THE EFFECT OF ALTERNATE AND EVERY FURROW IRRIGATION ON YIELD AND AGRONOMIC CHARACTERISTICS OF TWO SOYBEAN CULTIVARS

By

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CHAPTER 1

INTRODUCTION

In recent years, the objective of many researchers has changed from that of maximizing production to that of optimizing production with limited available water resources. In the case of irrigated production, research efforts have concentrated on establishing workable irrigation techniques for improving water-use efficiencies. These efforts have been aimed at minimizing evapotranspiration (ET) losses by improving the overall irrigation management and application techniques in order to provide for a minimum wetting of the soil surface. The objectives of this study were to:

1. Evaluate the yields of Essex and Sohoma soybeans when suplemental water was applied as every furrow and alternate furrow irrigation treatments in south central Oklahoma.
2. Evaluate the agronomic characteristics of plant height, number of branches per plant, number of pods on branches, number of pods on main stems, number of total pods on plant, number of seeds on branches, number of seeds on main stems, number of total seeds on plant, weight per 100 seeds on branches, weight per 100 seeds on main stems, total weight per 100 seeds on plant, yield on branches, yield on main stems, and total yield on plant of Essex and Sohoma soybeans as affected by the application of supplemental irrigation in every and alternate furrows.

CHAPTER II

LITERATURE REVIEW

The Effect of Environmental Stress on Growth and Development of Soybean Plants

Soybeans (*Glyicine max* (L.) Merr.) are frequently grown in areas characterized by variable crop season precipitation conditions. Under most field conditions, however, an optimum water environment is seldom prevalent, and some degree of growth limiting water deficits in soybeans is the rule rather than the exception (Monem *et al*., 1978).

Soil Water Deficits in Relation to Soybean Growth

Water deficits arise in plants either because of excessive transpiration rates or inadequate soil water. Deficits due to the former are the most common and occur because of the frictional resistance to water flow through roots and stems. By their nature, however, the deficits cannot be relieved by adding water to the soil (Reicosky and Deaton, 1979).

Crop yields are adversely affected by plant water deficits arising from inadequate soil water (Salter and Goode, 1967; Thompson, 1975). However, it is not known whether water deficits caused by excessive transpiration have similar effects on yield (Hsiao, 1973). Soybeans are particularly sensitive to deficits of soil moisture during germination.

Hunter and Erickson (1952) found that a moisture content of about 50 percent was required for germination of soybean seed, compared to 30, 25, and 31 percent for corn, rice, and sugar beet, respectively.

In his review, Howell (1960) indicated that the growth of the soybean from germination to maturity is proportional to the available moisture supply, although a precise mathematical description of available moisture is difficult to make. Ueda (1952) found the height, number of nodes, stem diameter, number of flowers, percentage of pod set, and number and weight of seeds all correlated positively with soil moisture content. It is well established, though, that the effects of water stress on growth and yield of soybeans depend on both the degree of stress and the stage of growth at which stress occurs (Hsiao and Acevedo, 1974; Lewis et al., 1974; and Sullivan and Eastin, 1974).

Following stand establishment, the soybean plant is most affected by moisture stress during the reproductive period. Stress during the vegetative period will reduce plant growth; but unless it is severe enough to prevent complete canopy closure, yield is usually not adversely affected. During flowering, moisture stress increases abortion of flowers and young pods (Hinso and Hartwig, 1982). Soybeans flower over a period of time and can compensate for early flowering and pod abortion by increased set of later flowers, provided sufficient moisture becomes available (Pendleton and Hartwig, 1973). When stress continues from flowering through pod set, however, yield reductions occur which are associated with a decrease in number of pods. Dusek et al. (1971) reported such a yield loss even when adequate irrigation was applied during pod filling.

Precipitation Patterns

Water use by soybean varies with climatic conditions, management practices, and length of the growing season (Hinson and Hartwig, 1982). Soybeans use water from progressively greater depth throughout the season. Peters and Johnson (1960) reported that a considerable amount of water was used from the lower part of the soil profile even under irrigation, and summer rainfall affected only the upper half of the rooting zone. Swan (1959) found water use directly in the row to be double that at points one-quarter and one-half the distance between rows. When moisture supply was increased by irrigation, the water use from the between-row locations increased to about two-thirds that in the row. In general, however, water use by the crop increases as the crop grows and is maximal during flowering and pod fill.

Temperature, Atmospheric Humidity, and Wind

Soybeans can be grown successfully under a wide range of temperature conditions. The maximum and minimum soil temperature for germination of soybeans are approximately 40°C and 5°C, respectively. Edwards (1934), Wilson (1928), and Delouche (1952) reported for various soybean cultivars that the optimum temperature for germination was approximately 30°C. Grabe and Metzer (1969) reported that some varieties germinated as well at 15°C as at 30°C. However, germination is delayed at the lower temperature. But as the temperatures increase above 30°C, both the rate and percentage of germination decline and are eventually reduced to zero at temperatures close to and exceeding 40°C. Temperatures above 40°C are known to have an adverse effect on rate of growth, flower initiation, and pod retention. The potential effects of such high temperature on soybean performance are particularly severe if water is limited (Hinson and Hartwig, 1982).

Various studies have indicated to some extent the effect of high temperatures on vegetative and reproductive development. In general, however, temperature is the major factor influencing vegetative development. Low temperatures retarded whereas high temperatures enhanced seedling emergence and leaf development (Brown, 1960).

Effects of temperature on blooming dates was studied by Garner and Allard (1930). They found that when temperatures average below 25^{o}C flowering is delayed. However, variation from year to year in date of flowering of a given soybean variety planted on a particular date is due mainly to differences in temperatures, while differences between varieties are due to their response to length of day.

The effects of temperature on yield have been studied less extensively than those of water, but it appears that temperature variations affect the composition more than the yield of seed. Runge and Odell (1960) found that yields were slightly lower when temperatures were above average during July and August, whereas above average maximum temperatures in June and September resulted in small increase in yield.

Yields of soybeans can be affected by low atmospheric humidity, even when grown with adequate supplies of soil moisture. Woodward and Begg (1976) reported yield reductions for soybeans grown with day and night relative himidities that ranged from 47 to 46 percent. Soybean yields decreased at these low atmospheric humidities as a result of a reduction in pod number which was associated with flower abortion. Also, the total dry weight of plant tops, dry weight of stems, and the number of nodes per plant were reduced in a lower atmospheric humidity environment. Therefore, consistently high soybean yields may be difficult to obtain in the more arid regions because of low atmospheric humidity and its effect on photosynthesis. Even when irrigation water is available, the internal plant structure may limit the supply of water to the leaves and reduce the growth rate of the plant (Keith and Harry, 1978).

Wind is a major environmental factor directly and indirectly influencing the productivity of a soybean crop. Several investigators have suggested that the deleterious effect of wind on plants is due to water stress caused by an enhanced rate of water loss (Warming, 1909). Radke and Burrows (1970) suggested that wind increases exposure of the more reflective underside of soybean leaves to light and thereby decreases efficiency of light utilization. Water-stressed leaves have less ability to maintain a normal orientation than do leaves not stressed for water (Radke and Hagstrom, 1973).

Water Management and Methods of Supplemental Water Application Using Furrow Irrigation

Water is often the primary limiting factor in soybean production and thus is an important management concern. Peters and Johnson (1960) in Illinois found that approximately 134 kg/ha of soybeans were produced for each 2.5 cm of water available from July 1 to September 20. Whitt and Van Bavel (1955) estimated water use at 0.75 cm per day during peak periods. In southern Brazil, Berlato and Bergormaschi (1978) measured a similar maximum daily evaporation rate (0.75 cm per day) compared to a seasonal water use average of 0.58 cm per day. Thus, in areas of low rainfall, irrigation is a necessary and often profitable practice.

Timing of irrigation water application is very important in increasing soybean yields. Somerhalder and Schleusener (1960) in Nebraska have shown that making one or two irrigations during the flowering and fruiting periods was almost as effective in increasing yields as maintaning a high moisture level all season. Grissom et al. (1955) and Spooner (1961) reported irrigation during the main period of vegetative growth to be of lesser importance than irrigating during flowering and fruiting. However, Stone et al. (1979) reported that irrigation during vegetative stages significantly increased lodging and could seriously affect the yields of the taller cultivars. Matson (1964), working on the irrigation of soybeans in Missouri, found that when irrigation water was applied only from flowering until approximately four weeks before maturity, yields were not greatly reduced over a three-year period compared with those obtained from plants irrigated throughout growth. Brady et al. (1947) in a two-year experiment concluded that irrigation increased soybean yield by about 20 percent and that only a third to a half of the water necessary for full-season irrigation could produce equally good yields if it were applied during the pod-filling stage.

A substantial number of studies have shown that soybeans respond with increased yields to additions of supplemental water during most years (Doss and Thurlow, 1974; Downey and Caviness, 1973; Salter, 1967; Spooner, 1961; and Whitt, 1954). However, if limited water is available for irrigation, application during the pod-filling stages will prove most beneficial (Rogers and Thurlow, 1970).

The declining ground water tables and well yields necessitate conservation and efficient use of limited irrigation water supplies. Alternate furrow irrigation offers opportunity for reducing size of irrigation and permits irrigating a field in a shorter time period with a given water supply. The reduced size of irrigation may not reduce yields appreciably and thus increase irrigation water efficiency.

Newman (1967) reported that when one furrow between two cotton rows was irrigated, water application was reduced and water use efficiencies were increased. Musick and Dusek (1971) found that reducing water application from 10 to 5 cm on clay loam soil increased irrigation water use efficiency.

Studies by Fischbach and Mulliner (1972) indicate that alternate furrow irrigation of corn on several soil types in eastern Nebraska produced yeilds similar to every furrow irrigation. Grimes et al. (1968) reported that alternate furrow irrigation of cotton on a Hesperia sandy loam in the San Joaquin Valley of California reduced size of irrigation by 23 percent. However, lint yields were as good or better than every furrow irrigation which received about 15 cm of additional water. Alternate furrow irrigation during vegetative development did reduce excessive vegetative growth and plant height without affecting yields.

Box et al. (1963) found that alternate furrow irrigation (90 cm furrow spacing) of potatoes grown on Pullman silty clay loam did not affect tuber yields significantly. However, they concluded that the every furrow irrigation method was superior in minimizing soil temperature. Alternate furrow applications normally increase the irrigation rate 50 to 70 percent. However, the increased irrigating rate permits more crop acreage to be irrigated during high water use periods when adequate moisture is essential to maintain production (New, 1971).

CHAPTER III

MATERIALS AND METHODS

A field study was conducted on the supplemental furrow irrigation of soybeans at the South Central Research Station, Chickasha, Oklahoma, on a McLain silty clay loam (Fine, Mixed, Thermic, Pachic, Parhic Argiustolls) with 0-1 percent slope.

The experimental area had previously been put to grade (0.5%) and cropped with soybeans without fertilizer additions for five years prior to the initiation of this research project. Soil samples were taken from over the area at 15 and 30 cm depths for soil test analyses. Soil test results showed the level of phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) as determined by the Oklahoma State University Soil Testing Laboratory procedures and recommendations to be at the 100 percent sufficiency level. A lister bedder was used to form 100 cm beds in early March of each year so late winter and early spring moisture could accumulate in the beds. Just prior to planting, trifluoralin (_a_, _a_, _a_-trifluoro-2, 6-dinitro-_N_, _N_-dipropyl-_p_-tahidine) was applied broadcast at a rate of 1.12 kg/ha in 234 liters/ha water and incorporated into the soil using a rolling cultiator set at the appropriate angle so that the form and integrity of the beds were maintained.

The experiment consisted of a 2 x 2 factorial arrangement of treatments with the two factors and their respective levels being variety (Essex and Sohoma) and irrigation method (alternate furrow and every

TABLE I

IRRIGATION DATES

1980		1981		1982		1983	
9 July	18 Aug.	8 July	4 Sept.	3 Aug.	14 Sept.	13 July	31 Aug.
16 July	28 Aug.	16 July	15 Sept.	12 Aug.	28 Sept.	19 July	8 Sept.
23 July	4 Sept.	23 July		24 Aug.		26 July	15 Sept.
7 Aug.	18 Sept.	18 July		31 Aug.		2 Aug.	
14 Aug.		28 July		10 Aug.		9 Aug.	

*On these dates 5 cm of supplemental water was applied to the every furrow irrigation treatment and approximately 2.5 cm of water was applied to the alternate furrow irrigation treatment.

furrow) in a randomized complete-block design with four replications. Each experimental unit consisted of four 100 cm beds on an area of 4.0 x 100.0 m. A flex planter was used to plant Essex (Maturity Group V) and Sohoma (Maturity Group VI) soybeans on 5 June 1980, 26 May 1981, 7 June 1982, and 7 June 1983 for a 247,000 plants per hectare population in single 100 cm rows. Seeds of both varieties were inoculated with Rhizobium japonicum prior to planting. All experimental units received mechanical cultivation using a rolling cultivator when the soybeans were in the third node (V3) stage of growth. Supplemental water, in amounts equivalent to 5 cm per hectare, was applied to the every furrow irrigation treatments using gated pipe in July, August, and September of each year (Table I). With this arrangement, the alternate furrow irrigation treatments received about one-half the amount of supplemental water compared to the every furrow irrigation treatments. Tensiometers were placed at a depth of 30 cm in the center of the two middle beds and in the middle of the irrigation run on two replications of the every furrow irrigation treatments. Tensiometer readings coupled with visual observation of plant water stress for the every furrow irrigation treatments were used to schedule irrigations. Supplemental water was metered and applied using gated pipe with gates open at every furrow and gates open only at alternate furrows for the every and alternate furrow irrigation treatments, respectively. On irrigation dates (Table I), all plots were watered. Time and duration of application were approximately the same for each furrow receiving irrigation.

At maturity, 20 plants were randomly selected from rows on the two center beds of each experimental unit for agronomic characteristic evaluation. Those agronomic characteristics evaluated were: 1) plant height; 2) number of branches; 3) number of pods on branches; 4) number of pods on main stems; 5) number of total pods on plant; 6) number of seeds on branches; 7) number of seeds on main stems; 8) number of total seeds on plant; 9) weight per 100 seeds on branches; 10) weight per 100 seeds on main stems; 11) total weight per 100 seeds on plant; 12) yield on branches; 13) yield on main stems; and 14) total yield on plant.

Plot yields were obtained by harvesting 2.0 x 80.0 m strips from the two middle rows of each plot on 24 October 1980, 23 October 1981, 25 October 1982, and 13 October 1983 for the Essex variety; and 1 November 1980, 31 October 1981, 4 November 1982, and 15 November 1983 for the Sohoma variety.

CHAPTER IV

RESULTS AND DISCUSSION

Rainfall Amounts and Distribution

Monthly rainfall amounts from 1 January 1980 to 31 December 1983 and the 25-year monthly averages (1959-1983) are given in Table II. Monthly distributions of rainfall for the four-year study period (1980-1983) are given in Figure 1. During the 1980 growing season, cumulative monthly precipitation from 1 January to 1 May was 17.1 cm compared to 18.2, 15.4, 25.0, and 16.8 cm for 1981, 1982, 1983, and the 25-year average, respectively. However, ample precipitation during months of May and June, 26.9 cm (Table II; Figure 1), provided for a good moisture buildup in the beds and the subsoil. With timely incorporation of herbicide and planting, stand establishment and weed control for the entire growing season were excellent. For the months of July, August, and September, precipitation amounts were 17.4 cm below the 25-year average. These low rainfall amounts, coupled with high temperatures and evaporative demand, necessitated supplemental irrigation in the amount of 45 cm for the every furrow and 22.5 cm for the alternate furrow irrigation treatments, respectively (Table I).

For 1981, total precipitation was higher (Table II; Figure 1) compared to 1980, 1982, and the 25-year average. Except for the month of January, precipitation was particularly good through April. Ample

TABLE II

RAINFALL FROM 1 JANUARY 1980 TO 31 DECEMBER 1983, AND THE 25-YEAR MONTHLY AVERAGES (1959-1983) AT THE SOUTH CENTRAL RESEARCH STATION AT CHICKASHA, OKLAHOMA

	Rainfall				
Month	1980	1981	1982	1983	25-Year Average
			centimeters		
January	4.8	0.1	7.0	5.4	2.4
February	3.2	4.0	2.0	9.7	2.8
March	4.6	7.9	3.3	5.5	5.0
April	4.5	6.2	3.1	4.4	6.6
May	21.2	10.9	29.0	12.6	10.2
June	5.7	15.4	10.1	12.8	7.8
July	0.0	7.9	4.1	0.0	7.6
August	1.5	9.8	3.0	5.8	7.4
September	6.9	3.5	6.1	1.8	10.8
October	3.5	19.3	1.6	33.7	6.9
November	2.4	8.2	6.8	1.4	4.4
December	4.2	0.2	3.2	1.6	2.7
Total	62.5	93.4	79.3	94.7	74.6

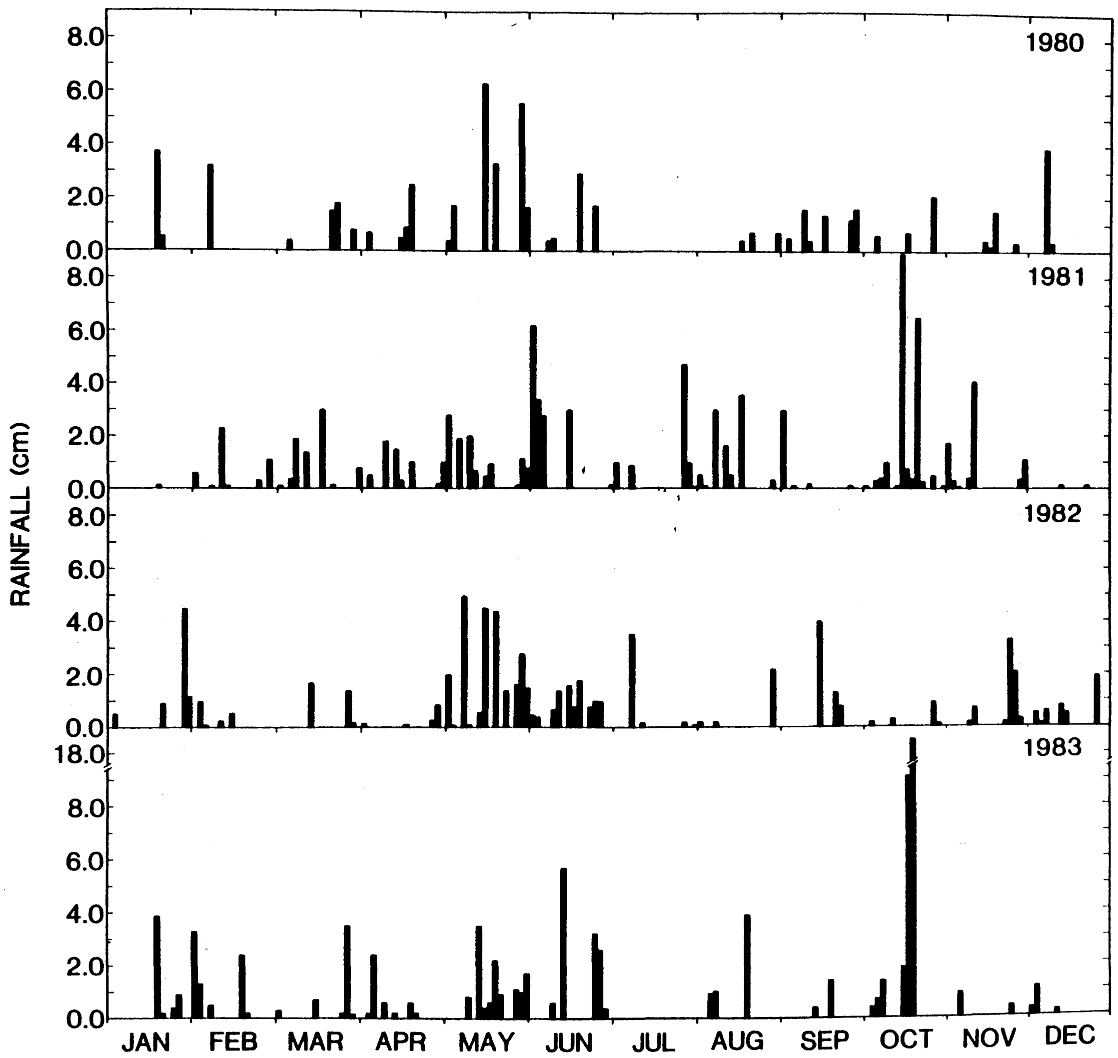

Figure 1. Rainfall Amounts and Distribution for 1980-83 at the South Central Research Station, Chickasha, Oklahoma.

precipitation during May and June, 26.3 cm (Table II), provided a buildup of water in the soil profile. As in 1980, timely incorporation of herbicide, stand establishment, and weed control for the entire growing season were good. Total precipitation during July, August, and September was 21.2 cm compared to 8.4, 13.2, 7.6, and 25.8 cm for the 1980, 1981, 1982, 1983, and the 25-year average (Table II). With these increased rainfall amounts, coupled with good distribution (Figure 1), during this three-month period supplemental irrigation in the amount of 35 cm was applied for the every furrow compared to 17.5 cm for the alternate furrow irrigation treatment for the 1981 growing season.

For the 1982 growing season, rainfall during the months of May and June (Table II) resulted in sufficient moisture buildup in the beds and soil profile for good stand establishment. However, during the latter part of July and most of August precipitation amounts were lower than the 25-year average (Table II; Figure 1). These low rainfall amounts, coupled with relatively high temperatures and evaporative demand during this period, necessitated supplemental irrigation in the amount of 35 and 17.5 cm for every and alternate furrow irrigation treatments, respectively, for the 1982 growing season.

During 1983, rainfall was particularly good from 1 January to 1 July (Table II; Figure 1). As in the three previous years, this amount of rainfall resulted in sufficient water for excellent stand establishment. During the months of July, August, and September precipitation was far below that of 1981 and the 25-year average, and slightly below that of 1980 and 1982. These low rainfall amounts (Table II; Figure 1) necessitated supplemental irrigation in the amount of 40 and

20 cm for every furrow and alternate furrow irrigation treatments, respectively (Table I).

Agronomic Characteristics (Study Years 1980, 1981, 1982, 1983, and 1980-83)

Plant Height, Number of Branches Per Plant, Number of Pods on Branches, and Number of Pods on Main Stems

The simple effects for plant height data indicate that at each irrigation level plants of the Sohoma variety were taller than plants of the Essex variety (Table III). However, within a given variety plants were taller for every furrow compared to alternate furrow irrigation treatment (Table III). Tables VII and VIII show that there was a significant difference between irrigation levels with respect to plant height for all years of study, except 1981 which most likely may be attributed to precipitation amounts and distribution (Table II; Figure 1). Also, there was a significant difference between variety levels with respect to plant height for all four years (Table VIII). For this variance, all irrigation x variety interactions were non-significant (Tables VII and VIII). However, when the data were combined over years, the irrigation x year and variety x year and the irrigation x variety x year interactions were significant at the 0.05 level (Table VIII).

Plants of the Sohoma variety produced more branches per plant (Table IV) compared to plants of the Essex variety. Within a variety, more branches were produced when every furrow was irrigated compared to alternate furrow irrigation treatment (Table IV). For branches per

TABLE III

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION ON PLANT HEIGHT (CM) IN 1980, 1981, 1982, 1983, AND 1980-83

	1980		1981		1982		1983		1980-83	
	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow
Essex	38.8	43.8	59.5	63.0	55.0	61.7	58.4	66.7	52.9	58.5
	4.0*		3.5*		6.7*		8.3*		5.6*	
Sohoma	47.2	55.4	71.8	69.0	67.2	71.1	72.1	80.8	64.6	69.1
	8.0*		-2.8*		3.5*		8.7*		4.5*	
LSD(0.05)	1.5**		1.7**		3.2**		2.0**		1.1***	

*Mean difference statistically significant at the 0.05 level.

**Mean of 80 plants.

***Mean of 320 plants.

TABLE IV

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION ON NUMBER OF BRANCHES PER PLANT IN 1980, 1981, 1982, 1983, AND 1980-83

	1980		1981		1982		1983		1980-83	
	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow
Essex	3.8	4.0	9.1	10.1	5.2	5.8	2.5	2.8	5.1	5.7
	0.2		1.0*		0.6		0.3		0.6*	
Sohoma	5.5	8.7	10.4	11.5	7.5	9.4	5.4	6.0	7.2	8.9
	3.2*		1.1*		1.9*		0.6*		1.7*	
LSD(0.05)	0.7**		0.9**		1.2**		0.4**		0.4***	

*Mean difference statistically significant at the 0.05 level.

**Mean of 80 plants.

***Mean of 320 plants.

TABLE V

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION ON NUMBER OF PODS ON BRANCHES IN 1980, 1981, 1982, 1983, AND 1980-83

	1980		1981		1982		1983		1980-83	
	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow
Essex	18.8	22.8	28.6	39.0	22.7	32.9	26.4	35.2	24.1	32.5
	4.0		10.4*		10.2*		8.8		8.4*	
Sohoma	20.6	44.7	42.0	59.3	56.1	68.3	62.9	86.0	42.9	64.6
	24.1*		17.3*		22.2*		23.1*		21.7*	
LSD(0.05)	4.6**		6.5**		8.3**		9.6**		3.7***	

*Mean difference statistically significant at the 0.05 level.

**Mean of 80 plants.

***Mean of 320 plants.

TABLE VI

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION ON NUMBER OF PODS ON MAIN STEMS IN 1980, 1981, 1982, 1983, AND 1980-83

	1980		1981		1982		1983		1980-83	
	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow
Essex	16.8	19.8	19.9	19.8	23.0	27.1	38.7	35.9	22.1	25.6
	3.0*		0.1		4.1*		2.8		3.5*	
Sohoma	14.5	17.5	16.0	12.7	20.2	23.3	24.8	36.4	18.9	22.5
	3.0*		3.3*		3.1		11.6*		3.6*	
LSD(0.05)	2.0**		1.8**		3.5**		2.9**		1.3***	

*Mean difference statistically significant at the 0.05 level.

**Mean of 80 plants.

***Mean of 320 plants.

TABLE VII

SUMMARY OF TREATMENTS AND TREATMENT INTERACTION FOR AGRONOMIC CHARACTERISTICS AND OBSERVED SIGNIFICANT LEVELS (OSL) DURING 1980, 1981, 1982, 1983, AND 1980-83

Treatments and Treatment Interaction	Plant Height				Branches per Plant				Pods on Branches				Pods on Main Stem			
	1980	1981	1982	1983	1980	1981	1982	1983	1980	1981	1982	1983	1980	1981	1982	1983
IRR	0.05	NS	0.01	0.01	1.06	2.36	0.31	2.03	0.40	0.07	0.01	0.01	3.67	4.10	0.86	0.05
VAR	0.01	0.02	0.01	0.01	0.02	0.73	0.01	0.01	1.07	0.02	0.01	0.01	NS	0.01	1.42	NS
IRR x VAR	NS	NS	NS	NS	1.89	NS	NS	NS	2.37	NS	3.83	0.66	NS	NS	NS	NS

TABLE VIII

SUMMARY OF TREATMENTS AND TREATMENT INTERACTION FOR AGRONOMIC CHARACTERISTICS AND OBSERVED SIGNIFICANT LEVELS (OSL) FOR 1980-83

Treatments and Treatment Interactions	Plant Height	Branches Per Plant	Pods on Branches	Pods on Main Stem
IRR	0.02	0.02	0.01	0.05
VAR	0.01	0.01	0.01	0.12
IRR x VAR	NS	1.05	0.21	NS
IRR x YEAR	0.01	NS	NS	0.01
VAR x YEAR	0.15	0.41	0.01	NS
IRR x VAR x YEAR	0.04	3.95	NS	NS

plant, all treatment levels show significance at the 0.05 level (Tables VII and VIII). The two-factor interaction, irrigation x variety, was non-significant except for 1980 (Table VII) and when combined over years (Table VIII). However, there was no apparent explanation for such behavior. The irrigation x year interaction was non-significant, but the variety x year and irrigation x variety x year interactions were significant at the 0.05 level (Table VIII).

For each of the two irrigation levels, plants of the Sohoma variety produced more pods on branches (Table V) than plants of the Essex variety. Within a given variety the number of pods on branches was smaller for alternate furrow compared to every furrow irrigation treatments (Table V). For pods on branches, the data show that there were significant differences between all irrigation and variety treatment levels (Tables VII and VIII). Also, there were significant differences between the varieties with respect to varying levels of irrigation treatment (Tables VII and VIII), except in 1981, and this can most likely be attributed to more and better distribution of precipitation during the flowering and early pod filling stage of growth (Figure 1). When the data were combined over years, there was a significant variety x year interaction, but there were no significant irrigation x year or irrigation x variety x year interactions at the 0.05 level (Table VIII).

Plants of the Essex variety produced more pods on main stems than plants of the Sohoma variety (Table VI). Despite its ability to produce more pods on main stems, however, Essex produced lower yields on main stems than Sohoma. This may be attributed to the fewer but larger seeds produced by the Sohoma variety compared to the Essex variety. Within a given variety, on the average, every furrow irrigation produced more pods on main stems compared to alternate furrow irrigation treatment levels (Table VI). For pods on main stem, the data show there was a significant difference between all irrigation treatment levels (Tables VII and VIII). Also, there was a significant difference between variety levels, except in the two dry years of 1980 and 1983. Irrigation x year interaction was significant at the (0.01) level. However, the two-factor interactions, irrigation x variety and variety x year, and the three-factor interaction irrigation x variety x year were all non-signifcant (Tables VII and VIII).

Number of Total Pods on Plant, Number of Seeds on Branches, Number of Seeds on Main Stems, and Number of Total Seeds on Plant

The simple effects for the number of total pods on plant indicate that at each of the irrigation treatment levels plants of the Sohoma variety produced more total pods on plant than the Essex variety (Table IX). For both Sohoma and Essex varieties, the alternate furrow irrigation level produced less total pods on plant when compared to every furrow irrigation treatments (Table IX). Tables XIII and XIV show that there were significant differences between all irrigation treatment levels, irrigation x year, and variety x year interactions. Also, there was a significant difference between variety treatments except in 1980. The analysis of variance for the total pods on plant show that there was a significant irrigation x variety interaction for 1980 and 1983, but not in 1981 and 1982. Again, this may be attributed to precipitation

TABLE IX

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION ON NUMBER OF TOTAL PODS ON PLANT IN 1980, 1981, 1982, 1983, AND 1980-83

	1980		1981		1982		1983		1980-83	
	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow
Essex	35.6	42.6	48.5	58.8	45.7	60.0	55.1	71.0	46.2	58.1
	7.0*		10.3*		14.3*		15.9*		11.9*	
Sohoma	35.1	62.2	58.0	72.0	66.3	91.6	87.7	122.4	61.8	87.1
	27.1*		14.0*		25.3*		34.7*		25.3*	
LSD(0.05)	5.3**		7.0**		10.0**		10.6**		4.2***	

*Mean difference statistically significant at the 0.05 level.

**Mean of 80 plants.

***Mean of 320 plants.

amounts and distribution during the flowering and pod set physiological stage of growth (Table II; Figure 1). The three-factor interaction, irrigation x variety x year, for this variable shows no significance at the 0.05 level (Tables XIII and XIV).

For both alternate and every furrow irrigation treatment levels, plants of the Sohoma variety produced more seeds on branches (Table X) than plants of the Essex variety. Within a given variety the number of seeds on branches was smaller for alternate furrow compared to every furrow irrigation treatments (Table X).

For seeds on branches, there were significant differences between all irrigation and variety treatment combinations (Tables XIII and XIV). In addition, all irrigation x variety interactions were significant except in 1981 and 1982. This most likely is attributed to precipitation patterns during the seed formation stage of growth for these two years (Table II; Figure 1). When combined over years, the irrigation x year interaction was not significant (0.05 level); however, the variety x year interaction was significant at the 0.01 level (Table XIV). When combined over the four-year period the irrigation x variety x year interaction for this variable was non-significant at the 0.05 level (Table XIV).

For the most part, plants of the Essex variety produced more seeds on main stems (Table XI) than the Sohoma variety. Although Sohoma produced less seeds on main stems, it out-produced the Essex variety by producing a larger seed size. For both varieties every furrow irrigation treatments produced more seeds on main stems compared to alternate furrow irrigation treatment levels (Table XI). When combined over the four-year period the irrigation and variety treatment levels were significant

TABLE X

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION ON NUMBER OF SEEDS ON BRANCHES IN 1980, 1981, 1982, 1983, AND 1980-83

	1980		1981		1982		1983		1980-83	
	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow
Essex	38.9	46.6	59.2	80.4	47.2	68.6	55.6	74.6	50.2	67.6
	7.7		21.2*		21.4*		19.0		17.4*	
Sohoma	44.7	93.5	84.6	120.4	95.9	43.2	138.2	182.6	90.9	134.9
	48.8*		35.8*		47.3*		44.4*		44.0*	
LSD(0.05)	9.6**		13.3**		17.6**		20.8*		7.9***	

*Mean difference statistically significant at the 0.05 level.

**Mean of 80 plants.

***Mean of 320 plants.

TABLE XI

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION ON NUMBER OF SEEDS ON MAIN STEMS IN 1980, 1981, 1982, 1983, AND 1980-83

	1980		1981		1982		1983		1980-83	
	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow
Essex	34.1	40.2	40.6	40.2	48.2	56.8	60.3	75.4	45.8	53.1
	3.9		0.4		8.6*		15.1*		7.3*	
Sohoma	30.6	36.4	31.9	26.4	43.6	49.7	57.2	80.0	40.8	48.1
	5.8*		5.5*		6.1		22.8*		7.3*	
LSD(0.05)	4.5**		3.6**		7.5**		6.3**		2.8***	

*Mean difference statistically significant at the 0.05 level.

**Mean of 80 plants.

***Mean of 320 plants.

TABLE XII

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION ON NUMBER OF TOTAL SEEDS ON PLANT IN 1980, 1981, 1982, 1983, AND 1980-83

	1980		1981		1982		1983		1980-83	
	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow
Essex	72.9	86.8	99.8	120.6	95.4	125.3	115.9	150.0	96.0	120.7
	13.9*		20.8*		29.9*		34.1*		24.7*	
Sohoma	75.3	129.9	116.6	146.8	139.5	192.9	195.4	262.6	131.7	183.0
	54.6*		30.2*		53.4*		67.2*		51.3*	
LSD(0.05)	11.2**		14.4**		21.1**		22.7**		9.0***	

*Mean difference statistically significant at the 0.05 level.

**Mean of 80 plants.

***Mean of 320 plants.

TABLE XIII

SUMMARY OF TREATMENTS AND TREATMENT INTERACTION FOR AGRONOMIC CHARACTERISTICS AND OBSERVED SIGNIFICANT LEVELS (OSL) DURING 1980, 1981, 1982, 1983, AND 1980-83

Treatments and Treatment Interaction	Total Pods on Plant				Seeds on Branches				Seeds on Main Stem				Total Seeds on Plant			
	1980	1981	1982	1983	1980	1981	1982	1983	1980	1981	1982	1983	1980	1981	1982	1983
IRR	0.32	0.15	0.01	0.01	0.66	0.10	0.02	0.01	NS	NS	1.22	0.07	0.61	0.24	0.01	0.01
VAR	NS	0.22	0.01	0.01	0.97	0.04	0.01	0.01	NS	0.01	3.33	NS	4.24	0.67	0.01	0.01
IRR x VAR	4.45	NS	NS	1.17	3.13	NS	NS	1.51	NS	NS	NS	NS	NS	NS	NS	2.39

TABLE XIV

SUMMARY OF TREATMENTS AND TREATMENT INTERACTION FOR AGRONOMIC CHARACTERISTICS AND OBSERVED SIGNIFICANT LEVELS (OSL) FOR 1980-83

Treatments and Treatment Interaction	Total Pods on Plant	Seeds on Branches	Seeds on Main Stem	Total Seeds on Plant
IRR	0.01	0.01	0.26	NS
VAR	0.01	0.01	2.03	0.01
IRR x VAR	0.54	0.42	NS	NS
IRR x YEAR	4.02	NS	0.01	NS
VAR x YEAR	0.01	0.01	1.34	0.01
IRR x VAR x YEAR	NS	NS	NS	NS

(Table XIV). Also, the two-factor interactions, irrigation x year and variety x year, were significant (Table XIV). The irrigation x variety and irrigation x variety x year interactions were not significant at the 0.05 level (Table XIV).

Mean values and simple effects for the total number of seeds on plant are given in Table XII. For the two irrigation treatments the Sohoma variety produced more total seeds on plant compared to the Essex variety. For both variety levels, the alternate furrow irrigation treatment produced less total seeds on plant than the every furrow irrigation treatment (Table XII). Table XIII shows there were significant differences for all irrigation and variety treatment levels. However, irrigation x variety was not significant at the 0.05 level except in 1983 (Table XIII). When combined over years, this interaction was not significant (Table XIV). Also, there was no significant difference between irrigation x year and irrigation x variety x year interactions but the two-factor interaction variety x year was significant at the 0.05 level (Table XIV).

Weight per 100 Seeds on Branches, Weight per 100 Seeds on Main Stems, Total Weight per 100 Seeds on Plant, and Yield on Branches

Plants of the Sohoma variety produced more weight per 100 seeds on branches (Table XV), more weight per 100 seeds on main stems (Table XVI), more total weight per 100 seeds on plant (Table XVII), and more yield on branches (Table XVIII) than the Essex variety. For all these agronomic characteristics the varietal response was smaller for alternate furrow irrigation compared to every furrow irrigation.

TABLE XV

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION ON WEIGHT PER 100 SEEDS ON BRANCHES IN 1980, 1981, 1982, 1983, AND 1980-83

	1980		1981		1982		1983		1980-83	
	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow
Essex	14.3	14.0	13.8	14.1	13.8	13.4	11.6	12.6	13.4	13.5
	0.3		0.3		0.4*		1.0*		0.1	
Sohoma	17.8	17.9	15.9	16.2	17.1	16.1	16.0	14.8	16.7	16.3
	0.1		0.3		1.0		1.2*		0.4	
LSD(0.05)	1.5**		0.4**		1.7**		0.7**		0.6***	

*Mean difference statistically significant at the 0.05 level.

*Mean of 80 plants.

***Mean of 320 plants.

TABLE XVI

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION ON WEIGHT PER 100 SEEDS ON MAIN STEMS IN 1980, 1981, 1982, 1983, AND 1980-83

	1980		1981		1982		1983		1980-83	
	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow
Essex	14.0	14.8	15.3	15.4	13.8	14.7	12.8	13.6	14.0	14.6
	0.8		0.1		0.9		0.8*		0.6	
Sohoma	19.7	18.2	16.8	16.5	17.0	16.3	15.3	14.7	17.2	16.4
	1.5		0.3		0.7		0.6		0.8*	
LSD(0.05)	2.5**		0.5**		1.1**		0.8**		0.7***	

*Mean difference statistically significant at the 0.05 level.

**Mean of 80 plants.

***Mean of 320 plants.

TABLE XVII

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION ON TOTAL WEIGHT PER 100 SEEDS ON PLANT IN 1980, 1981, 1982, 1983, AND 1980-83

	1980		1981		1982		1983		1980-83	
	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow
Essex	13.7	14.4	14.5	14.5	13.4	13.9	12.3	13.0	13.5	14.0
	0.7		0.0		0.5		0.7		0.5*	
Sohoma	18.6	18.0	16.2	16.3	16.7	16.2	15.6	14.8	16.8	16.3
	0.6		0.1		0.5		0.8		0.5*	
LSD(0.05)	1.1**		0.4**		0.8**		0.6**		0.4***	

*Mean difference statistically significant at the 0.05 level.

**Mean of 80 plants.

***Mean of 320 plants.

TABLE XVIII

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION ON YIELD ON BRANCHES IN 1980, 1981, 1982, 1983, AND 1980-83

	1980		1981		1982		1983		1980-83	
	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow
Essex	5.3	6.6	8.2	11.3	6.2	9.2	6.5	9.5	6.5	9.2
	1.3		3.1*		3.0*		3.0		2.7*	
Sohoma	8.0	16.7	13.6	19.4	15.6	22.6	21.5	27.2	14.7	21.5
	8.7*		5.8*		7.0*		5.7*		6.8*	
LSD(0.05)	1.6**		2.1**		2.6**		3.1**		1.2***	

*Mean difference statistically significant at the 0.05 level.

**Mean of 80 plants.

***Mean of 320 plants.

Weight per 100 seeds on branches was non-significant for any one year or when combined over years for irrigation levels, whereas all variety levels show significance (Tables XIX and XX). All interactions (Tables XIX and XX) for this variable were non-significant except the irrigation x variety interaction in 1982 and the variety x year interaction when combined over the four-year period.

For the weight per 100 seeds on main stems all irrigation treatments were significant, whereas all variety tretment levels were non-significant at the 0.05 level (Tables XIX and XX). Also, all other interactions were non-significant except variety x year (Tables XIX and XX). Tables XIX and XX show that there was no significant difference (0.05 level) between irrigation treatment levels for the total weight per 100 seeds on plant. However, there was a significant difference between variety treatments for this variable. For the irrigation x variety, irrigation x year, and irrigation x variety x year interactions the data show no significant differences at the 0.05 level, but there was s significant variety x year interaction (Table XX).

With respect to yield on branches, all irrigation and variety treatment levels were significantly different (Tables XIX and XX). Also, the irrigation x variety interaction was significant except in 1981 and 1982 and this may possibly be due to differences in precipitation amounts and distribution (Table II; Figure 1) during the pod-filling stage of growth. Other interactions, irrigation x year and irrigation x variety x year, were nonsignificant, but variety x year was significant at the 0.05 level (Table XX).

TABLE XIX

SUMMARY OF TREATMENTS AND TREATMENT INTERACTION FOR AGRONOMIC CHARACTERISTICS AND OBSERVED SIGNIFICANT LEVELS (OSL) DURING 1980, 1981, 1982, 1983, AND 1980-83

Treatments and Treatment Interaction	Weight of 100 Seeds on Branches				Weight of 100 Seeds on Main Stem				Total Weight of 100 Seeds on Plant				Yield on Branches			
	1980	1981	1982	1983	1980	1981	1982	1983	1980	1981	1982	1983	1980	1981	1982	1983
IRR	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.37	0.41	0.06	0.01
VAR	0.01	0.07	0.01	0.01	0.06	1.46	0.01	0.35	0.01	0.21	0.01	0.01	0.08	0.03	0.01	0.01
IRR x VAR	NS	NS	0.31	NS	NS	NS	NS	NS	NS	NS	NS	2.86	1.96	NS	NS	2.85

TABLE XX

SUMMARY OF TREATMENTS AND TREATMENT INTERACTION FOR AGRONOMIC CHARACTERISTICS AND OBSERVED SIGNIFICANT LEVELS (OSL) FOR 1980-83

Treatments and Treatment Interaction	Weight of 100 Seeds on Branches	Weight of 100 Seeds on Main Stem	Total Weight of 100 Seeds on Plant	Yield on Branches
IRR	NS	NS	NS	0.01
VAR	0.01	0.01	0.01	0.01
IRR x VAR	NS	NS	NS	1.23
IRR x YEAR	NS	NS	NS	NS
VAR x YEAR	1.40	0.08	0.01	0.01
IRR x VAR x YEAR	NS	NS	NS	NS

<u>Yield on Main Stems, Total Yield on Plant, and Plot Yields</u>

Mean values and simple effects of the above variables indicate that both Sohoma and Essex varieties produced higher yield on main stems (Table XXI), higher total yield on plant (Table XXII), and higher plot yields (Table XXIII) for the every furrow compared to the alternate furrow irrigation treatment level. However, for a given irrigation treatment the Sohoma variety produced a higher yield on main stems, a higher total yield on plant, and higher plot yields than the Essex variety.

For yield on main stems the irrigation treatment levels were significant only in 1982 and 1983 while the variety treatment levels were not significant in three out of the four years (Table XXIV). Also, the irrigation x variety interaction was nonsignificant at the 0.05 level (Table XXIV). When combined over years the two-factor interactions, irrigation x year and variety x year, were significant whereas the three-factor interaction, irrigation x variety x year, was nonsignificant at the 0.05 level (Table XXV). For the total yield on plant all irrigation and variety treatment levels were significant (Tables XXIV and XXV). The irrigation x variety, irrigation x year, and irrigation x variety x year interactions were all nonsignificant; however, the variety x year interaction was significant at the 0.01 level (Tables XXIV and XXV).

Response of the Essex and Sohoma varieties to irrigation treatment levels indicated the superiority of Sohoma over Essex in most instances (Tables XXVI-XXX, Appendix). This superiority for both alternate and every furrow irrigation treatments can be directly associated with more

TABLE XXI

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION ON YIELD ON MAIN STEMS IN 1980, 1981, 1982, 1983, AND 1980-83

	1980		1981		1982		1983		1980-83	
	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow
Essex	4.9	6.0	6.2	6.2	6.6	8.2	7.6	10.1	6.3	7.6
	1.1*		0.0		1.6*		2.5*		1.3*	
Sohoma	5.9	6.7	5.4	4.4	7.2	7.9	8.6	11.8	6.8	7.7
	0.8		1.0*		0.7		3.2*		0.9*	
LSD(0.05)	1.0**		0.6**		1.2**		0.9**		0.5***	

*Mean difference statistically significant at the 0.05 level.

**Mean of 80 plants.

***Mean of 320 plants.

TABLE XXII

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION ON TOTAL YIELD ON PLANT (G) IN 1980, 1981, 1982, 1983, AND 1980-83

	1980		1981		1982		1983		1980-83	
	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow
Essex	10.2	12.6	14.4	17.5	12.8	17.4	14.1	19.5	12.8	16.8
	2.4*		3.1*		4.6*		5.4*		4.0*	
Sohoma	13.9	23.3	19.0	23.7	22.8	3.05	30.0	39.0	21.5	29.1
	9.4*		4.7*		7.7*		9.0*		7.6*	
LSD(0.05)	2.0**		2.3**		3.2**		3.4**		1.4***	

*Mean difference statistically significant at the 0.05 level.

**Mean of 80 plants.

***Mean of 320 plants.

TABLE XXIII

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION ON PLOT YIELD (KG/HA) IN 1980, 1981, 1982, 1983, AND 1980-83

	1980		1981		1982		1983		1980-83	
	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow	Alternate Furrow	Every Furrow
Essex	2110	2360	2360	2510	1780	2300	1690	2180	1990	2340
	250*		150		520*		490*		350*	
Sohoma	2010	2700	2580	2800	2100	2390	1820	2490	2130	2590
	690*		220		290*		670*		460*	
LSD(0.05)	242**		330**		241**		275**		108***	

*Mean difference statistically significant at the 0.05 level.

**Mean of 4 plots.

***Mean of 16 plots.

TABLE XXIV

SUMMARY OF TREATMENTS AND TREATMENT INTERACTION FOR AGRONOMIC CHARACTERISTICS AND OBSERVED SIGNIFICANT LEVELS (OSL) DURING 1980, 1981, 1982, AND 1983

Treatments and Treatment Interaction	Yield on Main Stem				Total Yield on Plant				Plot Yield			
	1980	1981	1982	1983	1980	1981	1982	1983	1980	1981	1982	1983
IRR	NS	NS	1.12	0.20	0.45	1.51	0.03	0.01	0.01	NS	0.05	0.01
VAR	NS	0.16	NS	NS	0.13	0.25	0.01	0.01	NS	3.45	2.50	2.83
IRR x VAR	NS	NS	NS	NS	NS	NS	NS	NS	1.56	NS	NS	NS

TABLE XXV

SUMMARY OF TREATMENTS AND TREATMENT INTERACTION FOR AGRONOMICS CHARACTERISTICS AND OBSERVED SIGNIFICANT LEVELS (OSL) FOR 1980-83

Treatments and Treatment Interaction	Yield on Main Stem	Total Yield on Plant	Plot Yield
IRR	0.56	0.01	0.01
VAR	NS	0.01	1.11
IRR x VAR	NS	4.78	NS
IRR x YEAR	0.01	NS	0.22
VAR x YEAR	0.08	0.01	NS
IRR x VAR x YEAR	NS	NS	0.38

total pods on plant, more total seeds on plant, more total weight per 100 seeds on plant, and more total yield on plants of the Sohoma compared to the Essex variety. The superiority of the Sohoma over the Essex variety for each of the two irrigation treatments is not only associated with these agronomic characteristics but also could be traced through their respective component data on number of pods on branches, number of pods on main stems, number of seeds on branches, number of seeds on main stems, weight per 100 seeds on branches, weight per 100 seeds on main stems, yield on branches, and yield on main stems (Tables XXVI-XXX, Appendix).

Mean values and estimated simple effects of irrigation and variety on plot yields (kg/ha) are shown in Table XXIII. Analysis of variance for plot yields shows that variety treatment levels were significant for 1981, 1982, 1983 (Table XXI), and when combined over 1980-83 (Table XXV). Irrigation treatments were significant for all years except 1981 (Table XXIV), and can be attributed to more and a better distribution pattern of precipitation during the flowering, pod set, and pod filling stages of growth (Figure 1). In three out of four years and when combined over years the two-factor interaction, irrigation x variety, was not significant (Tables XXIV and XXV). The variety x year interaction was not significant (0.05 level); however, the three-factor interaction, irrigation x variety x year, was significant at the 0.013 level and makes the two-factor interaction, irrigation x year, confounded and noninterpretable (Table XXV).

Yields and least significant differences (LSD) values for all four study years are given in Table XXIII. For 1980 the magnitude in yields ranges from 2010 to 2700 kg/ha. For the alternate furrow irrigation treatment, little difference in yield was obtained between the Essex and Sohoma varieties, but a significantly higher yield of 340 kg/ha was obtained for the Sohoma compared to the Essex for the every furrow irrigation treatment (Table XXIII).

For 1981, alternate furrow irrigation treatments yielded 2360 compared to 2580 ka/ha for the Essex and Sohoma varieties, respectively, with no significant difference at the 0.05 level. Every furrow Sohoma irrigation treatments yielded 290 ka/ha more compared to the Essex variety but were also nonsignificant at the 0.05 level (Table XXIII). The 1981 environment was the only year out of the four-year study period that irrigation was not significant at the 0.05 level (Table XXIV) and can be attributed to the rainfall amounts and distribution (Figure 1) in late July and all of August during the flowering, pod set, and early pod filling stages of growth.

In 1982 the magnitude of yields ranged from 1780 to 2390 kg/ha. When irrigated in every furrow, Essex and Sohoma produced 2300 and 2390 kg/ha, respectively, and were nonsignificant at the 0.05 level. However, when alternate-furrow irrigated a significant (0.05 level) yield difference of 320 kg/ha was obtained (Table XXIII).

The magnitude of yields in 1983 for the alternate furrow irrigation treatment ranged from 1690 to 1820 kg/ha for the Essex and Sohoma varieties, respectively. There was no significant difference between these yields which represent the lowest single year yields for the alternate furrow irrigation treatment during the four-year study (Table XXIII). Every furrow irrigation treatments resulted in yields of 2180 and 2490 kg/ha for the Essex and Sohoma varieties, respectively, and were significantly different at the 0.05 level (Table XXIII).

Over the four-year study period the Sohoma soybean variety outyielded the Essex variety when irrigated in alternate furrows in three out of four years. When irrigated in every furrow the Sohoma variety also outyielded the Essex variety over a four-year period an average of 250 kg/ha/year (Table XXIII).

CHAPTER V

SUMMARY AND CONCLUSIONS

In south central Oklahoma, the lack of sufficient water, high temperatures, and winds during the growing season are by far the most limiting factors in soybean production. However, for optimum production in the area, a workable irrigation technique for improving water use efficiency and reducing water requirements must be established.

The objectives of this study were to: 1) evaluate the yields of Essex and Sohoma soybeans with alternate and every furrow irrigation in south central Oklahma; 2) evaluate the following agronomic characteristics of Essex and Sohoma soybeans as affected by the application of supplemental irrigation in alternate and every furrow: plant height, number of branches per plant, number of pods on branches, total number of pods on plant, number of seeds on branches, number of seeds on main stems, total number of seeds on plant, weight per 100 seeds on branches, weight per 100 seeds on main stems, total weight per 100 seeds on plant, seed yield on branches, seed yield on main stem, total seed yield on plant, and plot yields.

At maturity, 20 plants were randomly selected from rows on the two center beds of each experimental unit for agronomic characteristic evaluation. Yields were obtained by harvesting 2.0 x 80.0 m strips from each experimental unit in 1980, 1981, 1982, and 1983.

For each of the four years, plants of the Sohoma variety were taller, produced larger numbers of branches, more pods on branches, more total pods on plants, larger numbers of seeds on branches, more total seeds on plants, more weight per 100 seeds on branches, more weight per 100 seeds on main stems, more total weight per 100 seeds on plant, higher yield on branches, higher yield on main stems, higher total yield on plants, and higher plot yields than plants of the Essex variety for both alternate and every furrow irrigation treatment levels. In contrast to Sohoma, the Essex variety produced more pods on main stems and more seeds on main stems for each of the two irrigation treatment levels. Although Essex produced more pods on main stems and more seeds on main stems, Sohoma outproduced the Essex variety by producing fewer but larger seeds.

Both the Sohoma and Essex varieties produced taller plants, larger numbers of branches, more pods on branches, more pods on main stems, more total pods on plants, larger seeds on branches, more seeds on main stems, more total seeds on plants, larger seeds on main stems, larger weights per 100 seeds on branches, larger weights per 100 seeds on main stems, more total weight per 100 seeds on plant, higher yield on branches, higher yield on main stems, higher total yield on plant, and higher plot yields for the every furrow compared to the alternate furrow irrigation treatment level.

When combined over the four-year period, yield data averaged over irrigation treatments showed that the Essex variety produced 2165 compared to 2360 kg/ha for the Sohoma variety. However, when averaged over variety yield data showed that alternate irrigation treatments yielded

2060 compared to 2465 kg/ha for every furrow irrigation treatments. When alternately irrigated, Essex and Sohoma soybean varieties produced 1990 and 2130 ka/ha, respectively. When irrigated in every furrow the Essex and Sohoma soybean varieties produced 2340 and 2590 kg/ha, respectively, and were significant at the 0.05 level (Table XXIII). When averaged over the four-year study period, yield differences between the Essex and Sohoma varieties were significant at the 0.05 level when supplemental water was applied using the alternate or every furrow method of application.

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APPENDIX

TABLE XXVI

SUMMARY OF THE AGRONOMIC CHARACTERISTICS AND YIELD DATA FOR IRRIGATION TREATMENTS APPLIED TO ESSEX AND SOHOMA SOYBEAN VARIETIES IN 1980

Irrigation Levels	Variety Levels	Plant Height (cm)	Branches per Plant	Pods on Branches	Pods on Main Stem	Total Pods on Plant	Seeds on Branches	Seeds on Main Stem	Total Seeds on Plant	Weight of 100 Seeds on Branches (g)	Weight of 100 Seeds on Main Stem (g)	Total Weight of 100 Seeds on Plant (g)	Yield on Branches (g)	Yield on Main Stem (g)	Total Yield on Plant (g)	Yield (Kg/ha)
AF	E	38.8	3.8	18.8	16.8	35.6	38.9	34.1	72.9	14.3	14.0	13.7	5.3	4.9	10.2	2110
AF	S	47.2	5.5	20.6	14.5	35.1	44.7	30.6	75.3	17.8	19.7	18.6	8.0	5.9	13.9	2010
EF	E	42.8	4.0	22.8	19.8	42.6	46.6	40.2	86.8	14.0	14.8	14.4	6.7	6.0	12.6	2360
EF	S	55.4	8.7	44.7	17.5	62.2	93.5	36.4	129.9	17.9	18.2	18.0	16.7	6.7	23.3	2700
LSD(0.05)		1.5	0.7	4.6	2.0	5.3	9.6	4.5	11.2	1.5	2.5	1.1	1.6	1.0	2.0	242
LSD(0.01)		2.0	0.9	6.0	2.7	6.9	12.6	5.8	14.8	1.9	3.3	1.4	2.1	1.3	2.6	347

Irrigation Level: AF = Alternate Furrow; EF = Every Furrow.

Variety Level: E = Essex; S = Sohoma.

TABLE XVII

SUMMARY OF THE AGRONOMIC CHARACTERISTICS AND YIELD DATA FOR IRRIGATION TREATMENTS APPLIED TO ESSEX AND SOHOMA SOYBEAN VARIETIES IN 1981

Irrigation Levels	Variety Levels	Plant Height (cm)	Branches per Plant	Pods on Branches	Pods on Main Stem	Total Pods on Plant	Seeds on Branches	Seeds on Main Stem	Total Seeds on Plant	Weight of 100 Seeds on Branches (g)	Weight of 100 Seeds on Main Stem (g)	Total Weight of 100 Seeds on Plant (g)	Yield on Branches (g)	Yield on Main Stem (g)	Total Yield on Plant (g)	Yield (Kg/ha)
AF	E	59.5	9.1	28.6	19.9	48.5	59.2	40.6	99.8	13.8	15.3	14.5	8.2	6.2	14.4	2352
AF	S	71.8	10.4	42.0	16.0	58.0	84.6	31.9	116.6	15.5	16.8	16.2	13.6	5.4	19.0	2580
EF	E	63.0	10.1	39.0	19.8	58.8	80.4	40.2	120.6	14.1	15.4	14.5	11.3	6.2	17.5	2510
EF	S	69.0	11.5	59.3	12.7	72.0	120.4	26.4	146.8	16.2	16.5	16.3	19.4	4.4	23.7	2800
LSD(0.05)		1.7	0.9	6.5	1.8	7.0	13.3	3.6	14.4	0.4	0.5	0.4	2.1	0.6	2.3	330
LSD(0.01)		2.3	1.2	8.5	2.3	9.2	17.5	4.7	18.9	0.5	0.7	0.5	2.8	0.8	3.1	474

Irrigation Level: AF = Alternate Furrow; EF = Every Furrow.

Variety Level: E = Essex; S = Sohoma.

TABLE XVIII

SUMMARY OF THE AGRONOMIC CHARACTERISTICS AND YIELD DATA FOR IRRIGATION TREATMENTS APPLIED TO ESSEX AND SOHOMA SOYBEAN VARIETIES IN 1982

Irrigation Levels	Variety Levels	Plant Height (cm)	Branches per Plant	Pods on Branches	Pods on Main Stem	Total Pods on Plant	Seeds on Branches	Seeds on Main Stem	Total Seeds on Plant	Weight of 100 Seeds on Branches (g)	Weight of 100 Seeds on Main Stem (g)	Total Weight of 100 Seeds on Plant (g)	Yield on Branches (g)	Yield on Main Stem (g)	Total Yield on Plant (g)	Yield (Kg/ha)
AF	E	55.0	5.2	22.7	23.0	45.7	47.2	48.2	95.4	13.8	13.8	13.4	6.2	6.6	12.8	1781
AF	S	67.2	7.5	46.1	20.2	66.3	95.9	43.6	139.5	17.1	17.0	16.7	15.6	7.2	22.8	2100
EF	E	61.7	5.8	32.9	27.1	60.0	68.8	56.8	125.3	13.4	14.7	13.9	9.2	8.2	17.4	2300
EF	S	71.1	9.4	68.3	23.3	91.6	143.2	49.7	192.9	16.1	16.3	16.2	22.6	7.9	30.5	2390
LSD(0.05)		3.2	1.2	8.3	3.5	10.0	17.6	7.5	21.1	1.7	1.1	0.8	2.6	1.2	3.2	241
LSD(0.01)		4.2	1.6	10.9	4.5	13.1	23.1	9.9	27.7	2.2	1.5	1.0	3.5	1.6	4.2	346

Irrigation Level: AF = Alternate Furrow; EF = Every Furrow.

Variety Level: E = Essex; S = Sohoma.

TABLE XIX

SUMMARY OF THE AGRONOMIC CHARACTERISTICS AND YIELD DATA FOR IRRIGATION TREATMENTS APPLIED TO ESSEX AND SOHOMA SOYBEAN VARIETIES IN 1983

Irrigation Levels	Variety Levels	Plant Height (cm)	Branches per Plant	Pods on Branches	Pods on Main Stem	Total Pods on Plant	Seeds on Branches	Seeds on Main Stem	Total Seeds on Plant	Weight of 100 Seeds on Branches (g)	Weight of 100 Seeds on Main Stem (g)	Total Weight of 100 Seeds on Plant (g)	Yield on Branches (g)	Yield on Main Stem (g)	Total Yield on Plant (g)	Yield (Kg/ha)
AF	E	58.4	2.5	26.4	38.7	55.1	55.6	60.3	115.9	11.6	12.8	12.3	6.5	7.6	14.1	1690
AF	S	72.1	5.4	62.9	24.8	87.7	138.2	57.2	195.4	16.0	15.3	15.6	21.5	8.6	30.0	1820
EF	E	66.7	2.8	35.2	35.9	71.0	74.6	75.4	150.0	12.6	13.6	13.0	9.5	10.1	19.5	2180
EF	S	80.8	6.0	86.0	36.4	122.4	182.6	80.0	262.6	14.8	14.7	14.8	27.2	11.8	39.0	2490
LSD(0.05)		2.0	0.4	9.6	2.9	10.6	20.8	6.3	22.7	0.7	0.8	0.6	3.1	0.9	3.4	275
LSD(0.01)		2.7	0.6	12.7	3.8	13.9	27.3	8.3	29.8	0.9	1.1	0.8	4.1	1.2	4.5	395

Irrigation Level: AF = Alternate Furrow; EF = Every Furrow.

Variety Level: E = Essex; S = Sohoma.

TABLE XXX

SUMMARY OF THE AGRONOMIC CHARACTERISTICS AND YIELD DATA FOR IRRIGATION TREATMENTS APPLIED TO ESSEX AND SOHOMA SOYBEAN VARIETIES IN 1980-83

Irrigation Levels	Variety Levels	Plant Height (cm)	Branches per Plant	Pods on Branches	Pods on Main Stem	Total Pods on Plant	Seeds on Branches	Seeds on Main Stem	Total Seeds on Plant	Weight of 100 Seeds on Branches (g)	Weight of 100 Seeds on Main Stem (g)	Total Weight of 100 Seeds on Plant (g)	Yield on Branches (g)	Yield on Main Stem (g)	Total Yield on Plant (g)	Yield (Kg/ha)
AF	E	52.9	5.1	24.1	22.1	46.2	50.2	45.8	96.0	13.4	14.0	13.5	6.5	6.3	12.8	1990
AF	S	64.6	7.2	42.9	18.9	61.8	90.9	40.8	131.7	16.7	17.2	16.8	14.7	6.8	21.5	2130
EF	E	58.5	5.7	32.5	25.6	58.1	67.7	53.1	120.7	13.5	14.6	14.0	9.2	7.6	16.8	2340
EF	S	69.1	8.9	64.6	22.5	87.1	134.9	48.1	183.0	16.3	16.4	16.3	21.5	7.7	29.1	2590
LSD(0.05)		1.1	0.4	3.7	1.3	4.2	7.9	2.8	9.0	0.6	0.7	0.4	1.2	0.5	1.4	108
LSD(0.01)		1.5	0.6	4.9	1.7	5.6	10.4	3.7	11.8	0.8	1.0	0.5	1.6	0.6	1.8	155

Irrigation Level: AF = Alternate Furrow; EF = Every Furrow.

Variety Level: E = Essex; S = Sohoma.

Number of Observations: n = 320.

VITA 2

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