THE EFFECTS OF IRRIGATION AND PLANTING PATTERNS ON THE YIELD AND AGRONOMIC CHARACTERISTICS OF TWO SOYBEAN CULTIVARS

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CHAPTER I

INTRODUCTION

During the last two decades, increased world demand for soybean meal, oil, protein, and secondary products have necessitated improvements in soybean varieties, cultural, and fertilizer practices. These and other improved practices have contributed to expand soybean production in many new areas in the United States as well as in other countries. In many cases, however, environmental conditions are seldom well suited for optimum yield attainment. This has prompted the need for more research on the soil atmospheric environment on the growth and yield of soybean cultures.

In south central Oklahoma, the lack of sufficient water, high temperatures, and wind are probably the most limiting factors in soybean production. Total rainfall over the growing periods is somewhat low, with wide year-to-year distribution. During the critical growth periods (flowering, pod set, and pod filling), high temperatures and strong winds often occur that contribute to increased evapotranspiration and require supplemental water.

Studies conducted by Peters and Johnson (1960) on water use by soybeans showed that evapotranspiration from the soil surface can account for at least half of the water lost from the profile when the soil moisture levels are high, and from a fourth to a half of the water lost during a dry season. This evidence, although related to another area, leaves little doubt about the necessity of finding practical and economical ways in south central Oklahoma of minimizing the yield-limiting effects of the suboptimal precipitation. Optimum soybean production with limited available water resources might be possible through the establishment of workable irrigation techniques that would minimize evapotranspirational (ET) losses by improving the overall irrigation management and application techniques. The objectives of the study were to:

1. Evaluate the yield potential of furrow irrigated soybeans in south central Oklahoma.

2. Evaluate the following agronomic characteristics of soybeans (Essex and Sohoma) as affected by two different methods of application of supplemental irrigation water (every and alternate furrow) and two planting patterns (one and two rows per bed):

a. Plant height

b. Number of branches per plant

c. Number of nodes per plant

d. Number of pods on branches

e. Number of pods on main stems

f. Immature pods on branches

g. Immature pods on main stems

h. Number of seeds on branches

i. Number of seeds on main stems

j. Yield on branches

k. Yield on main stems

l. Weight of seeds on plant(s) below 10 cm (as an estimate of harvest loss)

m. Yield.

3. Make a quantitative determination of differences between the soybean varieties in their reaction to water stress by comparing the difference in yields under conditions of supplemental water being applied to every furrow with the yield under conditions of supplemental water being applied to alternate furrows.

CHAPTER II

LITERATURE REVIEW

Stages of Growth and Development of Soybean Plants

A plant's life cycle is generally divided into two major parts: growth and development. Landsberg (1977) defined plant growth as an irreversible increase in size which is commonly accompanied by an increase in dry weight and in the amount of protoplasm. Development, as it applies to whole seed plants arising by sexual reproduction, denotes the gradual and progressive change in size, structure, and function, which collectively comprise the transformation of a zygote into a mature, reproductive plant. Development involves controls at the molecular, organic and cellular levels, the activation and repression of genes and the determination of divergent patterns of differentiation leading to organ formation, biochemical differentiation, and maintenance of balance between organs. It is characterized by temporal and spatial discontinuities as well as changes in rates (Landsburg, 1977).

In soybeans (Glycine Max (L) Merr.), the growth and development periods are referred to as vegetative and reproductive stages, respectively. These stages last different lengths of time and are influenced in different degrees by internal and external factors. For soybeans, it has been convenient to divide each main stage (vegetative and reproductive) into substages. Although there is a major difference in plant development between indeterminate and determinate soybean varieties, these stage descriptions are unilaterally applied (Fehr and Caviness, 1977).

Description of Vegetative Stages

Vegetative stages are described by Fehr and Caviness (1977) as emergence, unfolding of the cotyledons, and then development of successive nodes on the main stem, beginning with the unifoliate nodes, taking into account nodes that have a fully developed leaf. Each stage description (Table 1) is given a vegetative (V) stage designation and an abbreviated title to facilitate communication.

TABLE 1

DESCRIPTION OF VEGETATIVE STAGES

Stage No.	Abbreviated Stage Title	Description
VE	Emergence	Cotyledons above soil surface
VC	Cotyledon	Unifoliate leaves unrolled sufficiently so the leaf edges are not touching
V1	First node	Fully developed leaves at unifoliate nodes
V2	Second node	Fully developed trifoliate leaf at node above unifoliate nodes
V3	Third node	Three nodes on the main stem with fully developed leaves beginning with the unifoliate nodes
. . . .		
V(η)		η number of nodes on the main stem with fully developed leaves beginning with the unifoliate nodes, η can be any number beginning with 1 for V1, first node stage

Source: Fehr and Caviness (1977).

Description of Reproductive Stages

Description of the reproductive stages is made using the main stem. These stages are based on flowering, pod development, seed development, and plant maturation (Fehr and Caviness, 1977). Each stage description is given a reproductive (R) stage number and an abbreviated title (Table 2).

TABLE 2

DESCRIPTION OF REPRODUCTIVE STAGES

Stage No.	Abbreviated Stage Title	Description
R1	Beginning bloom	One open flower at any node on the main stem
R2	Full bloom	Open flower at one of the two uppermost nodes on the main stem with a fully developed leaf
R3	Beginning pod	Pod 5 mm (3/16") long at one of the four uppermost nodes on the main stem with a fully developed leaf
R4	Full pod	Pod 2 cm (3/4") long at one of the four uppermost nodes on the main stem with a fully developed leaf
R5	Beginning seed	Seed 3 mm (1/8") long in a pod at one of the four uppermost nodes on the main stem with fully developed leaf
R6	Full seed	Pod containing a green seed that fills the pod cavity at one of the four uppermost nodes on the main stem with a fully developed leaf
R7	Beginning maturity	One normal pod on the main stem that has reached their mature pod color. Five to 10 days of drying weather are required after R8 before the soybeans have less than 15% moisture
R8	Full maturity	Ninety-five percent of the pods have reached their mature pod color

Source: Fehr and Caviness (1977).

Effects of Environmental Factors on Soybean Growth, Development, and Agronomic Characteristics

Crop production is generally determined by the prevailing physical, chemical, and biological environmental factors. In the case of soybeans, differential changes in their growth, development, and agronomic characteristics have been observed in response to the environment.

Water. Soybeans are frequently grown in geographical areas characterized by variable precipitation conditions. In most cases, periods of water deficit during the growing season are the rule rather than the exception (Monem et al., 1978).

Water consumption by soybeans will vary, depending on climatic conditions, management practices applied, and length of the growing season. Henderson and Miller (1973) estimated the water use of soybean plants for an entire growing season in the desert areas of southern California to be between 64 and 76 cm. In Texas, 65 cm of water were used during the growing season by soybeans which were irrigated when soil moisture was depleted to 60% at the 60-cm depth (Dusek et al., 1971).

Water availability is one of the major environmental factors affecting germination. The seed moisture content (dry weight basis) required for soybean germination is about 50%, compared with 30% for corn and 26% for rice (Hunter and Erickson, 1952).

The status of water in soybean plants represents an integration of the atmospheric demand, soil water potential, rooting density and distribution, and other plant characteristics (Kramer, 1969). The water taken up by the roots moves up in the xylem to the leaves where it vaporizes, and is released through the stomates into the atmosphere (Gates, 1968). As a result, plant water stress begins when transpiration water loss exceeds absorption of water by the roots. The amount and rate of water loss through plant leaves depends chiefly on leaf morphological characteristics and atmospheric conditions, whereas absorption of water by roots depends primarily on soil water conditions (Ritchie, 1974).

According to Grable and Danielson (1965), soybean roots develop faster at a soil moisture potential of -0.5 bars than at -0.9 bars. Excessive soil moisture levels, as would be expected, is not conducive to either germination or root gorwth because of the lack of oxygen (O_2) required for respiration. Such conditions may also affect nitrogen (N) fixation by the nodules. It is reported that maximum fixation occurs when a given soil is near its field capacity, and is reduced at levels above and below this value (Sprent, 1972; Hume et al., 1976). The decreased N fixation of water-stressed nodules was attributed to an insufficiency of respiratory O_2 in the bacteroids (Pankhurst and Sprent, 1975) and to reduced photosynthetic rates in the leaves of the plants (Huang et al., 1975).

Taylor and Klepper (1978) studied correlations between high plant rooting density and low mid-day water deficits. While it did not clearly appear to them whether or not dense rooting directly caused higher yields by permitting plants to avoid mid-day water deficits, they did observe differences in soybean seedlings that correlate with some differences in water deficits. These authors suggested that over the years, yield improvement through selection may have simultaneously selected for small mid-day water deficits and increased density of plant rooting patterns.

Plant water stress can affect plant growth by modifying the anatomy, morphology, physiology, and biochemical properties of plants (Boyer, 1970a, 1970b; Ciha and Brun, 1975), ultimately decreasing crop yields (Thompson, 1975). Mederski and Jeffers (1973) and Monem et al. (1978) have shown that soybean cultivars vary in their susceptibility to water stress. With limited available irrigation water, early maturing cultivars may perform better than late maturing cultivars in dry regions. The use of an early cultivar provides some protection against complete failure due to drought, but at the expense of maximum yield should moisture supply during the season be favorable (Matson, 1964).

Soybean plant height, number of nodes, stem diameter, number of flowers, percentage of pod set, number of seeds, and seed weight are positively correlated with soil moisture (Chen et al., 1971). However, the impact of water stress on the agronomic characteristics and yield of soybeans depends to a large extent on the stage of development at the time the stress occurs and on the duration of the stress.

When stress from flowering through pod set was followed by adequate irrigation during pod-filling, Dusek et al. (1971) found a yield reduction due to a decrease in the number of pods per plant. Soybeans flower over a relatively long 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). Water stress during the pod-filling stage not only reduces the total yield but also the seed size (Dusek et al., 1971). The reduction of dry matter accumulation in the seeds with late season moisture stress may be a result of premature loss of leaf area and a shortening of the pod-filling period.

Excessive transpiration rates and/or inadequate soil moisture causes internal plant water deficits. In general, plant water deficits due to excessive transpiration rates are more common than those due to inadequate soil moisture. These deficits occur because of the frictional resistance to water flow through roots and stems, which in turn depends on atmospheric conditions, soil water conditions, and flow resistance within the plant. Therefore, such water deficits cannot be relieved by simply adding water to the soil (Boyer et al., 1979).

Internal plant water deficits provoke some alteration in plant metabolism (Hsiao, 1973), and produce effects on crop yields similar to those caused by water deficits arising from inadequate soil moisture (Boyer et al., 1979). These researchers showed that considerable yield improvement was achieved over the years with the newer cultivars of Maturity Groups II and III. These yield improvements were associated with reduced afternoon water deficits when compared to the older cultivars. The differences in mid-day water deficits between the newer and older cultivars were shown to be associated with significant yield losses, probably because of the sensitivity of photosynthesis and other processes to these water deficits.

Scott and Geddes (1978) studied the effects of mid-day and diurnal water stress on soybean plants at different growth stages (V8, R1, and R6). Seasonal mid-day water stress observations indicated that the potential water stress imposed by the atmosphere as estimated by evaporation from an open pan, had a greater effect on the plants during bloom stage than during the vegetative growth stage. Mean values of xylem pressure potentials during the reproductive growth stage decreased to the -14 to -16 bar range, which suggests the importance of an adequate moisture supply during that critical period. The observations they made on diurnal plant-water stresses of field grown "Lee 74" soybeans indicated xylem pressure potentials to be generally lowest in the early morning, greatest in the early afternoon, and with a great rate of decreasing leaf water potential as the season progresses. Like Sionit and Kramer (1977) and Sojka et al. (1977), Scott and Geddes (1978) concluded that water stress definitely induces poor growth and development of soybeans.

Air Composition and Temperature. The ability of the soil to provide a suitable air composition to plant roots and soil microorganisms depends largely on the size, shape, continuity, and distribution of its pore spaces and moisture level. Increasing the carbon dioxide (CO_2) level of the air surrounding the canopy has had some positive effects on plant growth. Carbon dioxide levels ranging from 3 to 14% in the foliar atmosphere increased the fresh and dry weights of soybean plants (Ogren and Rinne, 1973). The same authors pointed out, however, that when concentrations were increased upward from 14 to 23% in the foliar atmosphere, all indexes of growth fell off sharply. They also reported that concentrations of CO_2 greater than 20% applied to the roots or tops or both together would depress the growth of soybean seedlings.

The effect of temperature on soybean germination has been extensively studied. Maximum germination in the shortest time requires a constant temperature of 30°C (Delouche, 1953); the optimum level for the process ranges between 34° and 36°C, with a minimum of 2° to

4°C and a maximum of 42° to 44°C (Inouye, 1953; Mague and Burris, 1972).

Temperature effects on soybean nodule activity were investigated by Kuo and Boersma (1971). They found the optimal soil temperature for nodulation to be 23.9°C over a wide range of soil water potentials. Pankhurst and Sprent (1976) reported a broad optimum temperature range of between 15°C and 30°C for N fixation by nodules of 'Portage' soybeans, and this optimum temperature range decreased with water stress. Because of its effects on translocation of carbohydrates from the leaves to the nodules, air temperature may have as great, if not greater, effect than soil temperatures. Jeffers and Shibles (1969) found the temperature response of canopy photosynthesis for three soybean varieties not to be very pronounced, with a poorly defined optimum at 25°C to 30°C.

The responses of soybeans to day length are somehow modified by temperature. Early maturing cultivars respond more to changes in temperature than to day length, and late maturing cultivars respond more to changes in day length than to temperature (Keith and Harry, 1978). In some tropically adapted soybeans, a 5°C change in night temperature is even more effective than a 100 minute change in day length in influencing time to the first open flower (Summerfield et al., 1975). Studies by Judith and David (1978) indicated that temperature also plays a critical role in controlling plant morphology such as main stem length, initiation and development of branches, number of nodes on branches, as well as pod to flower ratio. In general, temperature is the major factor influencing vegetative development. Low temperatures retard, and high temperatures enhance, seedling emergence and leaf development. Therefore, number of days from planting to the vegetative emergence (VE) stage can vary from about 5 to 15 days, depending on the temperature (Table 3).

TABLE 3

NUMBER OF DAYS REQUIRED FOR A PLANT TO DEVELOP FROM ONE VEGETATIVE STAGE TO THE NEXT

Vegetative Stages	Average Number of Days	Range in Number of Days
Planting VE	10	5-15
VE to VC	5	3-10
VC to V1	5	3-10
V1 to V2	5	3-10
V2 to V3	5	3-8
V3 to V4	5	3-8
V4 to V5	5	3-8
V5 to V6	3	3-8
Time interval between all vegetative stages after V5	3	2-5

Source: Fehr and Caviness (1977).

Day Length and Light Intensity. The main effect of day length on soybean development is that of flowering induction. This is commonly referred to as photo-periodism, a response to light and the energy levels involved. It is a time-measuring mechanism, inducing the production of a floral stimulus (probably a hormone) which activates, derepresses or "switches on" the genes responsible for differentiation, so that development in the apical meristems proceeds along the pathway which leads to the production of flowers (Landsberg, 1977).

Soybeans are classified as short day plants. They will flower in about 30 days if the day length is short. With continued long days, they will remain vegetative almost indefinitely (Dale, 1978). The grouping of soybean cultivars into maturity groups (00 to X) is based on their responsiveness to photoperiod. Thus, when a cultivar is planted south of its zone of adaptation as a full season cultivar, it will flower at an early phenological stage and mature earlier because the critical night length initiating flowering occurs at an earlier calendar date. Conversely, when planted at locations north of its zone of full season adaptation, floral initiation and maturation is delayed because the critical night length occurs at a later calendar date. Differences in day length result in responsiveness not only to number of days to flowering and to maturity (Keith and Harry, 1978), but also to plant height, internode number (Major and Johnson, 1974), number of pods set per total number of flowers initiated, and seed filling rate (Thomas and Raper, 1976). According to Keith and Harry (1978), late maturing cultivars (those adapted to the Southern United States) are more sensitive to flowering than are the early maturing cultivars (those adapted to the Northern United States). However, Polson (1972) found several soybean genotypes to be insensitive to day length and to flower in about 30 days after emergence during photoperiods of between 12 and 14 hours.

The effects of temperature, day length, and varietal differences on soybean reproductive stages are translated in the time intervals between stages listed in Table 4.

TABLE 4

NUMBER OF DAYS REQUIRED FOR A PLANT TO DEVELOP FROM ONE REPRODUCTIVE STAGE TO THE NEXT

Reproductive Stages	Average Number of Days	Range in Number of Days**
	0*,3	0-7
R1 to R2	10	5-15
R2 to R3	9	5-15
R3 to R4	9	4-26
R4 to R5	15	11-20
R6 to R7	18	9-30
R7 to R8	9	7-18

Source: Fehr and Caviness (1977).

*R1 and R2 generally occur simultaneously in determinate varieties. The time interval between R1 and R2 for indeterminate varieties is about three days.

**Data on the range may differ for cooler or more tropical climates.

Light strongly influences the morphology of the soybean plant by causing changes in the time of flowering and maturity. These changes often result in differences in plant height, pod height, leaf area, lodging, grain yield, total dry matter production, and the many other characteristics dependent on the production of photosynthate.

Jeffers and Shibles (1969) found a strong interaction between leaf area index (LAI) and light intensity in a study of the canopies of three field-grown soybean cultivars. Kan and Oshima (1952) reported light intensities 50% of normal reduced the number of branches, nodes, and pods, and reduced seed yield by 60%.

Bohning and Burnside (1956) reported that individual soybean leaves are light saturated at 23,860 lux, which is about 20% of full sunlight. In contrast, leaves from the upper canopy of field-grown 'Wayne' soybeans were reported to be light saturated at 107,690 lux, and leaves of spaced plants were not saturated at 161,460 lux (Beuerlein and Pendleton, 1971). Soybean leaves have the ability to adapt themselves to the prevailing environment and particularly to the light intensity surrounding the canopy. They develop sufficient adaptive photosynehtic capacity to utilize the maximum available light (Bowes et al., 1972). According to these researchers, this light adaptation process explains the wide range of photosynthetic rates and light saturation values reported in the literature: 20.2 mg CO_2 cm^{-2} $hour^{-1}$ on top of the canopy (Johnson et al., 1969) and 50 mg CO_2 dm^{-2} $hour^{-1}$ with all leaves in full sunlight (Buerelein and Pendleton, 1971). In general, bottom and middle leaves are more or less shaded and receive less light; therefore, their exposure to more sunlight has been shown to result in more pronounced photosynthetic activity (Johnson et al., 1969).

Sakamoto and Shaw (1965) reported the maximum photosynthetic rate for 'Hawkeye' soybeans to be at initial flowering, dropping slightly to a constant rate through pod formation and early bean filling, then dropping sharply during the latter part of pod-filling as the LAI rapidly decreased at senescence. In contrast, Dornhoff and Shibles (1970) reported that the leaf photosynthetic rate increased for 18 of 20 soybean varieties during the pod-filling stage. They speculated that this was due to an increase in "sink demand" from the filling seeds.

An interaction between light intensity and CO_2 concentration has been shown by Egli et al. (1970). A strong interaction between LAI and light intensity was also reported by Hodgkinson (1974). The effects of light quality on soybean photosynthesis is not fully understood. For kidney beans (Phaseolus vulgaris L.) the highest photosynthetic rate occurs in the red light with two peaks (at 630 and 670 nm); lower peaks in descending order were present in the blue (347 nm) and in the green (500 nm) part of the spectrum (Baleg and Biddulph, 1970). Light duration, which has pronounced photomorphogenic effects on soybeans, is not known to have any significant effect on soybean photosynthesis (William, 1978).

Wind. Strong, hot, and frequent winds can pose a serious threat to the growth, development, and productivity of a soybean crop. Wind greatly increases potential evaporation, thus depriving the crop of an adequate amount of water. Radke and Burrows (1970) suggest that wind increases exposure of the more reflective underside of soybean leaves to light and thereby decreases the efficiency of light utilization. Radke and Hagstrom (1973) reported that water-stressed leaves have less ability to maintain a normal orientation to light than do leaves not stressed for water. Further effects of wind on crops could be illustrated by its impact on leaf and flower detachment, propagation of plant pests, and canopy heat gains or losses by convection. Important characteristics of wind include its velocity, duration, direction, and frequency. These may interact and cause mechanical and abrasive damage to soybeans with profound repercussions on the global productivity of a soybean crop (Cooper, 1971).

Soil Physical and Chemical Conditions. Soil characteristics such as structure, texture, depth, permeability, water holding capacity, and nutrient supplying capacity are of primary importance in soybean production. Ideal soils for soybean production are medium-textured with pH values ranging from 6.0 to 6.8. Soils with severe compaction problems are not recommended because both plant and root growth can be restricted and yields reduced (Nelson et al., 1975).

Hanks and Thorp (1957) found soybean emergence from soil with low soil crust strengths to decrease from 90 to 70% as soil moisture decreased from field capacity to 25% available water by volume. Emergence from soils with high soil crust strengths decreased from 70 to 30% at comparable soil moisture levels. Zimmerman and Kaudos (1961), Vorhees et al. (1976), and Nelson et al. (1975) reported negative correlations on root penetration, nodule growth and mass, and increased soil compaction.

Soybeans as leguminous crops have the ability to synthesize their own N, provided seed inoculation is performed before planting and the appropriate bacterial strain (Rhizobia japonicum) is present in the soil. Consequently, in most cases N fertilizer is not needed unless applied as a starter. Soybean nodule numbers, size, and metabolic activity are generally reduced by increasing soil N (Weber, 1966; Raggio et al., 1957; Harper and Cooper, 1971). The relative rates of application of other essential macronutrients such as phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) are best estimated after soil testing. Micronutrient deficiencies are less of a problem in major soybean producing areas; however, corrective applications may need to be made on specific soil types.

Need for Supplemental Water in Soybean Production

Water use efficiency is defined as pounds of water required to produce a pound of dry matter and is generally high for many of the high value agronomic crops: 305 for sorghum, 349 for corn, 646 for soybeans, 844 for alfalfa (Scott and Aldrich, 1970).

The need for supplemental water in soybean production is further documented by the fact that, in most cases, the amount of water used by the growing crop plus that lost by evaporation from the soil surface, often exceeds the normal rainfall during the growing season (Mederski and Jeffers, 1973). To achieve higher yields, the irregular patterns of rainfall distribution and variation would have to be supplemented with irrigation (Salter and Goode, 1967).

Soybeans respond with increased yield to additions of supplemental water during most years (Doss and Thurlow, 1974). In Illinois, an additional 2.5 cm of rain above the average for an eight day period during pod-fill resulted in a yield increase of 134 kg/ha (Runge and Odell, 1960). Yield increases obtained in Arkansas during a five year irrigation experiment ranged from essentially 0 to 23 bushels for one variety and from 0 to 19 bushels for another variety (Scott and Aldrich, 1970). These authors also reported yield increases of up to 30 bushels per acre in Missouri as a result of irrigation, as opposed to non-irrigation, and also reported a lack of response in one of the three years of the experiment.

Grissom et al. (1955) reported that soybean irrigation at early stages of growth was not beneficial. Somerhalder and Schleuseur

(1960) showed a single irrigation of 11 cm of water applied at early flowering to be more effective than an equal amount applied at late flowering, or 19 to 25 cm of water applied to maintain low water tension throughout the season. Recent research conducted in Alabama indicated that insufficiency of water, particularly during the pod-fill stage, is frequently a major barrier to high soybean yields (Scott and Aldrich, 1970). Many crops have comparable stages of growth at which moisture stress is particularly harmful to the harvested yield (Doorenbos and Pruitt, 1977). However, the investments required to establish irrigation systems are often such that costs and expected benefits from application of supplemental water to crops may need to be seriously considered before initiating an irrigation development and installation program. Irrigation is potentially justifiable wherever periods of moisture stress occur that would reduce crop yields, and where a dependable supply of good quality water is available at reasonable cost (Wynne, 1979).

Supplemental water should be applied when soil moisture is reduced to the point at which significant reduction in plant growth rates occur (Wien et al., 1976); that is, when the soil matrix potential reaches a certain value such as 50 or 60% of the available soil moisture in the major root zone.

Both allowable time between irrigations and the quantity of water that should be applied per irrigation depend on differences in water holding capacities of soils and plant rooting depths. However, an ideal irrigation is assumed to supply enough water to wet the soil matrix uniformly to field capacity throughout the root zone (Wynne, 1979). Given depth d of water required to bring a required depth of soil to field capacity, and given an estimate I of the water infiltration rate, the estimate t of the time the water should be applied is obtained using the following formula: $t = d/I$ (Doorenbos and Pruitt, 1977). The degree to which such an application is attained is defined in terms of water application efficiency (Ea.) and is calculated as EA = 100 Ws/WF where Ea = water application efficiency; Ws = quantity of water stored in the rooting zone of the soil; Wf = quantity of water delivered to the area irrigated.

Over the years, it has been common to use one or more of the following criteria for deciding when to irrigate: plant appearance (occurrence of drought symptoms), critical stage of plant development, soil moisture data determined either tensiometrically, gravimetrically, radiometrically (with neutron probe tubes), soil characteristics (cohesiveness and plasticity in relation to texture), and soil depth (Wynne, 1979). However, the author cautions that there are problems associated with the use of these criteria: 1) drought symptoms vary with different crops; they may also change with stage of growth or in some cases resemble mineral deficiency symptoms, 2) irrigation during critical stages of crop development will benefit most crops only if water stress during other periods does not reach critical wilting levels, 3) since soil is heterogeneous, sampling to give reliable results is always a problem unless composite samples are taken, and 4) workers using instruments based on a measurement of some property of the soil which changes with a change in soil moisture have reported various degrees of satisfaction and helpfulness in their decision making process about timing of irrigation. Perhaps the simplest method is to observe both crop and soil closely for signs of moisture stress.

CHAPTER III

MATERIALS AND METHODS

A field study was conducted on supplemental furrow irrigation of soybeans at the Southcentral Research Station, Chickasha, Oklahoma, from March, 1980 to October, 1981, on a McLain silty clay loam (Fine, Mixed, Thermic, Pachic, Parhic Argiustolls) with 0-1% slope.

The experimental area had previously been put to grade (0.5%) and cropped with soybeans without fertilizer additions for three years prior to the initiation of this research project. Soil samples were taken from over the area at 15 and 30-cm depths for chemical analyses. Soil test results showed the levels of phosphorous (P), potassium (K), calcium (Ca), and magnesium (Mg), as determined by the Oklahoma State University soil testing laboratory procedures and recommendations to be 239, 663, 5590, and 1119 kg/ha, respectively. A lister bedder was used to form 102 cm beds in early March of each year so late winter and early spring moisture could accumulate in the beds. Just prior to planting, trifluralin (a, a, a-trifluoro-2, 6-dinitro-N, N-dipropyl-p-toluidine) was applied broadcast at a rate of 1.12 kg/ha in 234 liters/ha water and incorporated into the soil using a rolling cultivator set at the appropriate angle so that the form and integrity of the beds were maintained.

The experiment consisted of a 2^3 factorial arrangement of treatments with the three factors and their respective levels being variety

(Essex and Sohoma), planting pattern (one row/bed and 2-15 cm rows/bed), and irrigation method (every furrow and alternate furrow) in a randomized complete-block design with four replications. Each experimental unit consisted of 4-102 cm beds on a area of 4.08 x 100 m. A John Deere 71-flex-planter was used to plant 'Essex' (Maturity Group V) and 'Sohoma' (Maturity group VI) soybeans on June 5, 1980, and May 26, 1981, for a 300,000 plants per hectare population in single and 2-15 cm rows on each bed. Seeds of both varieties were inoculated with Rhizobium japonicum prior to planting. All experimental units received one mechanical cultivation using a rolling cultivator when the soybeans were in the second node (V2) stage of growth. Supplemental water, in amounts equivalent to 5 cm per hectare, was applied using gated pipe, on July 9, 16, 23, 30; August 7, 14, 18, 21, 28; September 4, 18, 1980, and July 8, 16, 23; August 18, 28; and September 4, and 15, 1981. With this arrangement, the alternate furrow irrigation treatments received 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 row of the single row, and between the rows of the 2-15 cm row per bed plots so each tensiometer would be at the same distance from the water in the irrigation furrow to determine irrigation scheduling.

At maturity, 20 plants were randomly selected from rows on the two center beds of each experimental unit for agronomic characteristic evaluations. Yields were obtained by harvesting 2.04 x 3.06 m strips from the two middle rows of each plot on October 24 and November 1, 1980, for the Essex and Sohoma varieties, respectively. A 3.06 x 91.4 m strip was harvested from the two middle rows of each plot on October 23 and 31, 1981, for the Essex and Sohoma varieties, respectively. Plant height, nodes, number of branches, mature pods on branches and main stems, immature pods on branches and main stems, seeds on branches and main stems, yield on branches and main stems, and yield below 10 cm as an estimate of harvesting loss values were ascertained so these agronomic characteristics could be compared for all experimental treatments.

CHAPTER IV

RESULTS AND DISCUSSION

Rainfall Distribution, Amounts, and Temperatures for 1980-81 Season

Monthly rainfall distributions, total rainfall amounts, and mean temperatures from January 1, 1980, to December 31, 1981, and the 20 year monthly averages (1960-79) are given in Table 5.

TABLE 5

RAINFALL AND TEMPERATURES FROM JANUARY 1, 1980, TO DECEMBER 31, 1981, AND THE 20 YEAR MONTHLY AVERAGES (1960-79) AT THE SOUTHCENTRAL RESEARCH STATION AT CHICKASHA, OKLAHOMA

	Rainfall, cm			Temperature, C		
Month	1980	1981	20 Year Avg.	1980	1981	20 Year Avg.
January	4.9	0.1	2.2	4.1	4.7	2.6
February	3.2	4.0	3.3	5.2	7.4	5.8
March	4.6	7.9	5.2	10.4	10.6	11.0
April	4.5	6.2	7.0	15.7	18.6	17.3
May	21.2	10.9	11.0	20.8	19.9	21.3
June	5.7	15.4	7.7	28.2	26.6	25.8
July	0.0	7.9	6.8	31.4	29.1	28.2
August	1.5	9.8	7.2	29.8	26.2	26.8
September	6.9	3.5	9.5	25.6	23.6	23.0
October	3.5	19.3	6.1	16.4	15.8	17.6
November	2.4	8.2	4.4	10.0	10.6	10.3
December	4.2	0.2	2.6	7.2	10.6	5.1
Totals	62.5	93.4	73.0			

During the 1980 growing season, cumulative monthly precipitation from January 1 to May 1 was 0.4 cm below the 20 year average; however, during May ample rainfall (21.2 cm) resulted in a high moisture buildup in the beds. With timely incorporation of herbicide and planting, stand establishment and weed control for the entire growing season were excellent. Precipitation amounts in July, August, and September were far below the 20 year average (see Table 5 and Figure 1). These low rainfall amounts, coupled with considerably higher temperatures than the 20 year average (Figure 2) during the same three month period, resulted in high atmospheric demands and water stress potentials that required additions of 55 cm (11-5 cm applications) of supplemental water.

More total precipitation fell in 1981 when compared to both 1980 and the 20 year average. Except for the month of January, rainfall conditions were particularly good through the month of April. Total precipitation between February 1 and April 31 amounted to 18.1 cm, compared to 12.3 cm and 15.5 cm for 1980 and the 20 year average, respectively (Table 5). During the months of May and June, 26.3 cm of rain fell, resulting in a buildup of moisture in the soil profile. As in 1980, timely incorporation of herbicide and planting, stand establishment and weed control for the entire growing season were excellent. From June 1 through August, precipitation was far above that of 1980, and slightly above the long term average for the same period. However, the relatively higher temperatures and evaporative demand encountered through this period necessitated supplemental irrigation in the amount of 25 cm (five-5 cm applications). During the month of September, precipitation fell below both that of 1980 and the long

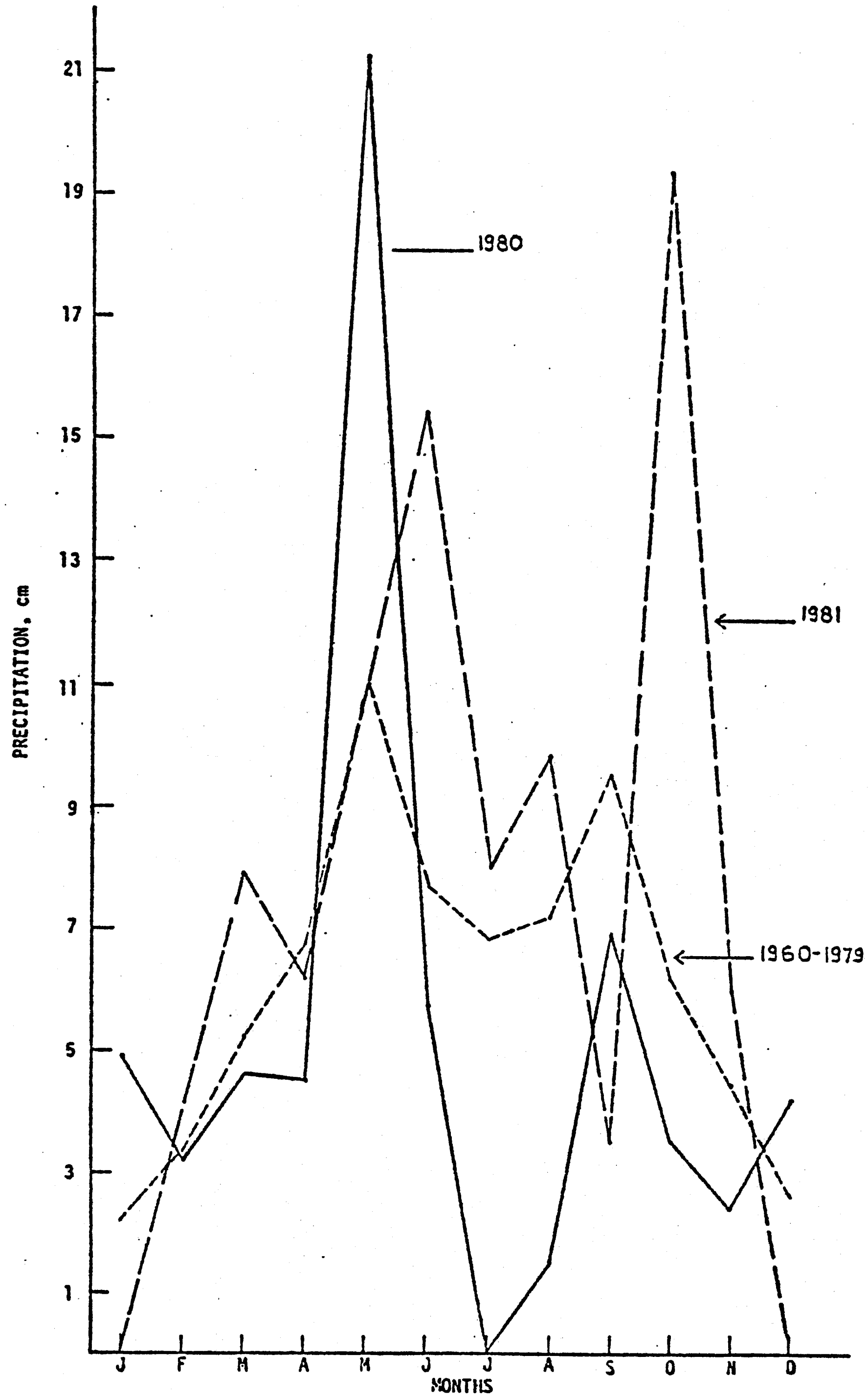

Figure 1. Precipitation Patterns of 1980, 1981, and 20 Year Average (1960-79) at Chickasha

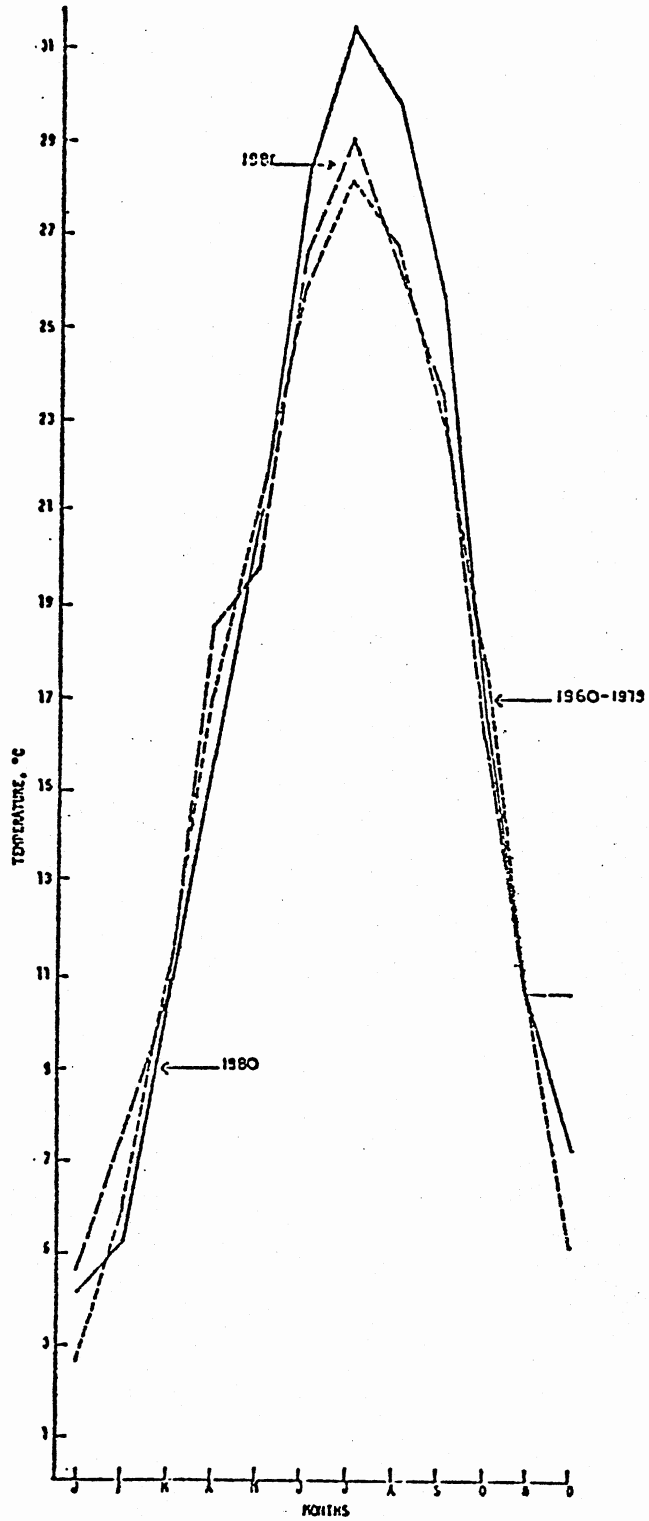

Figure 2. Temperature Patterns of 1980, 1981, and 20 Year Average (1960-79) at Chickasha

term average, which also necessitated 10 cm (two-5 cm) more supplemental water applications for a total of 35 cm (seven-5 cm applications) for the total growing season.

General Plan of Presentation and Discussion of the Results

Table 6 shows the nomenclature that defines the abbreviated terms used in the data tables. The mean values and estimated simple effects of the factors studied (irrigation, variety, and row spacing) on the agronomic characteristics are presented in Tables 7 to 19 for the year 1980, and in Tables 10 to 32 for the year 1981. Estimated simple effects are calculated ignoring the sign. Adoption of such a format for tables was felt necessary in order to convey the maximum possible information to the reader in a succinct, clear, and concise manner.

When reading under irrigation levels, variety levels, and number of row levels (Tables 7-32), figures under loof (level of other factors) pertain to levels of variety and number of rows, levels of irrigation, and number of rows, and to levels of irrigation and variety, respectively. For example: 38.8 and 42.8 represent the average height in centimeters of plants of the Essex variety, when planted one row per bed and irrigated in alternate and every furrow, respectively. Plants of the Sohoma and Essex variety averaged 55.4 and 42.8 cm, when planted one row per bed and irrigated in every furrow, respectively. On the other hand, 39.7 and 42.8 represent the average height of plants of the Essex variety when irrigated in every furrow and planted two and one row per bed, respectively.

TABLE 6

NOMENCLATURE

BR-PLT	No. of branches per plant
Coeff of variation	Coefficient of variation
Grand mean	Mean value of all observations
IMPDS-BR	No. of immature pods on branches
IMPDS-MS	No. of immature pods on main stems
Irrigation level 0	Every furrow irrigation
Irrigation level 1	Alternate furrow irrigation
Loof	Level of other factors
LSD	Least significant difference
M	Meter
MW-SDS-BR	Mean weight of seeds on branches in g
MW-SDS-MS	Mean weight of seeds on main stems in g
NDS-PLT	No. of nodes per plant
No. row level 0	One row per bed planting
No. row level 1	Two rows per bed planting
PCT-SB10	Percent seeds below 10 cm (harvest loss) in kg/ha
PDS-BR	No. of pods on branches
PDS-MS	No. of pods on main stems
PLT-HGHT	Plant height in cm
SDS-BR	No. of seeds on branches
SDS-MS	No. of seeds on main stems
TY-KPH	Total yield per treatment in kg/ha
Variety level 0	Essex variety
Variety level 1	Sohoma variety
WT-LS	Weight of loose seeds in kg/ha
YLD-BR	Seed yield on branches in g
YLD-MS	Seed yield on main stems in g

TABLE 7

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON PLANT HEIGHT (cm) IN 1980

Loof	Irrigation Levels 1	Irrigation Levels 0	Irrigation difference	Variety Levels 1	Variety Levels 0	Variety difference	No. Row Levels 1	No. Row Levels 0	No. Row difference
00	38.8	42.8	4.0*	55.4	42.8	12.6*	39.7	42.8	3.1*
01	38.4	39.7	1.5	48.1	39.7	8.4*	48.1	55.4	7.3*
10	47.2	55.4	8.2*	47.2	38.8	8.6*	38.4	38.8	0.4
11	44.3	48.1	3.8*	44.3	38.4	5.9*	44.3	47.2	2.9*

Note: LSD (0.05), 80=2.92; LSD (0.05), 160=2.06; LSD (0.05), 320=1.46.

*Mean difference statistically significant at the 5% level of probability.

TABLE 8

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON NUMBER OF BRANCHES PER PLANT IN 1980

Loof	Irrigation Levels 1	Irrigation Levels 0	Irrigation difference	Variety Levels 1	Variety Levels 0	Variety difference	No. Row Levels 1	No. Row Levels 0	No. Row difference
00	3.8	4.0	0.2	8.7	4.0	4.7*	5.1	4.0	1.1
01	4.3	5.1	0.8	8.3	5.1	3.2*	8.3	8.7	0.4
10	5.5	8.7	3.2*	5.5	3.8	1.7*	4.3	3.8	0.5
11	6.9	8.3	1.4	6.9	4.3	2.6*	6.9	5.5	1.4

Note: LSD (0.05), 80=1.7; LSD (0.05), 160=1.2; LSD (0.05), 320=0.85.

*Mean difference statistically significant at the 5% level of probability.

TABLE 9

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON NUMBER OF NODES PER PLANT IN 1980

Loof	Irrigation Levels 1	0	Variety Levels 1	0	No. Row Levels 1	0
00	14.1	15.0	14.7	15.0	14.3	15.0
	0.9*		0.3		0.7*	
01	14.7	14.3	14.8	14.3	14.8	14.7
	0.4		0.5		0.1	
10	14.5	14.7	14.5	14.1	14.7	14.1
	0.2		0.4		0.6	
11	14.6	14.8	14.6	14.7	14.6	14.5
	0.2		0.1		0.1	

Note: LSD (0.05), 80=0.7; LSD (0.05), 160=0.49; LSD (0.05), 320=0.35.

*Mean difference statistically significant at the 5% level of probability.

TABLE 10

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON NUMBER OF PODS ON BRANCHES IN 1980

Loof	Irrigation Levels 1	0	Variety Levels 1	0	No. Row Levels 1	0
00	18.8	22.8	44.7	22.8	33.5	22.8
	4.0		21.9*		10.7*	
01	27.3	33.7	40.3	33.5	40.3	44.7
	6.4		6.8		4.4	
10	20.6	44.7	20.6	18.8	27.3	18.8
	24.1*		1.8		8.5	
11	32.9	40.3	32.9	27.3	32.9	20.6
	7.4		5.6		12.3*	

Note: LSD (0.05), 80=10.4; LSD (0.05), 160=7.4; LSD (0.05), 320=5.2.

*Mean difference statistically significant at the 5% level of probability.

TABLE 11

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON NUMBER OF PODS ON MAIN STEMS IN 1980

Loof	Irrigation Levels 1	Irrigation Levels 0	Irrigation effect	Variety Levels 1	Variety Levels 0	Variety effect	No. Row Levels 1	No. Row Levels 0	No. Row effect
00	16.8	19.8	3.0	17.6	19.8	2.2	24.0	19.8	4.2*
01	20.0	24.0	4.0	16.9	24.0	7.1*	16.9	17.6	1.7
10	14.5	17.6	3.1	14.5	16.8	2.3	20.0	18.8	3.2
11	13.8	16.9	3.1	13.8	20.0	6.2*	13.8	14.5	0.7

Note: LSD (0.05), 80=4.1; LSD (0.05), 160=2.9; LSD (0.05), 320=2.05.

*Mean difference statistically significant at the 5% level of probability.

TABLE 12

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON NUMBER OF IMMATURE PODS ON BRANCHES IN 1980

Loof	Irrigation Levels 1	Irrigation Levels 0	Irrigation effect	Variety Levels 1	Variety Levels 0	Variety effect	No. Row Levels 1	No. Row Levels 0	No. Row effect
00	0.53	0.84	0.31	3.0	0.84	2.16*	1.0	0.84	0.16
01	0.93	1.0	0.7	3.3	1.0	2.3*	3.3	3.0	0.3
10	1.0	3.0	2.0*	1.0	0.53	0.47	0.93	0.53	0.4
11	1.8	3.3	1.5*	1.8	0.93	0.87	1.8	1.0	0.8

Note: LSD (0.05), 80=0.9; LSD (0.05), 160=0.64; LSD (0.05), 320=0.45.

*Mean difference statistically significant at the 5% level of probability.

TABLE 13

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON NUMBER OF IMMATURE PODS ON MAIN STEMS IN 1980

Loof	Irrigation Levels			Variety Levels			No. Row Levels		
	1	0		1	0		1	0	
00	0.5	0.6		1.1	0.6		0.8	0.6	
			0.1			0.5*			0.2
01	0.9	0.8		1.2	0.8		1.2	1.1	
			0.1			0.4*			0.1
10	0.5	1.1		0.5	0.5		0.9	0.5	
			0.6*			0.0			0.4*
11	0.6	1.2		0.6	0.9		0.6	0.5	
			0.6*			0.3			0.1

Note: LSD (0.05), 80=0.4; LSD (0.05), 160=0.3; LSD (0.05), 320=0.2.

*Mean difference statistically significant at the 5% level of probability.

TABLE 14

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON NUMBER OF SEEDS ON BRANCHES IN 1980

Loof	Irrigation Levels			Variety Levels			No. Row Levels		
	1	0		1	0		1	0	
00	38.9	46.6		93.5	46.6		68.8	46.6	
			7.7			46.9*			22.2*
01	56.4	68.8		84.2	68.8		84.2	93.5	
			12.4			15.4			9.3
10	44.7	93.5		44.7	38.9		56.4	38.9	
			48.8*			5.8			17.5
11	70.7	84.2		70.7	56.4		70.7	44.7	
			13.5			14.3			26.0*

Note: LSD (0.05), 80=21.9; LSD (0.05), 160=15.5; LSD (0.05), 320=11.45.

*Mean difference statistically significant at the 5% level of probability.

TABLE 15

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF
IRRIGATION, VARIETY, AND ROW SPACING
ON NUMBER OF SEEDS ON MAIN STEMS
IN 1980

Loof	Irrigation Levels 1	Irrigation Levels 0	Variety Levels 1	Variety Levels 0	No. Row Levels 1	No. Row Levels 0
00	43.1	40.2	36.4	40.2	49.6	40.2
	2.9		3.8		9.4*	
01	41.6	49.6	35.7	49.6	35.7	36.4
	8.0		13.9*		0.7	
10	30.6	36.4	30.6	43.1	41.6	43.1
	5.8		12.5*		1.7	
11	29.8	35.7	29.8	41.6	29.8	30.6
	5.9		11.8*		0.8	

Note: LSD (0.05), 80=8.3; LSD (0.05), 160=5.9: LSD (0.05), 320=4.15.

*Mean difference statistically significant at the 5% level of probability.

TABLE 16

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF
IRRIGATION, VARIETY, AND ROW SPACING
ON YIELD (g) ON BRANCHES
IN 1980

Loof	Irrigation Levels 1	Irrigation Levels 0	Variety Levels 1	Variety Levels 0	No. Row Levels 1	No. Row Levels 0
00	5.3	6.6	16.7	6.6	9.9	6.6
	1.3		10.1*		3.3	
01	7.5	9.9	15.3	9.9	15.3	16.7
	2.4		5.4*		1.4	
10	8.0	16.7	8.0	5.3	7.5	5.3
	8.7*		2.7		2.2	
11	12.6	15.3	12.6	7.5	12.6	8.0
	2.7		5.1*		4.6*	

Note: LSD (0.05), 80=3.8; LSD (0.05), 160=2.7; LSD (0.05), 320=1.9.

*Mean difference statistically significant at the 5% level of probability.

TABLE 17

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON YIELD (g) ON MAIN STEMS IN 1980

Loof	Irrigation Levels 1	Irrigation Levels 0	Difference	Variety Levels 1	Variety Levels 0	Difference	No. Row Levels 1	No. Row Levels 0	Difference
00	4.9	6.0	1.1	6.6	6.0	0.6	7.3	6.0	1.3
01	5.8	7.3	1.5*	6.5	7.3	0.8	6.5	6.6	0.1
10	5.9	6.6	0.7	5.9	4.9	1.0	5.8	4.9	0.9
11	5.4	6.5	1.1	5.4	5.8	0.4	5.4	5.9	0.5

Note: LSD (0.05), 80=1.5; LSD (0.05), 160=1.0; LSD (0.05), 320=0.75.

*Mean difference statistically significant at the 5% level of probability.

TABLE 18

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON HARVEST LOSS (kg/ha) PER TREATMENT IN 1980

Loof	Irrigation Levels 1	Irrigation Levels 0	Difference	Variety Levels 1	Variety Levels 0	Difference	No. Row Levels 1	No. Row Levels 0	Difference
00	12.2	13.0	0.8	16.2	13.0	3.2	11.0	13.0	2.0
01	13.0	11.0	2.0	17.0	11.0	6.0	17.0	16.2	0.8
10	21.3	16.2	5.1	21.3	12.2	9.1	13.0	12.2	0.8
11	23.1	17.0	6.1	23.1	13.0	10.1	23.1	21.3	1.8

Note: LSD (0.05), 80=11.3; LSD (0.05), 160=8.0; LSD (0.05), 320=5.65.

*Mean difference statistically significant at the 5% level of probability.

TABLE 19

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON YIELD PER TREATMENT (kg/ha) IN 1980

Loof	Irrigation Levels 1	Irrigation Levels 0	Variety Levels 1	Variety Levels 0	No. Row Levels 1	No. Row Levels 0
00	2315	2432	3066	2432	3091	2432
	117		634*		659*	
01	1978	3091	2982	3091	2982	3066
	1113*		109		84	
10	1936	3066	1936	2315	1978	2315
	1130*		379		337	
11	2448	2982	2448	1978	2448	1936
	534		470		512	

Note: LSD (0.05), 80=538; LSD (0.05), 160=380; LSD (0.05), 320=269.

*Mean difference statistically significant at the 5% level of probability.

TABLE 20

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON PLANT HEIGHT (cm) IN 1981

Loof	Irrigation Levels 1	Irrigation Levels 0	Variety Levels 1	Variety Levels 0	No. Row Levels 1	No. Row Levels 0
00	59.4	63.0	69.0	63.0	60.5	63.0
	3.5		6.0*		2.5	
01	57.0	60.5	65.1	60.5	65.1	69.0
	3.5		4.6*		3.9*	
10	71.8	69.0	71.8	59.5	56.9	59.5
	2.8		12.3*		2.4	
11	68.0	65.1	68.0	56.9	68.0	71.8
	2.9		11.1*		3.8*	

Note: LSD (0.05), 80=3.7; LSD (0.05), 160=2.6; LSD (0.05), 320=1.85.

*Mean difference statistically significant at the 5% level of probability.

TABLE 21

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON NUMBER OF BRANCHES PER PLANT IN 1981

	Irrigation Levels			Variety Levels			No. Row	Levels	
Loof	1		0	1		0	1		0
00	9.1		10.1	11.5		10.1	9.3		10.1
		1.0			1.4*			0.8	
01	8.2		9.3	11.0		9.3	11.0		11.5
		1.1			1.7*			0.5	
10	10.4		11.5	10.4		9.1	8.2		9.1
		1.1			1.3			0.9	
11	9.6		11.0	9.6		8.2	9.6		10.4
		1.4*			1.4*			0.8	

Note: LSD (0.05), 80=1.4; LSD (0.05), 160=1.0; LSD (0.05), 320=0.70.

*Mean difference statistically significant at the 5% level of probability.

TABLE 22

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON NUMBER OF NODES PER PLANT IN 1981

	Irrigation Levels			Variety Levels			No. Row	Levels	
Loof	1		0	1		0	1		0
00	15.1		15.2	14.5		15.2	15.2		15.2
		0.1			0.7*			0.0	
01	15.2		15.2	14.2		15.2	14.2		14.5
		0.0			1.0*			0.3	
10	15.1		14.5	15.1		15.1	15.1		15.2
		0.6*			0.0			0.1	
11	14.7		14.2	14.7		15.2	14.7		15.1
		0.5*			0.5*			0.4	

Note: LSD (0.05), 80=0.5; LSD (0.05), 160=0.4; LSD (0.05), 320=0.25.

*Mean difference statistically significant at the 5% level of probability.

TABLE 23

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON NUMBER OF PODS ON BRANCHES IN 1981

Loof	Irrigation Levels		Variety Levels		No. Row Levels	
	1	0	1	0	1	0
00	28.6	39.0	59.3	39.0	34.3	39.0
	10.4*		20.3*		4.7	
01	25.4	34.3	48.7	34.3	48.7	59.3
	8.9*		14.4*		10.6*	
10	42.0	59.3	42.0	28.6	25.4	28.6
	17.3*		13.4*		3.2	
11	36.4	48.7	36.4	25.4	36.4	42.0
	11.7*		11.0*		5.6	

Note: LSD (0.05), 80=1.4; LSD (0.05), 160=0.98; LSD (0.05), 320=0.70.

*Mean difference statistically significant at the 5% level of probability.

TABLE 24

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON NUMBER OF PODS ON MAIN STEMS IN 1981

Loof	Irrigation Levels		Variety Levels		No. Row Levels	
	1	0	1	0	1	0
00	19.9	19.8	12.7	19.8	21.6	19.8
	0.1		7.1*		1.8	
01	18.7	21.6	11.5	21.6	11.5	12.7
	2.9*		10.1*		1.2	
10	16.0	12.7	16.0	19.9	18.7	19.7
	3.3*		3.3*		1.0	
11	14.0	11.5	14.4	18.7	14.4	16.0
	2.9*		4.3*		1.6	

Note: LSD (0.05), 80=2.3; LSD (0.05), 160=1.6: LSD (0.05), 320=1.15.

*Mean difference statistically significant at the 5% level of probability.

TABLE 25

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON NUMBER OF IMMATURE PODS ON BRANCHES IN 1981

Loof	Irrigation Levels			Variety Levels			No. Row Levels		
	1		0	1		0	1		0
00	1.1		1.3	2.5		1.3	1.0		1.3
		0.2			1.2*			0.3	
01	1.3		1.0	2.1		1.0	2.1		2.5
		0.3			1.1*			0.4	
10	1.9		2.5	1.8		1.1	1.3		1.1
		0.6*			1.7*			0.2	
11	1.5		2.1	1.5		1.3	1.5		1.9
		0.6*			1.2*			0.4	

Note: LSD (0.05), 80=0.6; LSD (0.05), 160=0.4: LSD (0.05), 320=0.3.

*Mean difference statistically significant at the 5% level of probability.

TABLE 26

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON NUMBER OF IMMATURE PODS ON MAIN STEMS IN 1981

Loof	Irrigation Levels			Variety Levels			No. Row Levels		
	1		0	1		0	1		0
00	0.6		0.3	0.6		0.3	0.5		0.3
		0.3			0.3			0.2	
01	0.5		0.5	0.5		0.5	0.5		0.6
		0.0			0.0			0.1	
10	0.5		0.6	0.6		0.6	0.5		0.6
		0.1			0.0			0.1	
11	0.5		0.5	0.6		0.5	0.6		0.6
		0.0			0.1			0.0	

Note: LSD (0.05), 80=0.4; LSD (0.05), 160=0.3; LSD (0.05), 320=0.2.

*Mean difference statistically significant at the 5% level of probability.

TABLE 27

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON NUMBER OF SEEDS ON BRANCHES IN 1981

Loof	Irrigation Levels 1	Irrigation Levels 0	Variety Levels 1	Variety Levels 0	No. Row Levels 1	No. Row Levels 0
00	59.2	80.4	120.4	80.4	70.1	80.4
	21.2*		40.0*		10.3	
01	53.1	70.1	101.9	70.1	101.9	120.4
	17.0		30.8*		18.5*	
10	84.6	120.4	84.6	59.2	53.1	59.2
	35.8*		25.4*		6.1	
11	78.4	101.9	78.4	53.1	78.4	84.6
	23.5*		25.5*		6.2	

Note: LSD (0.05), 80=17.4; LSD (0.05), 160=12.3; LSD (0.05), 320=8.7.

*Mean difference statistically significant at the 5% level of probability.

TABLE 28

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON NUMBER OF SEEDS ON MAIN STEMS IN 1981

Loof	Irrigation Levels 1	Irrigation Levels 0	Variety Levels 1	Variety Levels 0	No. Row Levels 1	No. Row Levels 0
00	40.6	40.2	26.4	40.2	44.4	40.2
	0.4		13.8*		4.2	
01	39.6	44.4	22.8	44.4	22.8	26.4
	4.8		21.6*		3.6	
10	31.9	26.4	31.9	40.6	39.6	40.6
	5.5*		8.7*		1.0	
11	29.8	22.8	29.8	39.6	29.8	31.9
	7.0*		9.8*		2.1	

Note: LSD (0.05), 80=5.3; LSD (0.05), 160=3.75; LSD (0.05), 320=2.65.

*Mean difference statistically significant at the 5% level of probability.

TABLE 29

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON YIELD (g) ON BRANCHES IN 1981

Loof	Irrigation Levels 1	0		Variety Levels 1	0		No. Row Levels 1	0	
00	8.2	11.3	3.1*	19.4	11.3	8.1*	9.9	11.3	1.4
01	7.5	9.9	2.4	17.5	9.9	7.6*	17.5	19.4	1.9
10	13.6	19.4	5.8*	13.6	8.2	5.4*	7.5	8.2	0.7
11	13.1	17.5	4.4*	13.1	7.5	5.6*	13.1	13.6	0.5

Note: LSD (0.05), 80=2.9; LSD (0.05), 160=2.05: LSD (0.05), 320=1.45.

*Mean difference statistically significant at the 5% level of probability.

TABLE 30

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON YIELD (g) ON MAIN STEMS IN 1981

Loof	Irrigation Levels 1	0		Variety Levels 1	0		No. Row Levels 1	0	
00	6.2	6.2	0.0	4.4	6.2	1.8*	7.0	6.2	0.8
01	6.1	7.0	0.9*	3.9	7.0	3.1*	3.9	4.3	0.5
10	5.4	4.3	1.1*	5.4	6.2	0.8	6.1	6.2	0.1
11	5.0	3.9	1.1*	5.0	6.1	1.1*	5.0	5.4	0.4

Note: LSD (0.05), 80=0.9; LSD (0.05), 160= 0.64; LSD (0.05), 320=0.45.

*Mean difference statistically significant at the 5% level or probability.

TABLE 31

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON HARVEST LOSS (kg/ha) PER TREATMENT IN 1981

	Irrigation Levels			Variety Levels			No. Row Levels		
Loof	1		0	1		0	0		0
00	4.9		6.2	16.5		6.2	11.5		6.2
		1.3			0.3			5.3	
01	3.8		11.5	12.6		11.5	12.6		16.5
		7.5			1.1			3.9	
10	17.3		16.5	17.3		4.9	3.8		4.9
		0.8			12.4*			0.9	
11	11.2		12.6	11.2		3.8	11.2		17.3
		0.4			7.5			5.1	

Note: LSD (0.05), 80=9.5; LSD (0.05), 160=6.7; LSD (0.05), 320=4.75.

*Mean difference statistically significant at the 5% level of probability.

TABLE 32

MEAN VALUES AND ESTIMATED SIMPLE EFFECTS OF IRRIGATION, VARIETY, AND ROW SPACING ON YIELD PER TREATMENT (kg/ha) IN 1981

	Irrigation Levels			Variety Levels			No. Row Levels		
Loof	1		0	1		0	1		0
00	2465		2531	2818		2531	2701		2531
		66			287			170	
01	2527		2701	2875		2701	2875		2818
		174			174			57	
10	2599		2818	2599		2465	2527		2465
		317			134			62	
11	2605		2875	2605		2727	2605		2599
		270			78			6	

Note: LSD (0.05), 80=328; LSD (0.05), 160=232; LSD (0.05), 320=164.

*Mean difference statistically significant at the 5% level of probability.

In a factorial experiment involving more than two factors, the simple effects of a given factor on a given variable represent estimates of the changes in magnitude of that variable relative to changes in the level of the respective factor, when the other factors are held constant. The simple effects of irrigation on plant height in 1980 (see Table 7), when both variety and number of rows per bed are held at their low and high level, were 38.8 and 42.8 cm; 44.3 and 48.1 cm, respectively, for alternate and every furrow irrigation. The main effect of a factor or simply the effect of a given factor on a given variable is defined as the average of the simple effects of that particular factor on that variable. Main effects of irrigation, variety, and row spacing on any variable studied are obtained by averaging the simple effects obtained over the levels of the other factors. Each table also provides the opportunity to look at any two- or three-way interaction relationships. For all studied variables, the simple effects were calculated by taking the difference of two means, each based on 80 observations. Two-way interactions (i.e., irrigation x variety) of factors on any of the variables were calculated by taking the difference of two means, each based on 160 observations. Main effects of factors, on the other hand, are calculated by taking the difference of two means, each based on 320 observations.

Presentation and discussion of the results are done in chronological order from earlier (1980) to later studies (1981). For each study year, results on the agronomic characteristics and yields are presented and discussed in a sequence based on the existence of the following three- and/or two-way significant interactions: irrigation x variety x number of rows per bed, irrigation x number of rows per bed, variety x number of rows per bed, irrigation x variety. Where none of the above groups of factor interactions exist, results and discussion were essentially concentrated on main effects. At each level of factor interaction, general information on the responses of the varieties were first given, to ensure the possibility of a quick comparison, then the specific performance of each variety, starting with Essex, was documented, hoping to better illustrate eventual contrasts. Results and discussion of data pertaining to soybean yields are presented in the closing section of each study year.

Agronomic Characteristics (Study Year 1980)

Table 33 summarizes the interactions of factors that were found significant at the 5% level of probability after computation of the analysis of variance for each of the agronomic characteristics studied in 1980 and 1981. In 1980, a significant irrigation x variety x number x row per bed interaction resulted for the following: pods on branches, seeds on branches, and total yield in kilograms per hectare (kg/ha) per treatment. For yield on branches, the three-way interaction was significant at the 6% level of probability. For plant height, all two-way interactions, irrigation x variety, irrigation x number of rows per bed, variety x number of rows per bed were significant. However, the three-way interaction for this variable was not significant at the 5% level of probability. It was indicated statistically to present and discuss the results pertaining to all above agronomic characteristics in the same section.

TABLE 33

SUMMARY OF THE INTERACTIONS OF FACTORS ON THE VARIABLES STUDIED THAT WERE FOUND SIGNIFICANT AT THE 5% LEVEL OF PROBABILITY DURING THE 1980 AND 1981 STUDIES

	Years	
Interaction of Factors	1980 Variable Studied	1981 Variable Studied
Irrigation x variety	BR-PLT IMPDS-BR IMPDS-MS	PLT-HGHT NDS-PLT PDS-MS SDS-MS YLD-MS IMPDS-BR
Irrigation x number of rows per bed	--	--
Variety x number of rows per bed	PDS-MS SDS-MS YLD-MS	YLDS-MS -- --
Irrigation x variety x number of rows per bed	PLT-HGHT PDS-BR SDS-BR YLD-BR TY-KPH	-- -- -- --

Plant Height, Number of Pods on Branches, Seeds on Branches, and Seed Yield on Branches

Plant height in all treatments applied to Essex and Sohoma averaged 39.9 and 48.8 cm, respectively (see Table 7). At all combinations of row number and irrigation types, plants of the Sohoma variety were taller (see Table 7), had more pods (see Table 10), seeds (see Table 14), and seed yield on the branches (see Table 16) than did the plants of the Essex variety. Irrespective of variety and number of rows per bed, reduced moisture conditions (alternate furrow irrigation) negatively affected plant growth, number of pods, and seed production on the branches. For the Sohoma and Essex varieties, the estimated decreases in plant height, number of pods, seeds, and seed yield on the branches associated with alternate furrow irrigation were: 7.3, 4.4, 9.3, 1.4, and 3.1, 4.0, 7.1, 1.3, respectively, when both varieties were planted one row per bed. With two rows per bed planting and alternate furrow irrigation, the above characteristics were decreased by 3.8, 7.4, 13.5, 3.3, and 1.3, 6.2, 12.4, 2.4, respectively, for the Sohoma and Essex varieties. Table 34 summarized the irrigation by variety by number of rows per bed interaction on the above mentioned agronomic characteristics.

Plants of the Essex variety averaged 40.8 and 39.0 cm when planted one row and two rows per bed, respectively. With one and two rows per bed planting (see Table 7), taller plants 42.5 and 39.7, respectively, resulted when supplemental water was applied to Essex. The treatment combination of two rows per bed and every furrow irrigation resulted in tallest plants (39.7 cm) of all treatments applied to the variety. In contrast, plants were shortest (38.4 cm) under the combination of two rows per bed and alternate furrow irrigation. Differences in plant height due to irrigation were only significant with the one row per bed planting. This indicates that when planted two rows per bed, all Essex plants may have the same average height indifferent of the way the supplemental water is applied to the beds.

TABLE 34

SUMMARY OF THE IRRIGATION BY VARIETY BY NUMBER OF ROWS PER BED INTERACTION ON PLANT HEIGHT, NUMBER OF PODS ON BRANCHES, SEEDS ON BRANCHES, AND SEED YIELD ON BRANCHES (STUDY YEAR 1980)

		Variety Levels					
		No. Row Levels			No. Row Levels		
Variable	Irrigation Levels	0	1	Δ	0	1	Δ
PDS-BR	0	22.8	35.5	10.7*	44.7	40.3	4.4
	1	18.8	27.3	8.5	20.6	32.9	12.3*
	Δ	4.0	5.8		24.1*	7.4	
SDS-BR	0	46.6	68.8	22.2*	93.5	84.2	9.3
	1	38.8	56.4	17.6	44.7	70.7	26.0*
	Δ	7.8	12.4		48.8*	13.5	
YLD-BR	0	6.6	9.9	3.3	16.7	15.3	1.6
	1	5.3	7.5	2.2	8.0	12.6	4.6*
	Δ	1.3	2.4		8.7*	2.7	
TY-KPH	0	2432	3091	659*	3066	2982	84.0
	1	2315	1987	337	1936	2443	512.0
	Δ	117	1113		1130	534*	
PLT-HGHT	0	42.8	39.7	3.1*	55.4	48.1	7.3
	1	38.8	38.4	0.4	47.2	44.3	2.9
	Δ	4.0*	1.3		8.2*	3.8*	

*Significant at the 5% level of probability.

Δ = Mean difference.

With fixed irrigation levels and varying number of row numbers per bed, only every furrow irrigation induced a significant change in plant height. Alternate furrow irrigation had little effect on plant height, independent of the planting pattern adopted.

Larger numbers of pods on branches (see Table 10), seeds (see Table 14), and seed yield on branches (see Table 16) were obtained when Essex was planted two rows per bed than when planted one row per bed. When the data were averaged over levels of irrigation the differences between the two and one row per bed planting with respect to the above mentioned variables were, respectively: 10.0, 20.0, and 3.0. However, all these differences were less than the least significant difference (LSD 0.05); it is suggested that the degree to which the Essex variety responded to varying number of rows per bed was similar. Plants sampled from beds planted with two rows, 15 cm apart, may have had an earlier canopy soil coverage advantage, thus reducing soil moisture evaporation. Enhanced net assimilation rates may have then caused them to produce more pods, seeds, and seed yield on the branches than their homologues on single row planted beds.

At each row number per bed, varying irrigation method did not induce any significant change in the number of pods, seeds, and seed yield on the branches. This indicates that the response of the Essex variety to irrigation was quite similar for each planting pattern. However, with fixed levels of irrigation and varying row number per bed, significantly lower numbers of pods and seeds on the branches resulted with the alternate furrow irrigation. However, the above differences in number of pods and seeds on the branches did not result in significant yield differences at any of the irrigation levels. This is so because of the compensatory effect of individual seed weights on the seed yield on the branches. It is suggested that where metabolic sinks (developing pods and seeds) were lower in number, more carbohydrate was available for larger seed development.

In contrast to Essex, plants of the Sohoma variety were, on the average, taller (51.3 cm) when planted one row per bed than when planted two rows per bed (see Table 7). They produced a larger number of branches, pods, seeds, and a greater seed yield on the branches when planted one row per bed and given supplemental water in every furrow than under any other combination of treatments. When levels of irrigation were fixed and those of row number allowed to vary, significantly lower numbers of pods, seeds, and seed yield on the branches were associated with the one row per bed planting and alternate furrow irrigation. This result indicates that similar responses of the Sohoma variety to every furrow irrigation could be expected whether planted one row or two rows per bed. Also, varying levels of irrigation did not significantly affect the Sohoma response when planted two rows per bed; at this particular row number per bed, alternate furrow irrigation or less supplemental water could be applied with no significant reductive effect on seed production on the branches.

Pods on Main Stems, Seeds on Main Stems, and Seed Yield on Main Stems

On the average, Essex produced more pods (see Table 11) and seeds on main stems (see Table 15) than Sohoma. However, yield data on the main stems (see Table 17) did not indicate any substantial difference in the average seed yield between the two varieties. For all above characteristics, there was not any significant differential variety response to varying levels of irrigation. Therefore, similar numbers of pods, seeds, and seed yield on the main stems are produced by plants of both varieties, independent of the kind of irrigation treatment applied. In contrast, a significant variety x number of rows interaction was found for the number of pods, seeds, and seed yield on the main stem (Tables 33 and 35)

TABLE 35

SUMMARY OF THE VARIABLES FOR WHICH ONLY THE VARIETY BY NUMBER OF ROWS PER BED WAS SIGNIFICANT AT THE 5% LEVEL OF PROBABILITY IN 1980

Variable	Variety Levels	No. Row Levels		
		0	1	Δ
PDS-MS	0	18.3	22.0	3.7
	1	16.0	15.3	0.7
	Δ	2.3	6.7*	
SDS-MS	0	37.1	45.6	8.5
	1	33.5	32.8	0.7
	Δ	3.5	12.8*	
YLD-MS	0	5.4	6.6	1.2
	1	6.3	6.0	0.3
	Δ	0.9	0.6	

*Significant at the 5% level of probability.

Δ = Mean difference.

Regardless of row number per bed, Essex performed better than Sohoma (see Table 35), except for seed yield on the main stems for which a superior performance of Sohoma was noted when planted one row per bed.

For all variables and with Essex, the data indicated larger values when planted two rows per bed compared to one row per bed. On the average, plants sampled from two row planted beds had 3.7, 8.4, and 1.1 more pods, seeds, and seed yield, respectively, on the main stems than those sampled from single row planted beds. All differences were significant at the 5% level of probability.

In contrast to Essex, plants of the Sohoma variety had more pods, seeds, and seed yield on the main stems when planted one row per bed (see Table 35). However, for the above three agronomic characteristics, no significant differences due to row number per bed were declared. It can be said then that the pattern of Sohoma response to varying levels of row number per bed is likely the same.

Number of Branches per Plant, Number of Immature Pods on Branches and on Main Stems

On the average, Sohoma produced more branches (see Table 8), immature pods on branches (see Table 12), and on main stems (see Table 13) than Essex. In contrast, larger numbers of pods on main stems were, on the average, recorded on plants belonging to the Essex variety (see Table 11) than on those of Sohoma.

Tables 33 and 36 show that there was a significant irrigation x variety interaction on the number of branches per plant, number of immature pods on branches and on main stems. It can be observed that with each variety and for each characteristic, higher values were associated with every furrow irrigation when compared to alternate furrow irrigation. For all variables and with Essex, no significant differential response to varying levels of irrigation was declared at the 5% lebel of probability. For this reason, it can be said that the Essex variety produces similar numbers of branches per plant, immature pods on branches, and on main stems, irrespective of the irrigation method used.

TABLE 36

SUMMARY OF THE VARIABLES FOR WHICH ONLY THE IRRIGATION BY VARIETY INTERACTION WAS SIGNIFICANT AT THE 5% LEVEL OF PROBABILITY IN 1980

Variable	Irrigation Levels	Variety Levels 0	1	Δ
	0	4.5	8.5*	4.0
BR-PLT	1	4.1	6.2	2.1
	Δ	0.3	2.3*	
	0	0.9	3.2	2.3
IMPDS-BR	1	0.7	1.4	0.7
	Δ	0.2	1.8*	
	0	0.7	1.1	0.4
IMPDS-MS	1	0.7	0.6	0.1
	Δ	0.0	0.5	

*Significant at the 5% level of probability.

Δ = Mean difference.

In contrast to Essex, Sohoma produced significantly higher numbers of pods on branches, immature pods on branches, and on main stems, particularly when planted on beds that were supplied with irrigation water in every furrow.

The variety x irrigation interaction indicates a differential response of individual cultivars to varying soil moisture conditions. An attempt was made to give a possible explanation to this behavior, using the following data and reasoning. Given that Essex produces more pods on main stems than Sohoma and that Sohoma produces more branches, more immature pods on branches and on main stems than Essex, it could be assumed that under good soil moisture conditions (every furrow irrigation), each variety would tend to better express its full genetic potential. In this case, larger number of branches, more immature pods on branches and on main stems would result with Sohoma and more pods on main stems with Essex. Data in Table 36 actually confirm this conjecture. Johnson and Frey (1967) also reported that low or non-stress environments permit greater genetic expression. Furthermore, should reduced moisture conditions (alternate furrow irrigation) equally affect the varieties, then relatively higher differences in number of branches, pods on branches, immature pods on branches, and pods on main stems would result, with Sohoma and Essex, respectively, due to the changes in levels of irrigation. Finally, the lower variability associated with these data, coupled with the larger number of plants sampled, would term these differences to be significant.

In general, reports of a significant irrigation x variety interaction are scarce in the literature, despite the large number of studies on the effect of irrigation on soybean varieties. However, such interaction could provide evidence of adaptation reactions that may be of value to the plant breeder in his selection of an optimum environment for evaluating yield attributes among soybean varieties (Mederski and Jeffers, 1973). Schwab et al. (1958) also found an irrigation x variety interaction in soybean irrigation studies in Iowa.

Number of Nodes per Plant and Harvest Loss per Treatment

Analysis of variance showed neither of these two agronomic characteristics to be significantly affected by any factor, either alone or in combination with one another (see Tables 9 and 18). Differences in number of nodes per plant as influenced by levels of the factors studied were of low magnitude (tenths of a unit). The data suggest that number of nodes per plant might be quite a stable characteristic little influenced by environmental conditions. Kan and Oshima (1952) reported that when light intensity was 50% of normal, reduced soybean node numbers were observed. During the course of this research, it is not believed that light conditions ever fell to such low levels. It remains that the observed increases or decreases in plant height were primarily related to increases or reductions in internode length.

Differences in percent seeds below 10 cm (see Table 18) due to variety, irrigation, and row number per bed were 7, 3, and 0.2%, respectively, when averaged over the remaining factors. Significantly higher values were associated with Sohoma and with alternate furrow irrigation treatment. There was no significant difference in the percent seeds below 10 cm due to varying number of rows per bed.

Results on Soybean Yields (Study Year 1980)

Soybean Yields

The analysis of variance showed that there was a significant irrigation x variety x number of rows per bed interaction on soybean yields. The three factor interaction on the yield data is given in Table 37. The highest yield (3091 kg/ha) obtained with Essex resulted from the two row per bed planting with every furrow irrigation. The superiority of this treatment over the remaining three treatments applied to Essex was previously noted when data relative to pods, seeds, and seed yield on the branches and on the main stems were evaluated. The lowest of all treatment yields within the variety (1978 kg/ha) resulted from the combination of two rows per bed and alternate furrow irrigation. The yield rank of the above treatment can be attributed to its low average weight of individual seeds, particularly from the main stems (Table 39, Appendix).

TABLE 37

IRRIGATION BY VARIETY BY NUMBER OF ROWS PER BED INTERACTION ON SOYBEAN YIELDS

	Variety Levels					
	No. Row Levels			No. Row Levels		
Irrigation Levels	0	1	Δ	0	1	Δ
0	2432	3091	659*	3066	2982	84
1	2315	1978	337	1936	2448	512
Δ	117	1113*		1130*	534*	

*Significant at the 5% level of probability.

Δ = Difference.

With fixed number of rows per bed and varying levels of irrigation, no significant difference in yield was found when Essex was planted one row per bed. This finding suggest that under conditions of limited supply of irrigation water, one could still get fairly good yields by using the treatment combination of one row per bed and alternate furrow irrigation. In contrast, with two rows per bed planting and varying levels of irrigation, the advantage of the every furrow irrigation was evident. Over 1000 kg/ha grain yield could be gained over the alternate furrow irrigation, provided water remains a non-limiting factor.

Of the four treatments applied to the Sohoma variety, the highest yield (3066 kg/ha) was obtained when planted one row per bed with irrigation water applied in every furrow. The lowest yield (1936 kg/ha) resulted from the treatment combination of one row per bed planting and alternate furrow irrigation. It is interesting to note that the yield ranks of both treatments are very much related to their respective production of pods and seeds on the branches and on the main stems (Table 40, Appendix). With fixed number of rows per bed and varying levels of irrigation, significant yield differences due to water treatment were observed at each row number level. The yield gains by applying water in very furrow were 1130 and 534 kg/ha with the one and two rows per bed planting, respectively.

Differences among varieties in their response to soil moisture stress have been attributed to differences in response to protoplasmic dehydration or to differences in structural or physiological characteristics that sustain a relatively high plant water potential (Mederski and Jeffers, 1973). For the 1980 environment, the data indicated that for either of the two planting patterns, every furrow irrigation would be the best irrigation practice to adopt in Sohoma production if a good dependable source of quality water is available. However, in the event water is limited and/or an expensive commodity, two rows per bed planting and alternate furrow irrigation would be next best.

Yield Data Comparisons Between Homologous Treatments Applied to the Essex and Sohoma Variety (Study Year 1980)

Table 38 shows the yield data obtained with the various treatments applied to the Essex and Sohoma variety. These data are presented in such a way as to evidence the performance of each variety when a particular treatment was simultaneously applied to both.

The data indicate that Sohoma outyielded Essex in two instances: when both were planted one and two rows per bed with supplemental water being applied in every furrow and alternate furrow, respectively. In contrast, when both varieties received the treatment combinations of one and two rows per bed planting with alternate and every furrow irrigation, respectively, Essex produced larger yields than Sohoma. In other words, it is suggested that under conditions in which water is not a limiting factor, the Sohoma variety is preferable over Essex and one row per bed planting indicated. However, under limited water conditions, the treatment combination of one row per bed and alternate furrow irrigation would be best indicated with the Essex variety.

TABLE 38

YIELD DATA FOR SIMILAR TREATMENTS APPLIED TO ESSEX AND SOHOMA VARIETY IN 1980

Treatment Combination	Variety	Yield (kg/ha)	Yield Difference Between Varieties (kg/ha)
Every furrow irrigation and one row per bed planting	Essex Sohoma	2432 3066	634*
Every furrow irrigation and two rows per bed planting	Essex Sohoma	3091 2982	109
Alternate furrow irrigation and one row per bed planting	Essex Sohoma	2315 1936	379
Alternate furrow irrigation and two rows per bed planting	Essex Sohoma	1978 2448	470

*Significant at the 5% level of probability.

Agronomic Characteristics (Study Year 1981)

Data for this study year showed virtually no significant irrigation x variety x number of rows per bed interaction on any of the agronomic characteristics. However, significant irrigation x variety and variety x row number per bed interactions on some variables were observed (see Table 33).

Plant Height, Number of Pods on Main Stems, Immature Pods on Branches, Seeds on Main Stems, and Seed Yield on Main Stems

Mean values and simple effects of the factors studied on plant height, number of pods on main stems, immature pods on branches, seeds on main stems, and seed yield on main stems are given in Tables 20, 24, 25, 28, and 30, respectively. Plants of the Sohoma variety were, on the average, taller and had more immature pods on branches than those of Essex. In contrast, Essex produced plants with larger numbers of pods on main stems, seeds, and consequently larger yields on main stems than Sohoma. Similar observations were made during the 1980 studies.

When responses of the varieties to varying number of rows per bed were examined, it was noted that plants of the Essex variety were taller, had more pods, seeds, and seed yield on branches when planted one row than two rows per bed. However, they produced larger numbers of pods, seeds, and seed yield on main stems when planted two rows per bed than one row per bed. These results are all similar to those obtained in the 1980 studies. As in 1980, no significant difference in the number of immature pods on branches and on main stems due to changes in planting patterns was observed.

With Sohoma, plants were, on the average, taller when planted two rows per bed rather than one row per bed. However, much like the 1980 studies, more pods and seeds on main stems were produced when planted one row per bed. Number of immature pods on branches was slightly higher with the single row per bed planting than with the two rows per bed planting, but again with no significant difference between one and two rows per bed planting.

Table 20 shows that plants of the Essex variety averaged 61.2 and 58.7 cm when irrigated in every and alternate furrows, respectively. The resulting difference in plant height due to irrigation method was significant at the 5% level of probability. In contrast, smaller and non-significant differences in number of pods and seeds on main stems (see Tables 24 and 28), and in number of immature pods on branches (see Table 25), resulted with varying the level of irrigation. Seed yield on main stems, however, was significantly decreased by reduced moisture conditions. The decrease in seed yield on main stems can be attributed to a decrease in individual seed weight (Table 40, Appendix).

With Essex, and for all above agronomic characteristics, higher responses were observed when irrigation water was applied in every furrow. In contrast to Essex, the Sohoma variety showed higher respective values with alternate furrow irrigation, except with regard to the number of immature pods on branches for which an increase was associated with every furrow irrigation. All observed differences due to irrigation, except that of yields on main stems, were significant at the 5% level of probability. No reason for such behavior of the Sohoma variety was apparent.

Other Agronomic Characteristics

As in 1980, number of branches per plant, nodes per plant, seeds on branches, immature pods on main stems, and harvest loss (weight of seeds below 10 cm) per treatment were also evaluated. However, analyses of variances did not show any significant interaction of factors on these characteristics. Therefore, only the main effects of the factors are considered in the discussion below.

On the average, varietal differences in number of nodes per plant (see Table 22) were little influenced by irrigation or number of rows per bed. Similar results were obtained in 1980. Average differences in number of nodes per plant as influenced by variety, irrigation, and number of rows per bed levels were 0.51, 0.26, and 0.17, respectively.

The Essex variety produced its highest average number of nodes per plant (15.2) when it was planted one row per bed and irrigated in every furrow. Of the four treatments applied to the Essex variety, the combination alternate furrow irrigation and one row per bed planting resulted in the lowest average number of nodes per plant (15.1). For the Sohoma variety, the highest average number of nodes per plant was obtained with the treatment combination of alternate furrow irrigation and one row per bed (15.1). The lowest average number of nodes per plant was associated with the every furrow irrigation and two rows per bed planting (14.2). Only the average differences in number of nodes per plant due to variety and irrigation were significant at the 5% level of probability.

The number of immature pods on main stems (see Table 26) did not differ significantly with levels of irrigation, variety, and row number per bed. There was an average difference of 0.11 and 0.11 immature pods on main stems due to variety and irrigation, respectively. No difference was induced by changes in levels of row number per bed. None of the above differences were significant at the 5% level of probability. However, higher values were associated with Sohoma and alternate furrow irrigation.

In contrast to number of immature pods on main stems, number of seeds on branches (see Table 27) was significantly affected by all factors. Average differences due to variety, irrigation, and row number per bed were 30.6, 24.4, and 10.3, respectively. Larger numbers of seeds on branches were recorded for Sohoma when planted one row per bed and every furrow irrigated.

A summary of the mean values and simple effects of irrigation, variety, and row spacing on harvest loss per treatment in 1981 was given in Table 31. It can be observed that harvest losses per treatment was only significantly affected by variety. Averaged harvest losses over irrigation and row number per bed indicated that the difference in harvest loss between the Sohoma and Essex varieties was only 0.01%. Percentage of seeds that were below 10 cm relative to the treatment yields was 2.4%, at most.

Quick (1972) showed that, in most instances, total harvest losses with a combine (total seeds on the ground after harvest) have averaged 9% of the total crop. Under the conditions of this experiment, the estimated harvest losses did not include seeds that eventually remained on the ground after the combine harvest.

Results on Soybean Yields (Study Year 1981)

Soybean Yields

Table 32 shows the mean values and simple effects of irrigation, variety, and number of rows per bed on soybean yield (kg/ha) per treatment in 1981. Yield data averaged over irrigation and row number per bed showed that Essex produced 2556 compared to 2724 kg/ha (6.5% more) for the Sohoma variety. A similar yield difference between the varieties (6%) was obtained in 1980.

Averaged yield data over variety and row number per bed showed that alternately irrigated treatments yielded 2549 compared to 2773 kg/ha or 7% more for treatments which received every furrow irrigation.

When yield data were averaged over variety and irrigation levels, it was found that single row planted treatments averaged 2603 and those planted two rows per bed 2677 kg/ha; the relative increase in yield over the one row planted treatments was 71 kg/ha, or 2%. Of all studied factors, irrigation, as in 1980, most influenced soybean yields. Effects of row number per bed on yield was the same as in 1980, except that the yield difference induced by varying the levels of that factor was much less in 1981 than in 1980.

Responses of the varieties to row number per bed, indicated the superiority of Sohoma (2708 kg/ha) over Essex (2498 kg/ha) when both were planted one row per bed. With the two rows per bed planting, Sohoma yielded 2740, compared to 2614 kg/ha for the Essex variety. However, neither planting pattern resulted in a significant yield difference between the two varieties at the 5% level of probability. The relative superiority of Sohoma over Essex at each row level can be traced through their respective data on pods, seeds, and seed yields on branches, and mean weight of seeds on main stems (Table 40, Appendix). As in 1980, both varieties performed better when planted two rows per bed.

When irrigated in every furrow, Essex and Sohoma produced 2616 and 2846 kg/ha, respectively. At this level of irrigation, the yield difference between the two varieties was 230 kg/ha. Under alternate furrow irrigation, they produced 2496 and 2602 kg/ha, respectively, resulting in a difference of 106 kg/ha. Both yield differences were low compared to those obtained in 1980, probably because of the relatively better environmental growing conditions observed in the latter year. Only the yield difference of 230 kg/ha was significant at the

5% level of probability. Yield of both varieties, as influenced by irrigation, indicated that alternate furrow irrigation decreased the Sohoma yield by 244 kg/ha. In contrast to Sohoma, yields of the Essex variety did not significantly vary with levels of irrigation. It could be that Essex has a better ability to adapt to varying soil moisture conditions than Sohoma.

Yield data were then looked at considering the three factor relationships (see Table 32). As in 1980, the Essex variety produced its highest yield (2701 kg/ha) when planted two rows per bed and irrigated in every furrow. The treatment combination of one row per bed and alternate furrow irrigation produced the lowest yield (2465 kg/ha). The same treatment produced the lowest yield (1978 kg/ha) in 1980.

Of the four treatments applied in 1981 to Sohoma, the lowest yield (2599 kg/ha) was obtained when planted one row per bed and irrigated in alternate furrows. A similar result was also observed in 1980. The highest yield (2875 kg/ha) in 1981 resulted with the treatment combination of two rows per bed and every furrow irrigation. No significant difference in yield between treatments applied to either variety was significant at the 5% level of probability.

Yield Data Comparisons Between Homologous Treatments Applied to the Essex and Sohoma Variety (Study Year 1981)

Yield data for similar treatments applied to the Essex and Sohoma variety are presented in Table 39. Sohoma yielded better than Essex in all instances. However, the observed yield differences between the two varieties are relatively small (286 kg/ha at most) for the 1981 environment.

TABLE 39

YIELD DATA FOR SIMILAR TREATMENTS APPLIED TO THE ESSEX AND SOHOMA VARIETIES IN 1981

Treatment	Variety	Yield (kg/ha)	Yield Difference Between Varieties (kg/ha)
Every furrow irrigation and one row per bed planting	Essex Sohoma	2531 2817	286
Every furrow irrigation and two rows per bed planting	Essex Sohoma	2701 2875	174
Alternate furrow irrigation and one row per bed planting	Essex Sohoma	2465 2599	134
Alternate furrow irrigation and two rows per bed planting	Essex Sohoma	2527 2605	78

Since water is the major limiting factor in the study area, stability in varietal performance as affected by irrigation practice should be considered. With this in mind, it can be said that one row per bed planting using the Sohoma variety is best indicated for situations where the supply of quality irrigation water is not limited. Where conditions of limited irrigation water prevail, a one row per bed planting with Sohoma is likely the best treatment to use.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

Soybean production in south central Oklahoma is, in most years, impaired by low rainfall conditions, strong winds, and high temperatures. For optimum soybean production in the area, practical and economical ways of minimizing the yield-limiting effects of the suboptimal precipitation must be established.

The objectives of the study were to: 1) evaluate the yield potential of furrow irrigation of soybeans in south central Oklahoma, 2) evaluate agronomic characteristics such as plant height, number of branches per plant, nodes per plant, pods on branches, pods on main stems, immature pods on branches, immature pods on main stems, yield on branches, yield on main stems, weight of seeds below 10 cm (estimate of harvest loss), and yield, under two methods of supplemental irrigation water applications (every and alternate furrow), and two planting patterns (one row and two rows, 15 cm apart) on 102-cm beds, and 3) make a quantitative determination of differences between the Essex and Sohoma variety in their reaction to water stress by comparing their differences in growth and yield under both methods of supplemental water irrigation applications and planting patterns.

Prior to harvest, 20 plants were randomly selected from each experimental plot for agronomic characteristic evaluations. Yield data were obtained by harvesting 2.04 x 3.06 and 3.06 x 91.4 m strips from each experimental unit in 1980 and 1981, respectively.

Conclusions

Statistical analyses of variance were run on the agronomic characteristics and yields. Interpretation of the results led to the following conclusions:

1. The number of nodes per plant for each variety is a stable characteristic, little influenced by irrigation or row number per bed. Therefore, differences in plant height among treatments applied to each variety were primarily related to variations in internode length.

2. In each of the two year study periods, Sohoma produced taller plants with larger numbers of branches, more immature pods on branches, more immature pods on main stems, larger number of seeds, and higher seed yield on branches than did Essex.

3. In contrast, plants of the Essex variety had more pods and seeds on main stems than those of the Sohoma variety.

4. The genetic potential of each variety was probably better expressed in 1981 because of the better growing conditions of that year when compared to 1980. This explains the larger varietal differences in number of pods, seeds, seed yields on branches, and number of pods and seeds on main stems observed in 1981 when compared to 1980.

5. Despite its ability to produce more pods and seeds on main stems, Essex produced lower yields on main stems than Sohoma. An average yield difference on main stems of 1.1 g and 0.4 g per plant was found between Sohoma and Essex in 1980 and 1981, respectively. Fewer

but larger seeds were produced by the Sohoma variety when compared to the Essex variety.

6. The superiority of Sohoma over Essex in all above mentioned characteristics also resulted in its superior yield performance. For 1980 and 1981, yield data averaged over irrigation and row number per bed, showed that Sohoma produced 6.0 and 6.5% more yield than Essex, respectively.

7. Effects of row number per bed on soybean yields were the same in 1980 and in 1981; larger but non-significantly higher yields were obtained with the two rows per bed than the one row per bed planting.

8. Of the three factors studied (variety, planting pattern, and irrigation method), irrigation affected soybean yields the most.

9. Averaged yield data over irrigation methods and number of rows per bed indicated that for both study years and both varieties, higher yield performances were obtained when planted two rows per bed, compared to one row per bed. Average grain yields produced by the Sohoma variety were higher than those resulting with the Essex variety, independent of the planting pattern used.

10. Comparison of yield data among treatments applied to each variety showed that in 1980 and 1981, Essex produced its highest yield (3091 and 2701 kg/ha, respectively) when planted two rows per bed and irrigated in every furrow. For Sohoma, the highest yield in 1980 (3066 kg/ha) resulted with the treatment condition of one row per bed and every furrow irrigation; in 1981, however, the highest yield (2875 kg/ha) was obtained when planted two rows per bed with supplemental water being applied in every furrow.

11. With fixed row number per bed and varying methods of irrigation, significant yield differences due to irrigation treatment were observed at each row number level Sohoma was planted in 1980. With Essex, however, only the two rows per bed planting and varying levels of irrigation produced significantly different yields.

In contrast to 1980, no significant yield difference between treatments applied to either variety was found at the 5% level of probability in 1981. The data also indicated that Essex has a better adaptation ability to reduced soil moisture conditions than Sohoma.

When comparisons of yield data between homologous treatments applied to both varieties were made, it was found that for the 1980 environment and under conditions of every furrow irrigation, Sohoma planted one row per bed would be the best treatment combination. With limited supply of irrigation water (alternate furrow), Sohoma and two rows per bed planting was best.

For the 1981 environment, yield data obtained with all treatment combinations indicated a superior performance of Sohoma over Essex. However, there was not any significant yield difference between similar treatments applied to the Sohoma and Essex variety. A yield difference of 286 kg/ha was found between Sohoma and Essex when both were planted two rows per bed and irrigated in every furrow. This indicates a substantial advantage with Sohoma for that particular treatment. Under conditions of limited irrigation water supply, total amounts of water required for irrigation could be reduced by half if alternate furrow irrigation is applied. Under such conditions, the best treatment combination would be the one row per bed planting using the Sohoma variety.

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APPENDIX

TABLE 40

SUMMARY OF THE AGRONOMIC CHARACTERISTICS AND YIELD DATA FOR TREATMENTS APPLIED TO THE ESSEX AND SOHOMA VARIETIES (STUDY YEAR 1980)

VARIETY	IRRIGATION LEVELS NO. ROW LEVELS	PLT-HGHT	BR-PLT	NDS-PLT	PDS-BR	PDS-MS	IMPDS-BR	SDS-BR	IMPDS-MS	SDS-MS	YLD-BR	YLD-MS	MW-SDS-MS	MW-SDS-BR	WT-LS	YLD-SB10	PCT-SB10	TY-KPH
SOHOMA	00	55.43	8.73	14.71	44.74	17.54	2.99	93.48	1.07	36.41	16.67	6.65	0.185	0.174	22.96	16.15	0.28	3066.0
	01	48.06	8.30	14.75	40.25	16.85	3.25	84.19	1.18	35.74	15.34	6.51	0.171	0.177	23.39	16.58	0.28	2982.0
	10	47.21	5.53	14.52	20.56	14.50	1.01	44.68	0.50	30.60	8.00	5.93	0.172	0.183	25.46	21.30	0.59	1936.0
	11	44.34	6.89	14.56	32.91	13.84	1.83	70.65	0.60	29,78	12.62	5.41	0.192	0.176	42.23	23.15	0.53	2448.0
ESSEX	00	42.76	3.96	14.53	22.76	19.83	0.84	46.64	0.60	40.20	6.64	5.97	0.145	0.148	35.96	13.00	0.26	2432.0
	01	39.70	5.13	14.28	33.54	23.96	1.03	68.78	0.79	49.60	9.87	7.31	0.152	0.139	21.76	10.74	0.19	3091.0
	10	38.81	3.78	14.09	18.75	16.76	0.53	38.86	0.50	34.05	5.29	4.87	0.152	0.141	26.16	12.20	0.27	2315.0
	11	38.38	4.25	14.71	27.32	20.04	0.93	56.43	0.86	41.59	7.48	5.83	0.143	0.135	33.88	12.62	0.33	1978.0
Grand Mean		44.34	5.82	14.52	30.10	17.91	1.55	62.96	0.76	37.25	10.24	6.06			28.98	15.72	0.34	2531.0
Coeff. of Variation (%)		10.76	42.26	8.89	54.54	38.24	125.44	54.82	129.85	39.43	56.12	46.74			44.29	49.01	46.00	14.45
LSD 0.05		2.91	1.65	0.75	10.42	4.05	0.90	21.91	0.37	8.34	3.78	1.47			18.87	11.32	0.23	537.9
LSD 0.01		3.96	2.25	1.02	14.18	5.52	1.22	29.84	0.50	11.36	5.14	2.00			25.69	15.42	0.32	732.3

TABLE 41

SUMMARY OF THE AGRONOMIC CHARACTERISTICS AND YIELD DATA FOR TREATMENTS APPLIED TO THE ESSEX AND SOHOMA VARIETIES (STUDY YEAR 1981)

VARIETY	IRRIGATION LEVELS NO. ROW LEVELS	PLT-HGHT	BR-PLT	NDS-PLT	PDS-BR	PDS-MS	IMPDS-BR	SDS-BR	IMPDS-MS	SDS-MS	YLD-BR	YLD-MS	MW-SDS-MS	MW-SDS-BR	WT-LS	YLD-SB10	PCT-SB10	TY-KPH
SOHOMA	00	68.99	11.51	14.50	59.30	12.73	2.50	120.35	0.63	26.43	19.37	4.35	0.168	0.152	6.00	16.53	0.02	2817.0
	01	65.10	11.01	14.20	48.71	11.45	2.13	101.89	0.51	22.78	17.46	3.89	0.180	0.151	3.98	12.65	0.02	2875.0
	10	71.78	10.38	15.14	42.04	16.00	1.85	84.63	0.56	31.93	13.60	5.43	0.167	0.176	3.55	17.29	0.02	2599.0
	11	68.04	9.59	14.74	36.39	14.43	1.48	78.40	0.58	29.83	13.12	4.96	0.162	0.153	5.03	11.15	0.02	2605.0
ESSEX	00	62.99	10.09	15.21	38.95	19.84	1.25	80.40	0.26	40.24	11.33	6.19	0.155	0.136	1.21	6.24	0.01	2531.0
	01	60.54	9.33	15.15	34.27	21.64	1.00	70.15	0.45	44.39	9.95	6.95	0.150	1.139	0.98	11.54	0.02	2701.0
	10	59.51	9.08	15.08	28.58	19.93	1.10	59.18	0.61	40.63	8.17	6.24	0.158	0.161	1.45	4.86	0.01	2465.0
	11	56.86	8.21	15.16	25.39	18.73	1.33	53.11	0.53	39.56	7.50	6.08	0.168	0.165	0.44	3.78	0.01	2527.0
Grand Mean		64.23	9.90	14.90	39.20	16.84	1.58	81.01	0.52	34.47	12.56	5.51			2.83	10.50	0.01	2640.0
Coeff. of Variation (%)		8.21	28.55	8.66	49.29	33.19	107.35	49.43	160.30	33.69	54.42	36.20			48.94	61.75	63.9	8.44
LSD 0.05		3.73	1.38	0.54	8.30	2.30	0.63	17.41	0.39	5.32	2.86	0.52			2.04	9.54	0.01	328.0
LSD 0.01		5.08	1.87	0.74	11.29	3.14	0.86	23.71	0.53	7.24	3.89	1.26			2.77	13.00	0.02	446.0

VITA 2

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