, many of the individual studies are grouped this way because of their similarity of treatments and soybean varieties.

Moderate temperatures and frequent rainfall characterized the 1979 growing season (table 1). Only 14 days (14%) of the June 11 to Sept. 20 period had maximum temperatures of 95°F or greater, and the longest consecutive period at this level was the July 1 to July 6 period when all varieties were still in vegetative development. The longest period without significant rainfall (>0.5 inch) during May through August was 13 days. No significant rainfall fell from Sept. 5 through Sept. 20, which corresponded to the podfill period of Bragg.

In 1980, a majority of the days (76%) in the June 11 to Sept. 20 period had a maximum temperature of 95°F or greater, and the maximum exceeded 100°F on 30 days (38%) from June 30 to Sept. 16. Between June 30 and July 18 (bloom period of Bedford), all daily temperatures went above 100°F. Temperatures of this magnitude, especially during flowering, have been found to contribute significantly to lowered soybean yields (Stutte and Weiland 1980), even with adequate soil moisture. Daily minimum relative humidities between June 1 and Sept. 20, 1980, were usually much lower than those in

Table 1.--Total rainfall and average maximum temperature for 10- or 11-day intervals from May 1 to Sept. 30, 1979-82, at Stoneville, Miss.

	Rainfall (inches)				Temperature (°F)			
Period	1979	1980	1981	1982	1979	1980	1981	1982
May 1-10....	3.78	0.70	0.88	0.15	79	77	77	79
May 11-20...	.85	4.02	3.09	.35	82	80	76	87
May 21-31...	3.27	1.18	.64	1.19	79	84	85	91
June 1-10...	1.05	.00	2.81	.68	86	86	88	91
June 11-20..	.34	.52	.06	2.04	92	93	94	86
June 21-30..	2.24	1.91	.00	3.00	88	94	94	88
July 1-10...	1.78	.00	2.02	.00	94	102	88	94
July 11-20..	1.11	.68	.24	.00	91	103	96	96
July 21-31..	3.52	1.09	.82	1.74	92	92	94	93
Aug. 1-10...	.68	.30	.42	.00	93	97	95	92
Aug. 11-20..	1.16	.09	.88	1.18	90	98	92	91
Aug. 21-31..	1.12	.98	.91	.35	90	94	92	95
Sept. 1-10..	2.21	.00	1.70	.31	87	96	84	89
Sept. 11-20.	.08	.00	1.95	2.28	80	96	81	88
Sept. 21-30.	3.38	4.51	.00	.00	82	78	90	78

1979. This, in combination with the higher temperatures of 1980, created a much higher demand for water than in 1979.

1981-82

In 1981, 44 (43%) of the days between June 11 and Sept. 20 had maximum temperatures of 95°F or greater, but only 4% had maximums of 100°F or greater. Between June 30 and July 30, the period when all varieties had at least started blooming, only 13 days had temperatures exceeding 95°F. The remainder of the days with these temperatures were split about evenly between the vegetative periods and the postbloom periods. In contrast to this, the June 11 to Sept. 20 period of 1982 had only 32 days (31%) with temperature maximums of 95°F or greater; however, 18 of these fell between June 30 and July 30, the period when all varieties had at least started to bloom. Most of the remainder occurred during the last days of August when all varieties were in the seed-filling stage.

The July 1 to Aug. 30 period of 1981 received 5.29 inches of rainfall, whereas the same period of 1982 received 3.27 inches. However, the 1981 rainfall was more evenly distributed and subsequently brought more periods of cooler days interspersed among the days with high maximum temperatures. The July 1 to July 26, July 31 to Aug. 14, and Aug. 16 to Sept. 2 periods of 1982 all received no significant (>0.5 inch) rainfall. In 1981, the longest such period was the June 7 to June 30 period when all varieties were still vegetative and had adequate soil moisture for growth.

GENERAL PROCEDURES

Amount of water applied by the furrow method to Sharkey clay was uncontrolled due to the shrinking property of this soil type. Water was added at one end of a plot and was not cut off until it appeared at the opposite end. Amount of water applied by the overhead method was controlled to approximate the amount generally applied in one revolution of a center pivot irrigation system.

Plant height measurements and lodging scores were recorded at maturity in each study. However, nonsignificant differences for these traits among treatments were the general rule. Therefore, values for lodging and plant height are not presented.

Just before harvest, all plants on 2.5 ft of each end of each row were removed. Two rows (40-inch spacing) or four rows (20- or 21-inch spacing) from each plot were harvested. Weights of harvested seed were converted to bushels per acre at 13% moisture, and weights of two 100-seed samples per plot were recorded.

STUDY 1--PLANTING DATE AND IRRIGATION

1979-80 Procedure

Soybeans were planted on May 17 and June 11, 1979, and on May 12 and June 3, 1980, on Sharkey clay. Bedford, Tracy, and Bragg varieties were seeded at rates of 12 seed/ft of row in 1979 and 10 seed/ft in 1980, with 40-inch wide rows used in both years. No preplant-incorporated herbicide was applied prior to the 1979 plantings, but all plots were treated preemergence with a tank mix of alachlor [2-chloro-2',6'-diethyl-N-(methoxymethyl)acetanilide] and linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea]. Trifluralin (α,α,α-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine) was disk-incorporated on Feb. 29, 1980, and the study area received the same preemergence herbicide application as was applied in 1979. All plots were cultivated as needed.

The experiment was designed as a randomized complete block with three replicates of treatments in a split-split plot arrangement. Planting dates were randomized within replicate, varieties were randomized within planting date, and irrigation treatments were randomized within variety. All irrigation treatments were separated by fallowed zones to prevent water movement from an irrigated plot. Row length was 30 ft.

Irrigation treatment was either nonirrigated (NI) or irrigation initiated at beginning of bloom (BL) and continued for the remainder of the growing season. Water was applied by the furrow method (Heatherly and Ginn 1981) whenever soil water potential (SWP) at the 12-inch soil depth dropped to between -50 and -100 centibars. Dates of application and amount of water applied on each date are shown in table 2.

The first and second plantings of Bedford were harvested on Oct. 5 and 12, 1979, and Oct. 15 and 23, 1980. Both 1979 plantings of Tracy were harvested on Oct. 17, and both 1979 plantings of Bragg were harvested on Nov. 5. All 1980 Tracy and Bragg were harvested between Nov. 3 and 12.

1979-80 Results and Discussion

In 1979, soybeans planted on May 17 on clay soil gave no yield response to irrigation (table 3), with average yields of both nonirrigated and irrigated beans being slightly above 55 bu/acre. Yields from the BL treatment of the June 11 planting were slightly lower than NI treatment yields. All of this difference was associated with the Bedford and Tracy varieties, since yields of Bragg from BL and NI treatments applied to the June 11 planting were essentially equal. The slight yield reductions measured in the irrigated early-season Bedford and midseason Tracy were probably the result of the occurrence of significant rainfall within 3 days of all irrigations. Average yields from the earlier planting were higher whether irrigated or not.

Table 2.--Record of irrigation of 3 soybean varieties planted on 2 dates at Stoneville, Miss., 1979-80

Variety	Planting date: May — Irrigation date	May — Amount (inches)	June — Irrigation date	June — Amount (inches)
		1979		
Bedford...	July 20.....	1.75	Aug. 20.....	3.40
	Aug. 10.....	2.80	Sept. 19.....	3.80
	Aug. 30.....	2.90	Total.....	7.20
	Total.....	7.45		
Tracy.....	July 20.....	1.95	Aug. 20.....	2.95
	Aug. 17.....	2.40	Sept. 13.....	3.35
	Sept. 12.....	3.25	Total.....	6.30
	Total.....	7.60		
Bragg.....	Aug. 17.....	2.55	Aug. 17.....	2.30
	Sept. 12.....	3.40	Sept. 19.....	4.00
	Total.....	5.95	Total.....	6.30
		1980		
Bedford...	July 9.....	3.15	July 31.....	3.70
	July 18.....	3.70	Aug. 13.....	3.85
	July 31.....	2.85	Aug. 25.....	3.85
	Aug. 13.....	3.85	Sept. 9.....	3.85
	Aug. 22.....	3.85	Sept. 18.....	3.85
	Sept. 3.....	3.50	Total	19.10
	Total.....	20.90		
Tracy.....	July 16.....	3.85	Aug. 5.....	3.85
	July 31.....	3.10	Aug. 15.....	3.85
	Aug. 13.....	3.85	Aug. 25.....	5.85
	Aug. 25.....	4.90	Sept. 9.....	3.85
	Sept. 9.....	3.85	Sept. 18.....	3.85
	Sept. 19.....	5.15	Total.....	21.25
	Total.....	24.70		
Bragg.....	July 28.....	3.85	Aug. 11.....	3.85
	Aug. 6.....	3.35	Aug. 22.....	3.85
	Aug. 14.....	4.70	Sept. 3.....	3.00
	Aug. 22.....	3.85	Sept. 12.....	3.85
	Sept. 3.....	3.70	Sept. 22.....	3.85
	Sept. 12.....	3.85	Total.....	18.40
	Sept. 22.....	3.85		
	Total.....	27.15		

In 1980, a significant (P=0.10) interaction of planting date by variety by irrigation treatment was measured for yield (table 3). Yields from NI beans planted on May 12 were equivalent to those from NI beans planted on June 3 regardless of variety. However, under irrigation, only Bedford and Tracy produced equivalent yields from both plantings, whereas Bragg

Table 3.--Yield (bushels per acre) of irrigated and nonirrigated soybeans planted on 2 dates on Sharkey clay at Stoneville, Miss., 1979-80

Irrigation treatment	Planting date	Variety			
		Bedford	Tracy	Bragg	Average
			1979[1]		
NI	May 17	50.9	59.8	55.2	55.3x
	June 11	47.4	52.7	54.3	51.5y
	Average	49.2c	56.2a	54.8ab	53.4
BL	May 17	48.5	60.0	58.1	55.5x
	June 11	41.6	47.8	55.1	48.2z
	Average	45.0d	53.9b	56.6a	51.8
			1980[2]		
NI	May 12	14.7d	18.4cd	19.8cd	17.6
	June 3	17.2cd	21.6c	22.6c	20.5
	Average	16.0	20.0	21.2	19.0
BL	May 12	40.6b	45.4ab	52.4a	46.1
	June 3	46.8ab	41.9b	44.3b	44.3
	Average	43.7	43.6	48.4	45.2

[1]Significant interactions of planting date by irrigation treatment and variety by irrigation treatment (P=0.05). Values in each respective group followed by the same letter are not significantly different according to Waller-Duncan k-ratio t-test.

[2]Significant interaction of planting date by variety by irrigation treatment (P=0.05). Values followed by the same letter are not significantly different according to Waller-Duncan k-ratio t-test.

yields from the May 12 BL treatment significantly exceeded (by 8 bu/acre) yields from the June 3 BL treatment. Evidently, the extremely hot temperatures in the July 1 to July 20 period (table 1) caused problems with the May 12 planting of Bedford that adequate water could not overcome. Yields of Tracy and Bragg strongly suggest that irrigation can be more beneficial to May-planted soybeans, and this is further supported by the data of table 4, which show that yield increases from

Table 4.--Yield increase (bushels per acre) from irrigated soybeans planted on 2 dates on Sharkey clay at Stoneville, Miss., 1980-82

Planting date and variety	Yield increase	Increase per inch of applied water
	1980	
May 12:		
Bedford	25.9	1.24
Tracy	27.0	1.09
Bragg	32.5	1.20
June 3:		
Bedford	29.7	1.55
Tracy	20.2	.95
Bragg	21.8	1.18
	1981	
May 13:		
Bedford	26.7	2.11
Braxton	33.4	2.02
June 4:		
Bedford	19.7	2.56
Braxton	18.5	1.60
	1982	
May 12:		
Bedford	18.9	1.64
Braxton	25.4	1.65
May 28:		
Bedford	11.7	1.01
Braxton	17.3	1.50

irrigation of Tracy and Bragg planted on May 12 were 7 to 11 bu/acre more than those from irrigation of the June 3 planting, with more water being required to achieve these higher increases (table 2).

Neither irrigation treatment nor planting date significantly affected 100-seed weight in 1979 (table 5). Varietal differences followed the expected trend of greatest seed weight with Tracy and least with Bedford. A significant (P=0.05) interaction of variety by irrigation treatment was

Table 5.--100-seed weight (grams) of irrigated and nonirrigated soybeans planted on 2 dates on Sharkey clay at Stoneville, Miss., 1979-80

Irrigation treatment	Planting date	Variety			
		Bedford	Tracy	Bragg	Average
			1979[1]		
NI	May 17	11.1	15.7	14.2	13.7
	June 11	11.7	15.7	14.7	14.0
	Average	11.4c	15.7a	14.4b	13.9
BL	May 17	11.1	15.8	14.4	13.8
	June 11	11.5	15.9	15.2	14.2
	Average	11.3c	15.8a	14.8b	14.0
			1980[2]		
NI	May 12	9.8	15.2	14.0	13.0
	June 3	10.8	14.9	15.2	13.6
	Average	10.3d	15.0b	14.6b	13.3
BL	May 12	12.2	16.3	14.6	14.4
	June 3	12.8	17.2	15.1	15.0
	Average	12.5c	16.8a	14.8b	14.7

[1]Significant difference among varieties (P=0.05). Values followed by the same letter are not significantly different according to Waller-Duncan k-ratio t-test.
[2]Significant interaction of variety by irrigation treatment (P=0.05). Values followed by the same letter are not significantly different according to Waller-Duncan k-ratio t-test.

measured for this trait in 1980. Bedford and Tracy had higher average 100-seed weights from the BL treatment, whereas Bragg had equal seed weights from both NI and BL treatments. The average seed weight from the June 3 planting was heavier than from the May 12 planting. However, in three of the six interactions of variety by irrigation treatment, seed weight differences between planting dates did not reflect the same trend as yield differences between planting dates. This indicates that seed weight differences do not necessarily reflect the yield component which is contributing to the increased yields from irrigation.

1981-82 Procedure

Soybeans were planted on May 13 and June 4, 1981, and May 12 and 28, 1982, on Sharkey clay. Bedford was again used as the group V variety, but Bragg was replaced by Braxton. Seeding

Table 6.--Record of irrigation of 2 soybean varieties planted on 2 dates at Stoneville, Miss., 1981-82

Variety	Planting date: May — Irrigation date	May — Amount (inches)	June — Irrigation date	June — Amount (inches)
		1981		
Bedford...	July 22.....	4.95	July 31.....	3.85
	Aug. 3.....	3.85	Aug. 19.....	3.85
	Aug. 20.....	3.85	Total.....	7.70
	Total.....	12.65		
Braxton...	July 20.....	5.00	July 30.....	3.85
	Aug. 3	3.85	Aug. 19.....	3.85
	Aug. 20.....	3.85	Sept. 14.....	3.85
	Sept. 14.....	3.85	Total.....	11.55
	Total.....	16.55		
		1982		
Bedford...	July 21.....	3.85	July 29.....	3.85
	Aug. 11.....	3.85	Aug. 25.....	3.85
	Aug. 30.....	3.85	Sept. 8.....	3.85
	Total.....	11.55	Total.....	11.55
Braxton...	July 21.....	3.85	July 29.....	3.85
	Aug. 9.....	3.85	Aug. 25.....	3.85
	Aug. 27.....	3.85	Sept. 8.....	3.85
	Sept. 8.....	3.85	Total.....	11.55
	Total	15.40		

rate in both years was 10 seed/ft of row, and row spacing remained at 40 inches. Trifluralin was disk-incorporated on Jan. 15 and Nov. 17, 1981. The 1981 study area was treated preemergence with linuron, while 1982 plots received a preemergence application of metribuzin [4-amino-6-tert-butyl-3-(methylthio)-as-triazin-5(4H)-one]. In 1981, plots received a postdirected application of linuron plus 2,4-DB [4-(2,4-dichlorophenoxy)butyric acid] on July 7. All plots were cultivated as needed.

Experimental design and irrigation treatments were the same as in the 1979-80 studies. Dates of application and amount of water applied on each date are shown in table 6. The first 1981 plantings of Bedford and Braxton were harvested on Oct. 15 and Nov. 5, respectively. The second planting of each was harvested on Nov. 5. Both 1982 plantings of Bedford were harvested on Oct. 22, while Braxton was harvested on Nov. 5.

1981-82 Results and Discussion

A significant ($P=0.05$) interaction of planting date by irrigation treatment for yield occurred (table 7) in both years. In the 1981 NI environment, the June 4 planting produced a higher average yield than did the May 13 planting, and this increase was attributable almost entirely to Braxton, which yielded 15.3 bu/acre from the May 13 NI planting and 25.2 bu/acre from the June 4 NI planting. Obviously, the 1.70 inches of rain (table 1) that fell between Aug. 31 and Sept. 5 of 1981 overcame the effects of earlier moisture stress more in the June 4 NI Braxton than in the May 13 NI Braxton or either NI planting of Bedford. In 1982, yields from the NI treatment of both varieties planted on either May 12 or May 28 were similar.

In contrast to the NI treatment of both years, where average yield of the later plantings either equaled or exceeded yields from the earlier plantings, average yields from the BL treatment of the early plantings (May 13, 1981, and May 12, 1982) of both varieties exceeded those from the later plantings even though differences in planting dates were only 22 and 16 days for 1981 and 1982, respectively (table 7). Irrigation increased yields 26.7 and 18.9 bu/acre from the earlier plantings of Bedford in 1981 and 1982, respectively, but only 19.7 and 11.7 bu/acre from the later plantings in the respective years (table 4). The irrigated earlier plantings of Braxton in 1981 and 1982 produced increases of 33.4 and 25.4 bu/acre, respectively, whereas the irrigated later plantings produced increases of only 18.5 and 17.3 bu/acre for 1981 and 1982, respectively. Therefore, the 1980 trend of larger yield increases from irrigation of mid-May-planted soybeans vs. those planted in late May or early June was even more evident.

In 1982, a significant interaction of variety by irrigation treatment was measured (table 7). This was because the average yield from the BL treatment of Braxton (37.6 bu/acre) was significantly greater than that from Bedford (29.1 bu/acre), whereas the yields from the NI treatment of each cultivar were similar. In 1981, average Braxton yields significantly exceeded those of Bedford in both the NI and BL treatments.

Table 7.--Yield (bushels per acre) of irrigated and nonirrigated soybeans planted on 2 dates on Sharkey clay at Stoneville, Miss., 1981-82

Irrigation treatment	Planting date	Variety		
		Bedford	Braxton	Average
		1981[1]		
NI.....	May 13....	14.6	15.3	15.0d
	June 4....	15.6	25.2	20.4c
	Average.	15.1	20.2	17.7
BL.....	May 13....	41.3	48.7	45.0a
	June 4....	35.3	43.7	39.5b
	Average.	38.3	46.2	42.2
		1982[1,2]		
NI.....	May 12....	14.5	15.0	14.8c
	May 28....	13.1	17.6	15.4c
	Average.	13.8c	16.3c	15.1
BL.....	May 12....	33.4	40.4	36.9a
	May 28....	24.8	34.9	29.8b
	Average.	29.1b	37.6a	33.4

[1]Significant interaction of planting date by irrigation treatment ($P=0.05$). Values within each year followed by the same letter are not significantly different according to Waller-Duncan k-ratio t-test.

[2]Significant interaction of variety by irrigation treatment ($P=0.05$). Values followed by the same letter are not significantly different according to Waller-Duncan k-ratio t-test.

In 1982, a significant interaction of variety by irrigation treatment was measured for seed weight (table 8). This resulted from Bedford producing seed with lower weight in the NI treatment than in the BL treatment, whereas seed of Braxton from the two irrigation treatments were identical in weight. These shifts in seed weight between treatments and varieties appear to be of little consequence, and yield patterns (table 7) do not reflect the same trends. Planting date had no significant effect on seed weight.

Table 8.--100-seed weight (grams) of irrigated and nonirrigated soybeans planted on 2 dates on Sharkey clay at Stoneville, Miss., 1981-82

Irrigation treatment	Planting date	Variety		
		Bedford	Braxton	Average
		1981[1]		
NI	May 13	11.9e	16.6b	14.2
	June 4	13.3d	18.5a	15.9
	Average	12.6	17.6	15.0
BL	May 13	13.5d	16.7b	15.1
	June 4	13.5d	16.0c	14.8
	Average	13.5	16.4	15.0
		1982[2]		
NI	May 12	8.7	15.3	12.0
	May 28	8.9	14.7	11.8
	Average	8.8c	15.0a	11.9
BL	May 12	11.4	15.3	13.4
	May 28	11.6	14.8	13.2
	Average	11.5b	15.0a	13.3

[1]Significant interaction of planting date by variety by irrigation treatment ($P=0.05$). Values followed by the same letter are not significantly different according to Waller-Duncan k-ratio t-test.

[2]Significant interaction of irrigation treatment by variety ($P=0.05$). Values followed by the same letter are not significantly different according to Waller-Duncan k-ratio t-test.

STUDY 2--TIMING OF IRRIGATION

1979-80 Clay Procedure

Soybeans were planted on June 13, 1979, and May 8, 1980. Bedford, Tracy, and Bragg varieties were seeded at rates of 12 and 10 seed/ft of row in 1979 and 1980, respectively, and row spacing was 40 inches. All plots were treated preemergence with a tank mix of alachlor and linuron in both years, and the 1980 plots received a disk-incorporated application of trifluralin on Feb. 29. Also in 1980, postemergence applications of bentazon [3-isopropyl-1H-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide] and of linuron plus 2,4-DB were applied on June 10 and July 2, respectively. All plots were cultivated as needed.

The experiment was designed as a randomized complete block with three replicates of treatments in a split plot arrangement. Varieties were randomized within replicate, and irrigation treatments were randomized within variety. All irrigation treatments were separated by fallowed zones. Row length was 30 ft, and plots were four rows wide.

Irrigation treatments were designed to be the same for all varieties each year. However, because of differing weather patterns (table 1), the intended treatments were altered during the course of each year's experiment. In 1979, the treatments for Bedford and Tracy were (1) no irrigation (NI), (2) irrigation started at beginning of podset (PS), and (3) irrigation begun at the beginning of podfill (PF). For Bragg, an additional treatment of irrigation initiated at the beginning of bloom (BL) was also incorporated. In 1980, the treatments for Bedford were NI, BL, PS, and PF. For Tracy and Bragg, treatments were NI, BL, and PF, plus irrigation started prior to bloom (PB). For all treatments, irrigation was initiated at the indicated stage if SWP at the 12-inch depth was below -50 centibars. If SWP was higher (more positive) than this at the intended starting time, watering was delayed until it reached the designated level. Irrigation after the initial application was applied when SWP at the 12-inch depth dropped to between -50 and -100 centibars. Dates and amount of applied water are shown in table 9. All harvesting dates for this study were the same as those for the first plantings of study 1.

1979-80 Clay Results and Discussion

Neither Bedford nor Tracy yields were significantly affected by any irrigation treatment in 1979 (table 10). All irrigations except the Sept. 11 (Tracy PF) and Sept. 13 (Bedford PS) applications to Bedford or Tracy were followed by significant rainfall within 2 to 3 days. Even though these two September applications were followed by 10 and 8 days of no rain, respectively, the Bedford variety was beginning maturity and the Tracy variety was near the beginning of maturity. Obviously, this last application to each of these varieties was too late to be of benefit. Bragg, on the

Table 9.--Record of irrigation of 3 soybean varieties grown on Sharkey clay at Stoneville, Miss., 1979-80

Variety	Irrigation treatment							
	PB		BL		PS		PF	
	Date	Amount (inches)	Date	Amount (inches)	Date	Amount (inches)	Date	Amount (inches)
				1979				
Bedford					Aug. 21	3.15	Aug. 30	3.40
					Sept. 13	2.85	Total	3.40
					Total	6.00		
Tracy					Aug. 21	3.20	Aug. 29	2.95
					Sept. 18	3.65	Sept. 11	2.85
					Total	6.85	Total	5.80
Bragg			Aug. 21	3.30	Aug. 31	3.45	Sept. 14	3.55
			Sept. 19	3.65	Total	3.45	Total	3.55
			Total	6.95				
				1980				
Bedford			July 7	2.30	July 28	3.85	Aug. 13	6.50
			July 16	2.95	Aug. 8	3.85	Aug. 26	3.80
			July 31	3.00	Aug. 19	3.85	Sept. 10	3.60
			Aug. 13	3.85	Aug. 28	3.85	Total	13.90
			Aug. 26	3.75	Sept. 10	3.85		
			Sept. 5	2.95	Total	19.25		
			Total	18.80				
Tracy	July 11	3.20	July 16	3.85			Sept. 3	7.70
	July 30	3.25	July 30	2.80			Sept. 12	3.85
	Aug. 11	3.85	Aug. 8	3.85			Total	11.55
	Aug. 20	3.85	Aug. 19	3.85				
	Aug. 29	3.85	Aug. 28	3.85				
	Sept. 10	3.85	Sept. 10	3.85				
	Sept. 19	3.85	Sept. 19	3.85				
	Total	25.70	Total	25.90				
Bragg	July 7	2.35	July 25	3.85			Sept. 8	7.70
	July 16	3.05	Aug. 6	3.75			Sept. 18	3.85
	July 30	2.80	Aug. 14	3.85			Total	11.55
	Aug. 8	3.85	Aug. 25	3.80				
	Aug. 19	3.85	Sept. 5	3.85				
	Aug. 28	3.85	Sept. 16	3.85				
	Sept. 10	3.85	Total	22.95				
	Sept. 19	3.85						
	Total	27.45						

other hand, gave a significant yield response to irrigation started at beginning of podfill but not to the applications initiated at beginning of podset. All irrigations of Bragg except the Sept. 14 application (PF treatment, table 9) were followed within 2 to 3 days by significant rainfall. The Sept. 14 application had been preceded by 11 days and was followed by 7 days of no rain. Bragg on Sept. 14 was just beginning rapid seed enlargement, and the proper timing of this application is reflected in the yield response of 6.8 bu/acre and the 1.90 bu/acre per inch increase (table 11).

In 1980, Bedford data were analyzed separately from those for Tracy and Bragg since all varieties did not have totally comparable treatments. In this drier year, yields of the BL and PS treatments of Bedford were similar; both were

Table 10.—Yield (bushels per acre) of irrigated and nonirrigated soybeans planted on Sharkey clay at Stoneville, Miss., 1979-80

Irrigation treatment	Variety			
	Bedford	Tracy	Bragg	Average[1]
		1979[2]		
NI.....	40.9c	50.0b	47.1b	46.0
PS.....	39.7c	50.2b	47.7b	45.9
PF.....	38.4c	49.1b	53.9a	47.1
Average..	39.7	49.8	49.6	....
		1980[3]		
NI.....	10.9b	17.1	19.7	18.4c
PB.....	....	42.9	52.9	47.9
BL.....	29.7a	41.8	47.8	44.8a
PS.....	26.0a	....	....	....
PF.....	16.5b	21.8	26.6	24.2b
Average..	20.8	30.9	36.8	....

[1]1980 values are for Tracy and Bragg only.
[2]Significant interaction of variety by irrigation treatment ($P=0.05$). Values followed by the same letter are not significantly different according to Waller-Duncan k-ratio t-test.
[3]Values for Bedford followed by the same letter are not significantly different ($P=0.05$) according to Waller-Duncan k-ratio t-test. Average values for Tracy and Bragg followed by the same letter are not significantly different according to Waller-Duncan k-ratio t-test.

significantly (P=0.05) higher than those of PF and NI treatments (table 10). Initiation of irrigation after the beginning of podset was obviously too late for a significant benefit to yield of Bedford.

Table 11.--Yield increase (bushels per acre) from irrigated soybeans planted on Sharkey clay at Stoneville, Miss., 1979-80

Variety and irrigation treatment	Yield increase	Increase per inch of applied water
	1979	
Bedford:		
PS	-1.2	0.00
PF	-2.5	.00
Tracy:		
PS	.2	.00
PF	-.9	.00
Bragg:		
PS	.6	.20
PF	6.8	1.90
	1980	
Bedford:		
BL	18.8	1.00
PS	15.2	.80
PF	5.6	.40
Tracy:		
PB	25.8	1.00
BL	24.7	.95
PF	4.7	.40
Bragg:		
PB	33.2	1.20
BL	28.1	1.20
PF	6.9	.60

Yields of the PS and PF treatments were 13.7 and 21.9 bu/acre below yields of corresponding treatments of 1979, even though amount of water applied by irrigation was higher (table 9). The extremely high temperatures during the flowering period of Bedford (table 1) evidently had an irreversible effect on yield potential that irrigation could not overcome, as has been found by others (Stutte and Weiland 1980).

The effect of irrigation on 1980 yields of Tracy and Bragg was significant ($\underline{P}=0.05$), with both delayed irrigation (PF treatment) and no irrigation (NI treatment) resulting in lower yields (table 10). Irrigation prior to bloom (PB) provided no significant yield increase above the BL treatment of either variety. With Tracy, the PB and BL treatments had the same number of applications and essentially the same amount of water applied; with Bragg, however, the PB treatment required more water than did the BL treatment (table 9). The yield increases per inch of applied water for both treatments within each variety (table 11) were similar (Tracy, 1.00 and 0.95 bu/acre per inch for PB and BL, respectively; Bragg, 1.20 for both).

The lack of a yield response to prebloom irrigation of soybeans agrees with other reports (Ashley and Ethridge 1978, Doss et al. 1974, Grissom et al. 1955, Martin et al. 1979, Matson 1964), all of which present results obtained from sandy soils. Ashley and Ethridge (1978), growing 'Ransom' soybeans on a sandy loam soil, found that full-season irrigation (comparable to our PB treatment) produced more pods than irrigation started at either beginning bloom or beginning podfill. However, they found that the full-season treatment had more pods to drop off. We did not count pods in our studies, but their finding may be a partial explanation for the lack of a significant yield increase from even a full-season variety such as Bragg.

As with Bedford, waiting until beginning of podfill for beginning irrigation in 1980 was too late to achieve maximum yields from Tracy and Bragg (table 10), although the average yield from the PF treatment (24.2 bu/acre) was significantly greater than that from the NI treatment (18.4 bu/acre). The yield increases per inch of irrigation water resulting from the PF applications (table 11) were less than half of those obtained from earlier applications. This is in direct contrast to the results of 1979 (table 10), where one application of water to Bragg at beginning of podfill provided a greater yield than produced from treatments receiving earlier applications of water. The different response between the two years is attributable to the contrasting weather conditions (table 1) preceding the PF treatment of each year.

The best yields in the 1979 test are about 24 bu/acre higher than those obtained from Kobel clay in Arkansas (Scott and Batchelor 1979), where irrigation treatment was similar to our BL treatment and the growing season was classified as wet. Obviously, irrigation in the wet year of 1979 did not cause a reduction in yield of those varieties that developed totally during the period of adequate rainfall. Also, maximum yields attained with irrigation in this study are considerably higher than those achieved previously on clay soils (Grissom et al. 1955, Longer et al. 1981, Scott and Batchelor 1979, Shannon and Duclos 1977), probably because we irrigated more frequently and continued watering throughout the podfilling period.

Yields of the PF treatment of Tracy and Bragg in 1980 were each about 27 bu/acre below yields of the corresponding treatment of each variety in 1979 (table 10). However, the highest yielding treatments in 1980 were only 7.3 and 1.0 bu/acre below the highest yielding treatment of each respective variety in 1979. The top 1980 yields of Tracy and Bragg required 25.7 and 27.4 inches of irrigation water, respectively, whereas top 1979 yields required only 0 and 3.6 inches of additional water. The severe 1980 growing season, contrasted to the moderate 1979 season, resulted in significantly different irrigation requirements to achieve similar maximum yields.

A significant interaction of variety by irrigation treatment occurred for 100-seed weight in 1979 (table 12). This was due to the lower seed weights measured in the PS treatment of Bedford as compared with the NI treatment. Tracy and Bragg seed weights were similar from all irrigation treatments. These seed weight differences or similarities do not reflect the yield trends (table 10) that were measured. In 1980, differences in seed weight within varieties show essentially the same trend as yield differences, but the seed weight differences are not of the same magnitude as yield differences. This again indicates that some other yield component such as seed per plant may be the primary trait of importance in yield response to irrigation.

1979-80 Silt Loam Procedure

Forrest soybeans were planted on Dubbs silt loam on June 5, 1979, and May 5, 1980, at a rate of 12 and 10 seed per foot of row, respectively. Row spacing was 40 inches. All plots were treated preemergence with a tank mix of alachlor and linuron. Trifluralin had been applied in the fall of 1979. All plots were cultivated as needed.

Table 12.--100-seed weight (grams) of irrigated and nonirrigated soybeans planted on Sharkey clay at Stoneville, Miss., 1979-80

Irrigation treatment	Variety			
	Bedford	Tracy	Braxton	Average[1]
		1979[1]		
NI.....	13.2c	15.9a	14.9b	14.7
PS.....	12.1d	15.8a	15.5ab	14.4
PF.....	12.5cd	15.9a	14.7b	14.4
Average..	12.6	15.9	15.0	....
		1980[2]		
NI.....	10.5b	15.4	14.0	14.6c
PB.....	....	16.6	15.3	16.0a
BL.....	12.9a	16.2	15.1	15.6ab
PS.....	12.3a	....	....	....
PF.....	12.1a	16.4	14.1	15.2bc
Average..	12.0	16.2	14.6	....

[1]Significant interaction of variety by irrigation treatment (P=0.05). Values followed by the same letter are not significantly different according to Waller-Duncan k-ratio t-test.
[2]Values for Bedford followed by the same letter are not significantly different(P=0.05) according to Waller-Duncan k-ratio t-test. Average values for Tracy and Bragg followed by the same letter are not significantly different (P=0.05).

The experiment was designed as a randomized complete block with three replicates. Irrigation treatments in 1979 were NI and PF, while NI, BL, PS, and PF treatments were used in 1980. Water was applied by the overhead method using the same criteria used in previously described studies. Dates and amounts of applied water are shown in table 13. Harvest was on Oct. 5, 1979, and Oct. 9, 1980.

1979-80 Silt Loam Results and Discussion

Seed yield and 100-seed weight were both unaffected by irrigation of Forrest soybeans in 1979 (table 14). The yield level of the NI treatment indicates that adequate water was supplied by rainfall in this year.

Table 13.--Record of irrigation of Forrest soybeans grown on Dubbs silt loam at Stoneville, Miss., 1979-82

Irrigation treatment					
BL		PS		PF	
Date	Amount (inches)	Date	Amount (inches)	Date	Amount (inches)
			1979		
				Aug. 28...	1.50
				Sept. 11..	1.50
				Total...	3.00
			1980		
June 23..	1.00	July 23..	1.50	Aug. 11...	1.50
July 3...	1.00	Aug. 4...	1.50	Aug. 21...	2.25
July 10..	1.00	Aug. 12..	1.50	Aug. 27...	1.60
July 14..	1.00	Aug. 21..	1.75	Sept. 8...	1.40
July 24..	1.00	Aug. 27..	1.50	Total...	6.75
Aug. 4...	1.00	Sept. 8..	1.30		
Aug. 12..	1.50	Total..	9.05		
Aug. 21..	1.75				
Aug. 27..	1.50				
Sept. 8..	1.40				
Total..	12.15				
			1981		
June 29..	3.55				
July 17..	1.35				
July 27..	1.35				
Aug. 4...	1.35				
Aug. 11..	1.35				
Aug. 12..	1.15				
Aug. 21..	1.35				
Aug. 28..	1.35				
Total..	12.80				
			1982		
July 16...	1.50				
July 23...	1.50				
July 29...	1.00				
Aug. 10...	1.00				
Aug. 20...	1.00				
Aug. 30...	1.00				
Total...	7.00				

[1]Narrow spacing. Wide spacing had 2.65 inches applied on June 29 and none applied on Aug. 12--total amount, 10.75 inches.

Table 14.--Yield (bushels per acre) and 100-seed weight (grams) of irrigated and nonirrigated Forrest soybeans grown on Dubbs silt loam at Stoneville, Miss., 1979-80

Irrigation treatment	Seed yield	100-seed weight
	1979[1]	
NI	52.2a	11.6a
PF	53.9a	11.5a
	1980	
NI	16.7c	9.7b
BL	44.3a	12.2a
PS	36.9b	12.1a
PF	36.4b	12.4a

[1]Values in each column within each year followed by the same letter are not significantly different ($P=0.05$) according to Waller-Duncan k-ratio t-test.

In 1980, each of the three irrigation treatments (BL, PS, PF) increased seed yield significantly above the 16.7 bu/acre yield of the NI treatment (table 14). However, irrigation initiated at bloom (BL treatment) gave the highest yield, with the PS and PF treatment yields being nearly equal. Seed weights of the three irrigated treatments were essentially equal. The low yield and the significantly lower seed weight (9.7 g/100 seed) of the NI treatment reflect the effect of the extremely dry growing season and high maximum daily temperatures of 1980 (table 1).

All irrigation treatments in 1980 produced over 2 bu/acre yield increases per inch of irrigation water (table 15). Even though the highest increase per inch of water was measured from the PF treatment (2.92 bu/inch), the 8 bushels per acre higher yield from the BL treatment would seem to outweigh its lower efficiency of water use (2.27 bu/acre per inch).

The highest 1980 yield of 44.3 bu/acre is 9.6 bu/acre lower than the highest yield of 1979. This is exactly the same trend that was noted with Bedford (also group V maturity) grown and irrigated on the clay soil in 1979 and 1980 (table 10). This again points out that, as with clay soil, there is apparently some factor other than moisture that limits soybean yields on silt loam. The major difference between 1979 and

Table 15.--Yield increase (bushels per acre) from irrigated Forrest soybeans grown on Dubbs silt loam at Stoneville, Miss., 1979-82

Year	Irrigation treatment	Row spacing[1]	Yield increase	Increase per inch of applied water
1979	PF	Wide	1.7	0.57
1980	BL	Wide	27.6	2.27
	PS	Wide	20.2	2.23
	PF	Wide	19.7	2.92
1981	T12	Wide	4.6	.43
	T12	Narrow	14.6	1.14
1982	T12	Wide	17.5	2.50
	T12	Narrow	16.1	2.30

[1]Wide=40 inches; narrow=20 or 21 inches.

1980, other than moisture differences that were overcome by irrigation, was the tremendous difference in daily maximum temperatures in the June 21 to July 20 period (table 1). This period corresponded to the bloom period of both Forrest and Bedford in 1980 and may have contributed to the depressed yields, even in the presence of adequate water.

STUDY 3--METHOD OF IRRIGATION

1979-80 Procedure

Tracy and Centennial soybeans were planted on Sharkey clay on June 14, 1979, and June 2, 1980, at a rate of 10 seed/ft of row. Plots were four rows wide (40-inch spacing) and 60 ft long. Plots of both years were preemerged with a tank mix of alachlor and linuron. Trifluralin was disk-incorporated on Feb. 29, 1980. Cultivation was done as needed for additional weed control.

The experiment was designed as a randomized complete block with two replicates of treatments in a split plot arrangement. Irrigation types were randomized within replicate, time of irrigation initiation was randomized within type, and varieties were randomized within time of irrigation. All irrigation treatments and types were separated by fallowed zones to prevent water movement from irrigated plots.

Irrigation type was either furrow or overhead, with overhead water being applied by sprinkler risers. Furrow-irrigated plots were watered in alternate middles. Rain gages were inserted to measure amount of water applied by the overhead method.

Time of irrigation in 1979 was (1) nonirrigated (NI), (2) irrigation initiated at bloom (BL), or (3) irrigation initiated at beginning of podfill (PF). After initial application of water, subsequent irrigation water was applied whenever SWP at the 12-inch soil depth dropped to between -50 and -100 centibars. In 1980, the NI treatment was replaced by a treatment (VG) in which irrigation water was applied at planting to achieve a stand and again on July 11 to enhance vegetative growth. The other two treatments in 1980 were identical to the BL and PF treatments of 1979. Dates of application and amount of water applied (not measured on all dates) are shown in table 16. Plots were harvested on Oct. 25, 1979, and Nov. 6, 1980.

1979-80 Results and Discussion

In 1979, both overhead and furrow irrigation of Tracy and Centennial soybeans achieved equal yields that were no different from those of the NI treatment (table 17). All yields averaged 50 bu/acre or higher. Time of initiation of irrigation made no significant impact on seed yield of either of these group VI varieties.

In 1980, initiation of irrigation of both Tracy and Centennial varieties at bloom (BL treatment) by either the furrow or overhead method resulted in essentially equal yields that were significantly greater than those obtained from either of the other treatments. Varietal response to both irrigation treatment and method of irrigation was nearly equal.

Table 16.--Record of irrigation of 2 soybean varieties irrigated by 2 methods at Stoneville, Miss., 1979-80

Irrigation Method	Irrigation treatment					
	VG		BL		PF	
	Date	Amount (inches)	Date	Amount (inches)	Date	Amount (inches)
			1979			
Furrow			Aug. 20	4.50	Sept. 12	3.80
			Sept. 15	4.50	Total	3.80
			Total	9.00		
Overhead			Aug. 21	1.50	Sept. 14	1.90
			Sept. 14	1.90	Total	1.90
			Total	3.40		
			1980			
Furrow	June 5	(1)	June 5	(1)	June 5	(1)
	July 11	(1)	July 11	(1)	July 11	(1)
			Aug. 6	4.00	Sept. 11	(1)
			Aug. 18	(1)	Sept. 23	(1)
			Aug. 29	(1)		
			Sept. 10	(1)		
			Sept. 23	(1)		
Overhead	June 5	(1)	June 5	(1)	June 5	(1)
	July 11	(1)	July 11	(1)	July 11	(1)
			Aug. 6	1.80	Sept. 9	1.56
			Aug. 18	1.80	Sept. 18	1.55
			Aug. 28	1.75		
			Sept. 9	1.56		
			Sept. 18	1.55		

[1]Irrigation amounts were not measured.

The VG treatment received applications of water on June 5 and July 11, and both dates were before bloom had started. No more applications were made to the plots in this treatment. In contrast, the PF treatment received additional applications of water on Sept. 9 and Sept. 18 with no resulting effect on yield. It appears from these data that additional application of water after beginning of podfill offers no yield enhancement above that achieved from watering prior to bloom only. With only one year's data, the validity of this inference is certainly conditional.

Table 17.--Yield (bushels per acre) of soybeans grown on Sharkey clay and irrigated by 2 methods at Stoneville, Miss., 1979-80

Irrigation treatment	Variety	Irrigation method: Furrow	Irrigation method: Overhead	Average[1]
		1979		
NI.....	Tracy.....	([2])	([2])	53.2a
	Centennial...	([2])	([2])	52.4a
BL.....	Tracy.....	54.8	48.8	51.8a
	Centennial...	49.9	51.9	50.9a
PF.....	Tracy.....	50.1	49.5	49.8a
	Centennial...	49.7	51.8	50.8a
	Average....	51.1a	50.5a	....
		1980		
VG.....	Tracy.....	([3])	([3])	28.8b
	Centennial...	([3])	([3])	30.2b
BL.....	Tracy.....	45.2	46.1	45.6a
	Centennial...	49.2	49.2	49.2a
PF.....	Tracy.....	34.3	31.4	32.8b
	Centennial...	32.4	28.6	30.5b
	Average....	40.3a	38.8a	....

[1]Values within a row or column of each year followed by the same letter are not significantly different acccording to Waller-Duncan k-ratio t-test.
[2]NI treatment not irrigated by either method.
[3]VG treatment irrigated by furrow method only.

1981, 1983 Procedure

Tracy-M and Centennial varieties were planted on May 15, 1981, and May 9, 1983. Seeding rate was again 10 seed/ft of 40-inch row. Trifluralin was disk-incorporated on Jan. 15, 1981, and Nov. 9, 1982. A preemergence application of linuron was made in 1981, and metribuzin plus dinoseb (2-sec-butyl-4,6-dinitrophenol) was applied preemergence in 1983. Postdirected applications of acifluorfen [5-[2-chloro-4-(trifluoromethyl)-phenoxy]-2-nitrobenzoic acid] and 2,4-DB plus linuron were made in 1981 for additional weed control, and 2,4-DB plus linuron and dinoseb were postdirected in 1983. All plots were cultivated as needed.

Experimental design and irrigation methods were the same as in 1979-80. However, in 1981-83, time of irrigation was changed to either (1) irrigation initiated whenever SWP at the 12-inch soil depth dropped to between -50 and -100 centibars (T12), essentially equal to 1979-80 BL treatment or (2) irrigation initiated whenever SWP at the 24-inch soil depth dropped to between -50 and -100 centibars (T24). In both cases, subsequent irrigations were made using the same criteria as used for initiation of watering. Dates of irrigation and amount of water applied on each date are shown in table 18. Plots were harvested on Oct. 29, 1981, and on Oct. 30, 1983.

Table 18.--Record of irrigation of 2 soybean varieties irrigated by 2 methods at Stoneville, Miss., 1981, 1983

Irrigation method	Irrigation treatment			
	T12		T24	
	Date	Amount (inches)	Date	Amount (inches)
		1981		
Furrow	July 15	3.60	July 22	3.75
	July 28	3.20	Aug. 10	4.00
	Aug. 10	2.80	Total	7.75
	Aug. 28	3.15		
	Total	12.75		
Overhead	July 15	1.70	July 22	1.65
	July 22	1.65	Aug. 10	1.50
	Aug. 7	1.65	Aug. 27	1.65
	Aug. 24	1.70	Total	4.80
	Total	6.70		
		1983		
Furrow	July 14	3.25	July 14	3.25
	July 28	2.90	Aug. 29	4.45
	Aug. 19	3.00	Total	7.70
	Aug. 31	4.50		
	Total	13.65		
Overhead	July 20	1.60	July 20	1.60
	Aug. 1	1.90	Aug. 17	1.90
	Aug. 17	1.90	Sept. 2	1.50
	Aug. 29	1.75	Total	5.00
	Sept. 8	1.65		
	Total	8.80		

Table 19.--Yield (bushels per acre) of soybeans grown on Sharkey clay and irrigated by 2 methods at Stoneville, Miss., 1981, 1983

Irrigation treatment	Variety	Irrigation method: Furrow	Irrigation method: Overhead	Average
		1981[1]		
NI	Tracy-M	(2)	(2)	21.4b
	Centennial	(2)	(2)	22.0b
T12	Tracy-M	47.1	46.5	46.8a
	Centennial	48.8	45.9	47.4a
T24	Tracy-M	43.1	36.7	39.9a
	Centennial	47.1	41.6	44.4a
	Average	46.5a	42.7b	....
		1983[3]		
NI	Tracy-M	(2)	(2)	20.0
	Centennial	(2)	(2)	18.4
T12	Tracy-M	47.4	39.1	43.2
	Centennial	49.3	42.4	45.8
	Average	48.4a	40.8b	....
T24	Tracy-M	39.9	37.4	38.6
	Centennial	43.1	37.6	40.4
	Average	41.5b	37.5c	....

[1]Significant ($P=0.05$) irrigation-treatment effect. Average values followed by the same letter are not significantly different according to Waller-Duncan k-ratio t-test.
[2]NI treatment not irrigated by either method.
[3]Significant ($P=0.05$) interaction of irrigation treatment by irrigation type. Values followed by the same letter are not significantly different according to Waller-Duncan k-ratio t-test.

1981, 1983 Results and Discussion

In 1981, yields from furrow-irrigated plots were significantly higher ($P=0.10$) than those from overhead-irrigated areas (table 19). However, from the data of table 18, it can be seen that significantly more water was applied to the furrow-irrigated plots to achieve this extra 3.8 bu/acre. Therefore, the economic feasibility of this additional yield may be lacking. Also, most of the difference appears to be

derived from the T24 treatment, although the interaction of irrigation method by irrigation treatment was significant at only the 23% level of probability. Since there was no significant difference in yield between the T12 and T24 irrigation treatments and the T24 treatment had only 60% to 70% of the water applied to it as was applied to the T12 treatment (table 18), it appears that overhead irrigation according to the 12-inch depth and furrow irrigation according to the 24-inch depth offer roughly equal yield enhancement with similar amounts of water.

In 1983, a significant ($P=0.05$) interaction of irrigation method by irrigation treatment was measured for seed yield. Yields from furrow-irrigated plots were greater in both the T12 and T24 treatments, and yields from the T12 treatment were greater with both irrigation methods. These differences are essentially the same as those found in the 1981 data. The magnitude of difference in yield between furrow and overhead methods was greater in the T12 treatment, and this was probably the major factor in the significant interaction. Overhead irrigation according to the 12-inch depth and furrow irrigation according to the 24-inch depth achieved essentially equal yields with similar amounts of irrigation water applied to both. This pattern is also similar to that observed in 1981. In both years, highest yields were achieved where the greatest amount of water was applied, and lowest yields were measured where the lowest amount was applied.

1980

Seeding rate was 10 seed/ft of 40-inch row and 5 seed/ft of 20-inch row. Trifluralin had been disk-incorporated on Feb. 29, and a preemergence tank mix application of alachlor and linuron was applied. Bentazon was applied over-the-top on June 10. Plots were cultivated as needed.

Experimental design was a randomized complete block with three replicates of treatments in a split plot arrangement. Row spacings were randomized within replicate and irrigation treatments were randomized within row spacing. Plots were either four rows wide (40-inch spacing--"wide") or 8 rows wide (20-inch spacing--"narrow") and 30 ft long. Areas between plots were fallowed to prevent water movement from plot to plot. Irrigation treatments were NI, PB, BL, and PF. Once started, irrigation was continued using the SWP criterion at the 12-inch depth as previously described. Dates of application and amount of water applied on each date are shown in table 20.

Table 20.--Record of irrigation of Tracy soybeans grown in 2 row spacings on Sharkey clay at Stoneville, Miss., 1980

Irrigation treatment	Row Spacing			
	40-inch		20-inch	
	Date	Amount (inches)	Date	Amount (inches)
PB	July 11	2.80	July 9	2.80
	July 28	2.50	July 16	2.75
	Aug. 8	3.85	July 30	2.85
	Aug. 20	3.85	Aug. 8	3.85
	Sept. 2	3.85	Aug. 20	5.15
	Sept. 11	3.85	Sept. 2	3.85
	Sept. 22	3.85	Sept. 11	3.85
	Total	24.55	Sept. 22	3.85
			Total	28.95
BL	July 24	3.20	July 24	3.05
	Aug. 6	3.85	Aug. 6	3.80
	Aug. 15	3.85	Aug. 15	3.70
	Aug. 26	3.75	Aug. 26	5.10
	Sept. 9	3.85	Sept. 9	3.85
	Sept. 18	3.85	Sept. 18	3.85
	Total	22.35	Total	23.35
PF	Sept. 4	7.95	Sept. 4	7.70
	Sept. 16	3.70	Sept. 16	3.85
	Total	11.65	Total	11.55

1980 Clay Results and Discussion

The interaction between irrigation treatment and row spacing was significant ($P=0.10$) for seed yield (table 21). The 53.4 bu/acre yield harvested from the PB treatment of the narrow rows was 10 bu/acre higher than the yield from the comparable treatment of the wide rows. The yield from the BL treatment of the narrow rows (46.1 bu/acre) showed the same trend but was not significantly greater than the 39.7 bu/acre from the BL treatment of the wide rows. Therefore, yield advantage from use of narrow rows was realized only in the most optimum moisture environment (PB) of this study.

This is in total agreement with data of Taylor (1980), who found that narrow-row (10 inches) soybeans grown on a silt loam soil in Iowa outyielded those grown in 40-inch rows by 17% in the year with the greatest seasonal water supply. Yields from narrow rows were numerically, but not significantly, above those of wide rows in a season with an intermediate seasonal water supply, and, in a drought year comparable to our 1980 season, row spacing had no effect on yield of nonirrigated soybeans.

Irrigation of both row spacings at either PB or BL resulted in yields that were significantly greater than those from the PF or NI treatments. Also, as data from other studies have shown (tables 10, 12, and 17), waiting until beginning of podfill to initiate irrigation was too late for maximum yield enhancement. It is also interesting to note that yields from each irrigation treatment of the wide rows in this study are almost identical to the yields from comparable irrigation treatments of Tracy grown in wide rows in a corresponding study (table 10). This supports the inference from these data that irrigation of narrow rows in the extremely dry year of 1980 did offer additional yield enhancement above that given from irrigation of wide rows. The data in table 21 also show the trend toward a greater increase in yield per inch of applied water in the narrow rows, indicating that, in this particular growing season, soybeans grown in narrow rows utilized added water more efficiently. Weight of 100 seed followed the same trend as yield; as irrigation was delayed or not applied, seed weight declined. However, the differences in seed weight between treatments does not nearly account for the difference in yields.

1981-82 Clay Procedure

Bedford, Tracy-M, and Braxton soybeans were planted on May 12, 1981, and May 11, 1982. Seeding rates were 10 and 5 seed/ft of wide and narrow rows, respectively. Trifluralin was disk-incorporated on Jan. 15 and Nov. 17, 1981. All plots were treated preemergence with linuron in 1981 and metribuzin

in 1982. Acifluorfen was applied over-the-top to all plots in 1981, and 2,4-DB plus linuron was applied as a postdirected spray to the wide rows for additional weed control. Cultivation was done as needed in both years.

The experimental design in both years was a randomized complete block with four replicates of treatments in a split-split plot arrangement. Row spacings were randomized within replicate, varieties were randomized within row spacing, and irrigation treatments were randomized within variety. All irrigation treatments were separated by fallowed zones. Row length was 30 ft, and plot width was either four

Table 21.--Yield data and 100-seed weight of irrigated and nonirrigated Tracy soybeans grown in 2 row spacings on Sharkey clay at Stoneville, Miss., 1980

			Yield data (bushels per acre)		
Irrigation treatment	Row spacing[1]	100-seed weight[2]	Seed yield[3]	Yield increase	Increase per inch of applied water
NI.....	Wide.....	15.6	17.2d	....	....
	Narrow.....	15.4	16.9d	....	....
	Average..	15.5b			
PB.....	Wide.....	16.7	43.6b	26.4	1.08
	Narrow.....	16.6	53.4a	36.5	1.26
	Average..	16.6a			
BL.....	Wide.....	16.6	39.7b	22.5	1.00
	Narrow.....	17.0	46.1b	29.2	1.25
	Average..	16.8a			
PF.....	Wide.....	16.1	23.3cd	6.1	.52
	Narrow.....	16.1	24.3c	7.4	.64
	Average..	16.1ab			

[1]Wide=40 inches; narrow=20 or 21 inches.
[2]Significant irrigation-treatment effect ($P=0.10$). Values followed by the same letter are not significantly different according to Waller-Duncan k-ratio t-test.
[3]Significant interaction of irrigation treatment by row spacing ($P=0.05$). Values followed by the same letter are not significantly different according to Waller-Duncan k-ratio t-test.

rows (wide spacing) or eight rows (narrow spacing). The wide row spacing remained at 40 inches, but the narrow spacing was modified somewhat (18-inch rows with a 30-inch-wide middle every fourth row) to give an average row width of 21 inches. Irrigation treatments were NI, T12, and T24 and were done as previously described for these treatments. Dates of irrigation and amount of water applied on each date are given in table 22.

1981-82 Clay Results and Discussion

All factors in this study significantly affected seed yield in 1981 (table 23). Average narrow-row yield of 42.4 bu/acre was significantly greater ($P=0.05$) than the average wide-row yield of 38.9 bu/acre. Most of this difference was accounted for by the least-watered (T24) and nonwatered (NI) treatments. Average yields of all varieties were significantly different from each other, with the average Braxton yield of 47.3 bu/acre being greater than the 39.8 bu/acre average for Tracy-M, which was greater than the 34.7 bu/acre average yield of Bedford. Average yields of all irrigation treatments were also significantly different from each other, with T12 giving the highest average yield and NI the lowest. The average difference of 2.9 bu/acre between T12 and T24 was relatively small but statistically significant. This difference is less significant in economic terms because more water was required in T12 treatments (table 22). The 3.5 bu/acre higher yield from the narrow rows is also less meaningful when the data of table 22 are considered, since the narrow rows required more water during the growing season. Also, in almost all cases, the wide-row yields showed a higher increase per inch of applied water (table 24) than did narrow-row yields, suggesting that the maximum yields obtained from the narrow rows in the presence of irrigation may not be economically optimum yields.

In 1982, significant interactions of row spacing by variety ($P=0.08$) and variety by irrigation treatment ($P=0.05$) were measured for yield (table 23). Bedford and Braxton grown in narrow rows both produced about 3 bu/acre more than when grown in wide rows, whereas Tracy-M grown in the narrow rows produced an average of 7 bu/acre more seed. Stands in all Tracy-M plots were severely reduced in mid-June by some unidentified agent, and the effect was much more noticeable in the wide-row plots. Evidently, this resulted in a greater reduction in yield from the wide-row plots compared with the narrow-row plots of Tracy-M.

The significant interaction of variety by irrigation treatment was related in large part to the large 11.8 bu/acre difference between the T12 average yield (39.8 bu/acre) and T24 average

Table 22.--Record of irrigation of 3 soybean varieties grown on Sharkey clay at Stoneville, Miss., 1981-82

Variety	Irrigation treatment	1981				1982			
		Wide rows[1]		Narrow rows		Wide rows		Narrow rows	
		Date	Amount (inches)	Date	Amount (inches)	Date	Amount (inches)	Date	Amount (inches)
Bedford.....	T12.....	July 16	3.50	July 16	3.85	July 20	3.85	July 19	3.85
		July 30	3.85	July 29	3.85	Aug. 9	3.85	Aug. 5	3.85
		Aug. 14	4.00	Aug. 13	5.70	Aug. 27	3.85	Aug. 24	3.85
		Aug. 28	3.25	Aug. 28	3.75	Total	11.55	Total	11.55
		Total	14.60	Total	17.15				
	T24.....	July 23	4.30	July 23	5.50	July 27	3.85	July 27	6.05
		Aug. 8	3.85	Aug. 8	4.80	Aug. 26	3.85	Aug. 26	3.85
		Aug. 25	3.55	Aug. 25	4.20	Total	7.70	Total	9.90
		Total	11.70	Total	14.50				
Tracy-M.....	T12.....	July 16	3.60	July 16	3.85	July 20	3.85	July 19	3.85
		July 30	3.85	July 29	3.85	Aug. 9	3.85	Aug. 5	3.85
		Aug. 14	4.30	Aug. 13	5.65	Aug. 26	3.85	Aug. 24	3.85
		Aug. 31	3.85	Aug. 31	3.85	Sept. 9	3.85	Sept. 9	5.20
		Total	15.60	Total	17.20	Total	15.40	Total	16.75
	T24.....	July 23	4.15	July 23	5.60	July 27	3.85	July 27	5.80
		Aug. 8	3.85	Aug. 8	4.65	Aug. 27	3.85	Sept. 9	7.90
		Total	8.00	Total	10.25	Total	7.70	Total	13.70
Braxton.....	T12.....	July 16	3.70	July 16	3.85	July 20	3.85	July 19	3.85
		July 30	3.85	July 29	3.85	Aug. 5	3.85	Aug. 5	3.85
		Aug. 14	4.75	Aug. 13	5.90	Aug. 24	3.85	Aug. 24	3.85
		Aug. 20	3.85	Aug. 28	3.85	Sept. 9	5.10	Sept. 10	7.70
		Total	16.15	Total	17.45	Total	16.65	Total	19.25
	T24.....	July 23	5.10	July 23	5.65	July 26	3.85	July 26	6.00
		Aug. 8	3.85	Aug. 8	4.80	Aug. 26	3.85	Aug. 25	3.85
		Total	8.95	Total	10.45	Total	7.70	Total	9.85

[1]Wide=40 inches; narrow=20 or 21 inches.

yield (28.0 bu/acre) of Tracy-M when compared with the much lower differences between similar treatments of Bedford and Braxton. This large discrepancy is probably the result of a

Table 23.--Yield (bushels per acre) of irrigated and nonirrigated soybeans grown in 2 row spacings on Sharkey clay at Stoneville, Miss., 1981-82

Irrigation treatment	Row spacing[1]	Variety			Average
		Bedford	Tracy	Braxton	
			1981[2]		
NI	Wide	19.0	22.6	34.0	25.2
	Narrow	20.3	27.4	37.4	28.4
	Average	19.6	25.0	35.7	26.8c
T12	Wide	43.8	46.3	54.3	48.1
	Narrow	43.6	50.6	55.3	49.8
	Average	43.7	48.4	54.8	49.0a
T24	Wide	38.0	42.5	49.4	43.3
	Narrow	44.0	49.4	53.2	48.8
	Average	41.0	46.0	51.3	46.1b
			1982[3]		
NI	Wide	18.1	19.2	23.2	20.2
	Narrow				23.6
					21.9
T12	Wide	34.2	33.5	43.4	37.0
	Narrow	36.0	45.3	45.9	42.7
	Average	35.1	39.4b	44.6a	39.8
T24	Wide	28.1	26.6	37.1	30.6
	Narrow	33.3	29.4	40.2	34.3
	Average	30.7	28.0b	38.6b	32.4

[1]Wide=40 inches; narrow=20 or 21 inches.
[2]Significant irrigation-treatment, variety, and row spacing effect (P=0.05). Irrigation treatment means followed by the same letter are not significantly different according to Waller-Duncan k-ratio t-test.
[3]Significant interaction of irrigation treatment by variety (P=0.05). Interaction means followed by the same letter are not significantly different.

Table 24.--Yield increase (bushels per acre) from irrigated soybeans grown in 2 row spacings on Sharkey clay at Stoneville, Miss., 1981-82

Irrigation treatment	Row spacing[1]	Yield increase			Increase per inch of applied water		
		Bedford	Tracy-M	Braxton	Bedford	Tracy-M	Braxton
				1981			
T12.....	Wide.....	24.8	23.7	20.3	1.70	1.52	1.26
	Narrow.....	23.3	23.2	17.9	1.36	1.35	1.03
T24.....	Wide.....	19.0	19.9	15.4	1.62	2.45	1.72
	Narrow.....	23.7	22.0	15.8	1.63	2.15	1.51
				1982			
T12.....	Wide.....	16.1	14.3	20.2	1.39	.93	1.21
	Narrow.....	16.0	22.2	19.2	1.38	1.32	1.00
T24.....	Wide.....	10.0	7.4	13.9	1.30	.96	1.80
	Narrow.....	13.3	5.4	13.5	1.34	.39	1.37

[1]Wide=40 inches; narrow=20 or 21 inches.

mistake in watering that occurred (table 22); on Aug. 27, T24 of both the wide- and narrow-row plots should have been watered; however, only the wide row plots of this treatment were actually watered. This mistake was not recognized until Sept. 9, at which time 7.9 inches of water were applied to the narrow row plots. As the yields indicate, this water application was of little or no use in correcting the mistake.

Both T12 and T24 treatments of all varieties produced yields that were significantly greater than the NI treatment yields. Yields produced from all treatments of Braxton were greater than those of Bedford. This trend of greater yield from the later-maturing variety was the same as the pattern established in 1981. The T12 treatment of Braxton required much more irrigation water (table 22) and had a smaller yield increase per inch of applied water than did Bedford (table 24). The longer growing season thus allowed for maximum yields to be achieved but also required a longer irrigation period for this maximum yield level to be attained.

Weight of 100 seed in 1981 did not differ significantly between row spacings or among irrigation treatments. However, a significant difference among varieties and a significant interaction of variety by irrigation treatment for this trait

did occur (table 25), mainly because of the opposite trends of seed weight of Bedford and Braxton in the NI environment compared to the irrigated treatments. This is the result of seed of each variety developing at different times in relation to rainfall distribution (table 1).

In 1982, the same significant interaction (variety by irrigation treatment) occurred (table 25), but the pattern of differences was unlike that of 1981. Braxton seed from all three irrigation treatments were essentially the same weight, whereas seed weight of Tracy-M and Bedford differed significantly among irrigation treatments. Also, weight of seed obtained from all treatments of all varieties in 1982 was lower than that of seed from comparable treatments in 1981. This pattern of differences in seed weight between the two years is similar to the pattern of differences in yield between the two years and indicates that the conditions of each individual growing season will interact with available water supply to differentially alter crop response.

1981-82 Silt Loam Procedure

Forrest soybeans were planted on May 11, 1981, and May 10, 1982, on a Dubbs silt loam. Seeding rates were 10 and 5 seed/ft of wide and narrow rows, respectively. Trifluralin was applied on Mar. 17, 1981, and Mar. 25, 1982. All plots were treated preemergence with linuron in 1981 and metribuzin in 1982. Cultivation was done as needed for additional weed control.

The experimental design in both years was a randomized complete block with three replicates of treatments arranged in a 2^2 factorial. Plot layout, row spacing, and experimental conduct were the same as for the 1981-82 clay. Irrigation treatments were NI and T12. Dates of irrigation and amount of water applied on each date are given in table 13. Harvesting was done on Oct. 15, 1981, and Oct. 4, 1982.

1981-82 Silt Loam Results and Discussion

Irrigation treatment significantly affected seed yield of Forrest soybeans in both 1981 and 1982 (table 26). Row spacing did not significantly affect nor significantly interact with irrigation treatment to affect seed yield or seed weight in either year.

In 1981, the T12 treatment (53.9 bu/acre average) significantly outyielded the NI treatment (44.3 bu/acre average) by 9.6 bu/acre. The increase in yield per inch of applied water was much greater for the narrow rows (table 15), even though more water was applied to them (table 13). In 1982, the yield difference (16.8 bu/acre) was greater, but yields of both T12 (47.1 bu/acre average) and NI (30.3 bu/acre average) treatments were lower than yields of comparable

Table 25.--100-seed weight (grams) of irrigated and nonirrigated soybeans grown in 2 row spacings on Sharkey clay at Stoneville, Miss., 1981-82

Irrigation treatment	Row spacing[1]	Variety[2] Bedford	Tracy-M	Braxton	Average
			1981		
NI.....	Wide.....	13.0	16.8	16.9	15.6
	Narrow.....	13.2	16.9	17.4	15.8
	Average...	13.1e	16.8ab	17.2a	....
T12.....	Wide.....	14.1	16.6	16.0	15.6
	Narrow.....	13.8	16.6	15.8	15.4
	Average...	14.0d	16.6b	15.9c	....
T24.....	Wide.....	13.8	16.4	16.6	15.6
	Narrow.....	13.9	16.7	16.7	15.8
	Average...	13.8d	16.6b	16.6b	....
			1982		
NI.....	Wide.....	9.8	13.9	15.8	13.2
	Narrow.....	9.4	14.4	15.3	13.0
	Average...	9.6g	14.2d	15.6a	....
T12.....	Wide.....	10.6	14.5	15.4	13.5
	Narrow.....	10.6	14.9	15.6	13.7
	Average...	10.6f	14.7bc	15.5a	....
T24.....	Wide.....	11.2	14.6	15.4	13.7
	Narrow.....	11.8	14.3	14.9	13.7
	Average...	11.5e	14.4cd	15.2ab	....

[1]Wide=40 inches; narrow=20 or 21 inches.
[2]Significant interaction of variety by irrigation treatment ($P=0.05$). Values followed by the same letter are not significantly different according to Waller-Duncan k-ratio t-test.

treatments in 1981. Yield increase per inch of applied water was similar for the two row spacings (table 15), and amount of applied water was the same (table 13). Less water was applied in 1982 than in 1981, but since it was applied by exactly the same standards as in 1981, the lowered yields of the 1982 T12 treatment must be related to some other factor. Since planting and beginning bloom dates were almost identical, the lower 1982 production may be associated with the hotter maximum daily temperatures that occurred in the July 1-10 period of 1982 (table 1). This period encompassed the major

Table 26.--Yield (bushels per acre) and 100-seed weight (grams) of irrigated and nonirrigated Forrest soybeans grown in 2 row spacings on Dubbs silt loam at Stoneville, Miss., 1981-82

Irrigation treatment	Row spacing[1]	Seed yield[2]	100-seed weight[2]
	1981		
NI	Wide	45.9	13.7
	Narrow	42.7	13.6
	Average	44.3b	13.6a
T12	Wide	50.5	13.6
	Narrow	57.3	14.2
	Average	53.9a	13.9a
	1982		
NI	Wide	28.4	9.6
	Narrow	32.2	9.6
	Average	30.3b	9.6b
T12	Wide	45.9	10.6
	Narrow	48.3	11.9
	Average	47.1a	11.2a

[1]Wide=40 inches; narrow=20 or 21 inches.
[2]Average values within each year followed by the same letter are not significantly different ($P=0.05$) according to Waller-Duncan k-ratio t-test.

portion of the bloom period of Forrest in both years, and results from other studies have indicated that high temperatures during this time may be detrimental to yield (Stutte and Weiland 1980).

In 1982, seed weight followed the same trend as seed yield; T12-treatment beans weighed significantly more (table 26). Also, beans from the 1982 T12 treatment averaged about 20% lower in weight than those from the 1981 T12 treatment. This again points out the adverse effect of the 1982 season on seed formation and development.

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