RESPONSE OF SIX SOYBEAN CULTIVARS
TO VARIOUS ROW SPACINGS

By

MAHMOUD Y. SABBOUH

Bachelor of Science

Damascus University

Damascus, Syria

1977

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 1982

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Thesis Approved:

Lewis H. Edwards
Thesis Adviser

James S. Kirby

Jewell Crabtree

David T. Weeks

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGMENTS

I wish to express my sincere appreciation to my adviser, Dr. L. H. Edwards, for his guidance, encouragement, and helpful advice in the course of this study. I also wish to express my appreciation for the help and valuable suggestions made by Dr. Weeks, Dr. Kirby and Dr. Crabtree as members of my graduate committee.

I am indebted to the Faculty of Agriculture of Damascus University, Department of Agronomy, Oklahoma State University and the Agency for International Development for the facilities and financial assistance which made this study possible.

Gratitude is also expressed to the members of the Soybean Breeding Program for their encouragement and assistance throughout the course of this study.

Special appreciation is expressed to my father and mother, Yousef and Tamrah, and my brothers, Ali, Souleiman and Ahmed for their encouragement, support and many sacrifices.

A very special appreciation is expressed to my wife, Aiyda, for her understanding, patience, encouragement and many sacrifices throughout the course of this study.

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CHAPTER I

INTRODUCTION

The world population is increasing at a rate far exceeding any other period in the world history. Increased crop production is a worldwide important need particularly in the underdeveloped countries where people are gradually losing the ability to feed themselves. Soybean, Glycine max (L.) Merrill, is one of the most important crops that has the potential to provide the world's increasing demand for food and forage. It is grown primarily for the oil and protein products derived from the seed. The plant itself can be used for pasture, silage, hay, and as a soiling crop. The grain has high nutritional value and is used in manufacturing many human foods (18). The soy oil accounts for 83% of all the vegetable oil consumed in the United States and is mainly used in food products, fuel, paints and soap. The soybean meal is extensively used for feeding livestock. Soy products can also be used as carriers for vitamins, antibiotics and drugs in animal feeds (38).

Soybean acreage and total bean production in the U. S. have increased steadily over the years and have greatly contributed to the rapid development of American agriculture. The total planted acreage increased by approximately 36% between 1969 to 1973 (31). The farm value of the harvested soybeans has also increased 25% between 1973 and 1980 (31, 42). About 66% of the U. S. total production is produced in the north central states. Oklahoma soybean acreage increased 34.5% between 1976 and 1979 (42). The total production also increased.

The yield of soybeans is the result of many genetic and environmental interactions. The selection of an adapted, high yielding, lodging-resistant, disease resistant, nonshattering cultivar and seed of known high viability and quality is the first step in soybean management (42). The influence of factors such as lodging, seeding rate, seed size and row width on soybean yields have been investigated moderately, but other production practices such as planting date and depth of planting are also important factors affecting the soybean yield (46). Row spacing is one of the most important management practices that affects soybean yields.

This study evaluated four row spacings and six cultivars at two locations. The objectives of this study were to evaluate the response of six soybean cultivars at four row spacings under two climatic and soil conditions, and to determine which combination of treatments yielded the best.

CHAPTER II

REVIEW OF LITERATURE

The world-wide clamor for soybeans has made the "gold that grows" the number one crop in cash sales for U. S. farmers who now export every other row of soybeans grown (19). Although soybean yields have increased from an average of 24 bushels per acre in the 60's to an average of nearly 30 bushels per acre in the late 70's, the increase falls far short of the future world needs. In the southern U. S., soybean production has risen rapidly in the last 15 years, but yields on a per-acre basis have shown very little change and most of the added production has resulted from increases in acreages (44). The profitability of soybeans depends upon the ability of producers to improve management and production practices to meet the increasing demand.

Soybeans do not readily adapt themselves to changes in climate and soil, and time of their flowering and maturity are affected by the length of days and nights (18). According to Lawn and Byth (33), sensitivity to photoperiod is the most important single factor involved in the adaptation of soybean genotypes with respect to latitude and planting date. Thus, the commonly grown cultivars are limited to local areas rather than to broad regions. The cultivars of soybeans grown all over the world are generally described as having an indeterminate or determinate growth habit (22).

Beaver and Johnson (2) indicated that determinate soybean cultivars have traditionally been grown in Japan, Korea, and the southern U. S. and they flower under short days. Indeterminate soybean cultivars have been grown in northeast China and the northern U. S. and they flower under long days (25). Indeterminate plants carry on vegetative growth and flowering at the same time. Determinate plants complete most of the vegetative growth first and then shift to flowering and reproductive development (18). Bernard (4) defined a determinate type as one in which the stem growth terminated abruptly at the onset of flowering while in the indeterminate type, stem growth, node and leaf production continued for several weeks after flowering began. He and others have concluded that there are graduations in the degree of determinacy (4, 22). Terman (55) reported that northern indeterminate soybean cultivars continued to flower after initiation of grain filling by the upper pods while southern determinate cultivars flower much later within a short period before appreciable pod filling. Egli and Legget (22) found that a determinate cultivar grown in Kentucky produced 67% of the maximum dry matter by initial flowering as compared to only 30% by an indeterminate cultivar.

It has been postulated that the competition between vegetative and reproductive growth in indeterminate soybean cultivars may be detrimental to yield. Hicks et al. (28) reported a 4.6% yield increase for the total determinate types over the normal indeterminate checks.

Considerable variation among soybean genotypes in photoperiodic response has resulted in the development of a maturity grouping classification within the United States, as a broad basis for characterizing cultivar response (33). Under this system, each new cultivar is assigned to a maturity group, based on the length of time from planting to maturity. Cultivars have been classified into 10 maturity groups, 00 to VIII, from 75 to 200 days in their maturity period (18). Group 00 cultivars are adapted to southern Canada and extreme northern parts of the United States. Group III and IV cultivars are grown in the Corn Belt and Group VIII cultivars are adapted to the extreme southern part of the United States (7).

During the period from 1947 to 1970, soybean hectarage in the U. S. increased 12 times and average seed yield increased 43%. This rapid rise in grain yields of soybeans is generally credited to a combination of higher-yielding cultivars, increased use of fertilizers, herbicides and pesticides, and increased irrigation and other management practices (6). Research on production problems and the development of superior cultivars by breeders have had a major role in increasing the efficiency of soybean production (30). Soybean yields often vary considerably, not only between fields, but also within a given field. These variations are largely related to differences in soil properties, climate conditions, and management practices (44).

Yield of crop plants in general is a complex character. In soybeans it can be resolved to two basic production components, average seed size and number of seeds per unit area. The latter can be described further in terms of number of seeds per pod, number of pods per plant, and number of plants per unit area. Plants per unit area can be varied by varying spacings both between and within rows and consequently affect other yield components (35). Several researchers have investigated the effects of various row spacings on yield and other agronomic characteristics of soybeans with somewhat variable results (23). Wiggans (59) found that the soybean plant has the ability to make wide adjustments to space. Optimum rates and spacings for soybeans should be determined not only for the various soybean production areas but also for the cultivars to be grown (43). Doss and Thurlow (20) concluded that the row width which will result in maximum yield is dependent upon the length of growing season, growth type of cultivars, and fertility level of the soil. In general, row widths narrower than the conventional 90-100 cm will result in highest yields in indeterminate soybean cultivars (13). Wilcox (60), in a study of five row widths ranging from 18 to 90 cm and at plant spacings of 2.5, 5, and 7.5 cm within the row found that maximum yield was obtained from the combination of narrowest row width and widest plant spacing within the row.

Increases in grain yield due to planting indeterminate soybeans in narrow rows (less than 50 cm) rather than wide rows (more than 75 cm) have been reported and several researchers have noted that cultivars differ in the degree of response (17, 39). In a study of two row widths, Ryder and Beuerlein (46) found that 38 cm rows out-yielded 75 cm rows by 3.8 bushels per acre. They also found that 75 cm rows out-yielded 100 cm rows by 6 bushels per acre. Their conclusion was that, for maximum yields, row width should not be wider than 38 cm (47). A very recent study indicated an average yield advantage of 35 to 45% for 30 cm rows as compared to 100 cm rows (51), but another study indicated that narrow row spacings did not increase soybean seed yield (29).

Yield response to different row spacings has varied with cultivar and environmental influence. Spilde et al. (53) reported that soybean yields in the primary growing regions of the Midwest were generally 10 to 30% greater in the narrow rows. They also found that the yield increase for narrow rows was generally greater with early maturing cultivars and when planting was delayed. In the north central U. S., higher yields have resulted when soybeans were planted in narrow rows (46 cm or less) rather than in wide rows (92 cm or greater) with the greatest increase occurring with early maturity cultivars (3, 29). However, in the southern U. S. some investigations showed that soybeans have not responded to planting in narrow rows (40). In Florida, yields of five cultivars (group VI through VII) were higher in narrow rows (46 cm or less) than in wide rows (65 to 105 cm) (40). Wiggans (59) in an early study in New York reported that planting soybeans in 20 cm rows produced highest yields. Lehman and Lambert (35) stated that yields in Minnesota and Illinois in 45 to 60 cm rows have been 15 percent greater than in 90 to 100 cm rows. Cooper (15) also demonstrated higher yields in narrow rows (25 cm) than in wide rows (50 cm) in central Illinois.

Considerable evidence has accumulated indicating that most soybean cultivars consistently yield 10 to 15 percent more when grown in 50 or 75 cm rows compared with the traditional 100 cm rows. The increased yield of soybeans in narrow rows appears to be primarily due to a more even distribution of plants which results in more effective use of the light available in the field (14, 18).

Both theory and research data indicate that equidistant plant distribution should maximize crop yields. Wilcox (60) studied the response of three soybean cultivars to equidistant spacings and found that maximum yields result when plants approach equidistant spacings. Wiggans (59) theorized that each cultivar has different requirements for optimum plants per unit area for maximum yield, and regardless of the method of distribution, 65 plants/m^2 produced highest yield of soybeans. He also indicated that the yield increases as the arrangement of plants in a given area approaches a uniform distribution. Several researchers suggested that optimum crop yields on an area basis should arise from planting where intra-row and inter-row competition is minimum. The evidence that square planting gives the highest yield is not wholly consistent, but seems reasonably firm (26, 32). Pendleton et al. (17) studied the response of soybean cultivars to planting patterns and found that planting soybeans in rows narrower than the conventionally spaced (76 to 102 cm) is one way of obtaining a more uniform plant distribution. Probst (43) reported that for 76 cm rows, intra-row spacings of 5 and 8 cm produced highest seed yield. Weber (58) stated that plant density of about 129,000 and 247,000 plants per hectare gave highest yields for 13, 25, and 51 cm rows. Lehman and Lambert (35) found that 50 cm rows generally outyielded 100 cm rows, while yield differences due to intra-row spacings were inconclusive. They also noted that seed weight and seeds per pod were not affected considerably by spacing or population change, whereas the number of seeds, pods, and branches per plant decreased with increased plant population. Kantanka and Lawson (32) reported that high density (32 plants/m^2) planting of soybeans resulted in small plants but high dry weight per unit area, while low density (4 plants/m^2) produced larger plants with lower dry weight per unit area. High density also reduced the proportion of flowers forming mature pods. Experiments have shown that soybeans usually produce the same yield over wide variation in population. Wilcox (60) in one experiment showed no measureable difference in yield when population varied from 83,000 to 582,000 plants per hectare in equidistant spacings. Basnet et al. (1) concluded that increased yield from narrow rows varies with plant population and cultivar. The optimum seeding rate has to be adjusted for different row spacings and cultivars for maximum yield response. Reiss and Sherwood (45) indicated that low seeding rates produced lower yields especially in very narrow rows. Doss and Thurlow (20) found that planting rates of 20 to 40 viable seeds per meter usually give most satisfactory results in 90 to 100 cm row width.

The soybean has tremendous flexibility for variation in population. Therefore, the penalty for over or under planting is relatively small. Scott and Aldrich (48) indicated that as row width is narrowed planting rate should be adjusted. Probst (43), and Caviness (14) found that larger seed yield variations appeared among different cultivars than among different plant populations. They also found that a seeding rate of 22 kg per hectare in 90 cm row produced highest yields of both grain and straw. Beuerlein et al. (5) reported that most Midwest researchers recommended a moderate seeding rate of 51 to 70 kg per hectare. This seeding rate is adequate for maximum yields, reduces lodging, and makes more efficient use of the seed planted. Kantanka and Lawson (32) found that plant height, height of the lowest pod, and lodging increased with increasing plant density. Probst (43) reported that spacing generally had little effect on seed size. Weber et al. (58) studied the effect of row spacing, planting date, and plant density on the growth and yield of determinate soybeans. They found that the optimum plant populations per acre appear to be in the ranges of 90,000 for 100 cm row and 130,000 for 25 and 50 cm rows. They also found that these densities not only maximized yields but also minimized lodging and soil moisture depletion. Soybeans in the southern U. S. are often seeded at a rate of 67 kg per hectare or more in rows 90 to 100 cm apart. A seed density of more than 50 seed/m of row is often attained and is considered above the optimum when high quality seed is planted under good management. Hortung et al. (25) working with adapted determinate soybeans found that from 25 to 30 plants/m was optimum in rows 92 to 100 cm apart. Hoggard et al. (30) found that number of nodes per plant, pods per plant, filled pods per plant, and seeds per pod are inversely related to plant population. Weber et al. (58) found that seed weight and seeds per pod were not affected considerably by spacing or population change, whereas the number of seeds, pods, and branches per plant decreased as plant density increased. Shibles and Green (51) recommended short plants (about 65-75 cm) for the narrow row areas. They believe that shorter plants are highly desirable because of a need for higher plant density in narrow rows. With highest density, shorter plants will provide needed lodging control.

Since soybeans are usually produced under row culture, it seems reasonable to assume that variation in row and plant spacing will greatly influence solar radiation. Costa et al. (17) stated that, if water and nutrients are in adequate supply, then solar radiation becomes a factor limiting soybean production. One objective of changing plant arrangement is to improve light interception. They found that plants in wider row spacings generally accumulate their leaf area index at a slower rate than plants in narrow row spacings. Shibles and Weber (50) in a study of 12.5, 25, 50, and 100 cm rows found that, when soybeans were grown in narrow rows (50 cm or less), plant arrangement at any population above 52,000 was of little significance in solar radiation interception. Wider spacing (100 cm rows), however, resulted in less interception at any stage of growth and considerably delayed maximum interception. Results of many experiments on soybeans and other agronomic crops have been reported which either directly or indirectly suggest the importance of adequate light for optimum yield. Pendleton et al. (41) studied the effect of supplemental light on apparent photosynthesis, yield, and yield components of soybeans. They found that, as the plants grow, light penetration to the middle and lower leaves is inhibited by intra- and inter-plant competition. Shaw and Weber (49) indicated that maximum light penetration occurred with a moderate amount of plant spreading stimulating a small but definite amount of lodging. Taylor (54) reported that the yield increases from soybeans planted in narrow rows over that obtained from the historical 102 cm rows at equivalent plant populations is attributed to the development of a canopy which provides complete ground cover in narrow rows by the time rapid pod-fill occurs. Shibles and Weber (50) noted that full ground cover canopies intercept more solar radiation and have greater photosynthesis than low partial ground cover canopies. Hicks et al. (28) showed that light penetrated further into the canopy of narrow leaflet type than the normal leaflet type, but no difference in yield was found. The role of solar radiation in different row spacings can be summarized as follows: In the 100 cm rows, the plants would be very close to each other with considerable leaf interaction among the plants causing interplant shading while much of the incoming radiation reaching the area between rows is lost in terms of photosynthetic purposes. In 50 cm rows the plants would be more evenly distributed over the soil surface and a much greater percentage of the incoming radiation intercepted by the plant canopy area (32, 36, 37, 41, 49, 50).

In addition to improvement in light interception, Timmons et al. (56) showed that highest water use efficiency was obtained in 20 cm rows. Doss et al. (21) indicated that the lack of water during the pod-filling period is the basic reason for reduced soybean yields. Many experiments showed that the efficiency of water use was greater in 51 cm than in 102 cm rows (17, 20, 21).

One of the most desirable characteristics in a soybean cultivar is lodging resistance. Lodging prevents soybeans from achieving their maximum yield potential and greatly increases harvesting losses (18, 34). Cooper (15, 16) demonstrated that early lodging in highly productive environments reduced yield 23 percent. He concluded that early lodging may be an important factor affecting the response of soybeans to planting dates, row spacings and plant densities. In a study of cultivar across spacings, Probst (43) found increased lodging with increasing density in the row, while height, seed size, and maturity were generally unaffected. He also found that lodging was most severe with 2.5 cm spacing and almost absent in the 7.5, 10 and 12.5 cm spacings. Lodging resistance in cultivars may be more rapidly detected under conditions of thick stands than with thin stands. Scott and Aldrich (48) suggested that lodging is the character most affected by increasing the density within the row that tends to increase the plant height and lodging. Hoggard et al. (20) have shown that planting soybeans above an optimum seeding rate resulted in increased plant lodging and possibly decreased yields. Leffel (34) found little effect of lodging on soybean yield. However, Gedge et al. (24) found that moderate lodging reduced seed yield 13% as compared with the same cultivar staked to prevent lodging. Basnet et al. (1) attributed decreased yield to increased lodging with high plant population densities. Costa et al. (17) reported that decreasing the inter and intra-row spacing usually results in increased plant height which in turn increased lodging. Due to the fact that early lodging is detrimental to yield, some general studies in some years do not show an advantage for narrow rows over the conventional rows (17). Soybean plants grown at high densities under conditions of optimal fertility and high moisture may have a tendency to lodge. Several researchers indicated that, although lodging resisbtance differs with cultivar, its expression is greatly influenced by environmental conditions. They added, lodging is usually scored on a scale of 1 to 5 (28, 29, 34, 51).

One of the most serious problems that narrow row soybean producers have faced is weeds. Soybeans are usually grown in rows 50 to 100 cm apart in the Midwest to enable farmers to cultivate to control weeds, but herbicides have reduced the need for cultivation and when more effective herbicides become available they may eliminate the need for soybean cultivation (36, 60). The potential yield advantage for producing soybeans in narrow rows has been recognized in the Corn Belt for a long time, but acceptance of narrow rows has been poor mainly because of the problem of controlling weeds (48). Weed control is essential not only because weeds lower the bean yield through competition but also because weedy fields make the harvest with a combine much more difficult and increase harvest losses (7). Soybean yield losses from weeds are usually proportional to amount of water, nutrient, and light used by weeds at the expense of soybeans (11). To obtain high yields in soybeans, weeds must be controlled. Present day dependence on cultivation for partial weed control necessitates planting soybeans in wider rows rather than narrow rows (10). Burnside and Moomaw (10) stated that the narrow row grower must give greater consideration to proper cultural procedures because he will have less opportunity to destroy missed weeds with cultivation. Consideration should include cultivar selection, seed quality and planting pattern and methods. Wax (57) indicated that soybeans planted in 20 cm rows shade the soil faster and therefore, aid in controlling the late germinated weeds. Spilde et al. (53), and Costa et al. (17) concluded that chemical and mechanical weed control in row spacings of 30 cm or less may be more effective than in 75 or 100 cm rows because the control needs to be effective only for a shorter period before the soybean canopy inhibits weed growth by shading. They also indicated that row spacings of at least 50 cm have an advantage from the practical stand point because they can be cultivated or receive post emergence herbicide if preemergence herbicide fails.

It is a safe conclusion that improved herbicides that can eliminate the need for mechanical cultivation for weed control must be developed before row spacing as narrow as 18 to 25 cm will become feasible.

CHAPTER III

MATERIALS AND METHODS

To study the effects of row spacings of soybeans on yield and some other agronomic characters, an experiment was conducted with six cultivars and four row widths at the Agronomy Research Station near Perkins, Oklahoma, and at the Vegetable Research Station, Bixby, Oklahoma in the 1981 growing season.

Cultivars

The six cultivars used were 'Elf', 'Douglas', 'Forrest', 'Essex', 'Gail', and 'Ransom'. Elf (16) is a determinate semi dwarf soybean which originated as an F_4 selection from a cross, 'Williams' X 'Ransom'. It was released by the Illinois Agricultural Experiment Station, The Ohio Agricultural Research and Development Center, and the U.S.D.A. Elf is about one half the height of the cultivar Williams, similar in maturity, has purple flowers, brown pubescence, tan pods, and shiny yellow seeds with a black hilum. It is superior in lodging resistance, higher yielding in high yield environments, and adapted to the Midwest. Elf belongs to maturity Group III. Douglas is an

F_4 plant selection from the cross 'Williams' X 'Calland', made at the Kansas Agricultural Experiment Station. Douglas is characterized as having white flowers, tawny pubescence, brown pods, yellow seed with dull coat luster and black hila. Douglas has an indeterminate growth habit and belongs to maturity Group IV.

Forrest (27) originated as an F_5 line selected from the cross 'Dyer' X 'Bragg'. It was developed in a cooperative program of the U.S.D.A., Agricultural Research Service and the Mississippi and Tennessee Agricultural Experiment Stations. It is characterized as having white flowers, tawny pubescence, tan pods, yellow seed coats, and black hila. Forrest is highly resistant to races 1 and 3 of the soybean cyst nematode and to the root knot nematode. It is moderately resistant to phytophthora and has excellent resistance to seed shattering. Forrest has a determinate growth type and belongs to maturity Group V.

Essex (52) originated as an F_7 line selected at the Virginia Agricultural Experiment Station from the cross 'Lee' X S5-7075. It was released by the Virginia Agricultural Experiment station in cooperation with experiment stations in Delaware, Maryland, Georgia, Kentucky, Louisiana, and U.S.D.A. Essex is characterized by high seed yields, excellent standing ability, and good seed quality. Plants have purple flowers and gray pubescence, seeds have buff hila, yellow cotyledons, and yellow seed coat. It is resistant to bacterial pustule, several races of downy mildew, and moderately resistant to phytophthora rot. Essex has a determinate growth type and belongs to maturity Group V.

Gail (8) originated from a cross of 'Hood' X D60-9647 made by U.S.D.A. personnel at Stoneville, Mississippi. It was released by the Texas Agricultural Experiment Station and U.S.D.A. It is characterized as a high yielding cultivar, high protein and oil content, medium seed size, shattering and lodging resistance. Plants average 75 cm in height with purple flowers, tawny pubescence, tan pods, shiny yellow seed coats, and black hila. Gail has a determinate growth type and belongs to maturity Group VI.

Ransom (9) originated as an F_5 plant selection from the cross (N55-5931 X N55-3818) X D56-1185. It was developed and released by the U.S.D.A., Agricultural Research Service cooperating with the North Carolina Agricultural Experiment Station. Ransom is superior in lodging and shattering resistance, resistant to purple seed stain, seed mottling and the leaf diseases, bacterial pustule, wildfire, and target spot, moderately susceptible to phytopthora root rot and root knot nematode. It has purple flowers, tawny pubscence, yellow seeds with black hila and bright luster. Ransom has a determinate growth habit and belongs to maturity Group VII. All cultivars were selected because yield tests have proved their high-yielding and adaptability to various areas in Oklahoma.

Row Widths

The row widths used at both locations were 25, 50, 75, and 100 cm (10, 20, 30, and 40 inches) row spacings. These spacings were the distance between rows of plants in each plot. The 25 cm row width is considered as the narrowest row width and the 100 cm row width is considered as the widest row width.

Plant Populations

The plant population used in Location I was 27 plants per square meter (2.5 plants per square foot), and the plant population used in Location II was 32 plants per square meter (3 plants per square foot), which is equivalent to 270,000 plants/ha, and 320,000 plants/ha, respectively. These plant populations were selected as representing the populations used by soybean producers.

Design and Field Layout

The second part of this study was conducted on a Teller loam soil at the Agronomy Research Station Perkins, Oklahoma. The first part was conducted on a Wynona silt loam soil at the Oklahoma Vegetable Research Station, Bixby, Oklahoma. Nitrogen fixing bacteria, *Rhizobium japonicum*, were applied to the seed before planting.

The factorial arrangement of the cultivars and row widths was layed out in a randomized complete block design with four blocks per location. Each block contained 24 plots, and each plot was 11 square meters (120 square feet).

The second location (Perkins) was planted on June 8, 1981, and the first location (Bixby) was planted on June 11, 1981. A four-cone research planter was used in both locations.

During the growing season both locations were continuously scouted for diseases, insects, and weeds. Soybean plants at location II were attacked at a late stage by the Blister beetle insect. Studies have shown that soybean yields are not affected at this stage so no insecticides were used. The plots at both locations were hoed twice by hand to control weeds, and the preplant herbicide, Treflan, was used to control grass.

In order to maintain the crop, the Perkins plots were irrigated three times during the first month of the growing season. Approximately 15 inches of irrigation water were applied by a sprinkler system. Due to the adequate rainfall that occurred at the Bixby location, no irrigation was applied to the soybean plants at this location.

Characters Investigated

The characters observed and evaluated on all plots in both locations were: a) grain yield, b) plant height, c) shattering, d) 100-seed weight, e) plants per plot, f) seeds per plant.

Grain Yield and Plants Per Plot

Due to the low germination percentage in some of the cultivars used and in order to keep the desired population per unit area, seeds were replanted in some plots at both locations. Four weeks after emergence and when the plants were up to a good stand, the ends of soybean plots were trimmed and plots shortened to 2.5 meters. Plants within each plot were thinned to desired population numbers at this time. The plots were harvested by hand using a plot cutter, and the harvested plants were threshed in the field with a plot thresher. Elf at location II was havested and threshed on September 22, 1981, while Douglas, Essex, Forrest, Gail and Ransom in the same location were harvested and threshed on October 21, 1981. In the first location (Bixby), all cultivars were harvested and threshed on November 18, 1981. The center rows were harvested in all plots of both locations. The plots with 25-cm row width had the center six rows harvested. The plots with 50 cm-row width had the center three rows harvested. Plots with 75-cm row spacing had the center two rows harvested. Plots with 100-cm row spacing had the center row and half row of another row were harvested. The harvested area from each plot was 3.72 square meter (40 square feet) at both locations. The number of harvested plants was 100 plants at location I, and 120 plants at location II from each plot. After the soybean plants were harvested, the seeds were dried in a drying room to decrease the moisture to a uniform content, then the seeds were cleaned and weighed. The seed weight from each plot was recorded on a grams per plot basis then converted to kilogram per hectare.

Plant Height

Plant heights were recorded at maturity as the distance in centimeters from the soil surface to the tip of the main stem. The height of 3-4 plants per plot was measured then averaged. The same procedures were used at both locations.

Shattering

This character was estimated just before harvesting all cultivars at each location. The amount of soybean shattering was averaged over the entire plot and scored on a scale of 1 to 5 with 1 meaning no shattering and 5 meaning more than 20% shattering.

100-Seed Weight

This variable was evaluated by taking a random sample of 100 complete, clean seeds from each plot, weighing, and recording the number of grams per 100 seeds for each plot at both locations.

Seeds Per Plant

The number of seeds per plant was determined by dividing the number of seeds in each plot by the number of harvested plants in each plot. The number of seeds per plot was determined by dividing the number of grams per plot by the weight of 100 seeds and multiplying the quotient by 100. These calculations were done by using a small calculator for all plots at both locations.

Statistical Analyses

The statistical analyses were carried out on all characters observed. An analysis of variance was calculated for each character by location by using the Statistical Analysis System at Oklahoma State University Computer Center.

CHAPTER IV

RESULTS AND DISCUSSION

Grain Yield

The mean squares for grain yield and its components at both locations are presented in Tables I and II. Table I shows that grain yield at location one was significantly affected by cultivars at the 0.01 level of probability and by row widths at the 0.05 level of probability. No significant interaction was found between cultivars and row widths. Table II indicates that grain yield at location two was significantly affected by both row widths and cultivars at the 0.01 level of probability, but no significant interaction was found between cultivars and row widths. This indicates that the cultivars used in this study responded in the same manner to the row widths.

The average grain yields for the six cultivars in various row widths at both locations are presented in Tables III and IV. Table III shows that cultivars at location one yielded the highest when they were grown in the 100-cm row width. The LSD at the 0.05 level of probability for detecting a difference between row widths at location one is 451.9 kg/ha indicating that the mean grain yield for all

TABLE I

MEAN SQUARES OF FIVE AGRONOMIC CHARACTERS OF SIX SOYBEAN CULTIVARS (LOCATION I)

Source of Variation	d.f.	Grain Yield	Height	Shat.	100 Seed Wt.	Seeds Per Plant
Cultivar	5	8836131.4**	6395.7**	401.1**	10162.1**	8904.9**
Row Width	3	1624162.4*	189.3**	.1	12.8	817.5*
Cultivar X Row Width	15	566068.9	17.0	.2	61.4	288.9
Error	69	614459.5	23.9	.2	73.3	297.5

* significant at the 05 level of probability
** significant at the 01 level of probability

TABLE II

MEAN SQUARES OF FOUR AGRONOMIC CHARACTERS OF SIX SOYBEAN CULTIVARS (LOCATION II)

Source of Variation	d.f.	Grain Yield	Height	100 Seed Wt.	Seeds Per Plant
Cultivar	5	7771149.2**	7013.7**	13483.9**	1220.1**
Row Width	3	686288.2**	17.6	43.1	372.1**
Cultivar X Row Width	15	179144.7	17.9	50.2	88.3
Error	69	160751.7	15.2	49.4	80.7

* significant at the .05 level of probability
** significant at the .01 level of probability

TABLE III

AVERAGE EFFECT OF ROW WIDTH AND CULTIVAR ON GRAIN YIELD OF SIX SOYBEAN CULTIVARS (LOCATION I)

Cultivar	Row Width (cm)				Mean Grain Yield (kg/ha)
	25	50	75	100	
Elf	1837.2	2315.5	1820.4	2149.4	2030.6
Douglas	4485.1	4384.2	3237.8	4824.8	4232.9
Essex	3296.4	3068.3	3377.1	3331.4	3268.3
Forrest	3647.5	3967.8	3519.0	3642.2	3694.1
Gail	4198.5	3942.2	2931.1	3693.3	3691.3
Ransom	3154.4	2955.9	3110.7	4004.8	3306.5
Mean Grain Yield (kg/ha)	3436.5	3438.9	2999.4	3607.7	

LSD(0.05) for Row Width = 451.9 kg/ha
LSD(0.05) for Cultivars = 553.5 kg/ha

TABLE IV

AVERAGE EFFECT OF ROW WIDTH AND CULTIVAR ON GRAIN YIELD OF SIX SOYBEAN CULTIVARS (LOCATION II)

Cultivar	Row Width (cm)				Mean Grain Yield (kg/ha)
	25	50	75	100	
Elf	3811.0	3866.8	3509.6	3061.6	3582.3
Douglas	3850.0	3908.6	3640.8	3598.4	3749.5
Essex	3077.1	3218.3	2838.5	3120.1	3088.5
Forrest	2573.2	2772.9	2379.4	2816.0	2635.4
Gail	3532.1	3494.8	2816.0	3558.7	3348.2
Ransom	1657.6	2154.1	1681.2	1948.9	1860.5
Mean Grain (kg/ha) Yield	3082.0	3235.9	2827.6	3017.3	

LSD(0.05) for Row Width = 231.1 kg/ha
LSD(0.05) for Cultivars = 283.1 kg/ha

cultivars was significantly higher when they were grown in 100 cm rows than when grown in the 75-cm rows. No significant difference was found between the mean grain yield of cultivars grown in 25-, 50-, and 75-cm rows. These results agree with Egli (22) and Parker et al. (40) who indicated that rows narrower than 100-cm usually do not show higher yields in soybean production areas in the southern U. S.

Table IV indicates that cultivars at location two yielded better when grown in 25, 50, or 100 cm row width compared to the 75 cm row width. The LSD at the 0.05 level of probability for detecting differences between row widths at location two is 231.13 kg/ha. The mean yield for the 25 cm row width was not significantly different from the mean yield at the 50 cm row width. Also, the mean yield for the 75 cm row width was not significantly different from the mean yield at the 100 cm row width. This yield increase obtained from the narrower row width is thought to be primarily due to a more even distribution of plants which results in a more effective use of water and light available in the field. Several researchers (13, 17, 18, 24, 32, 53, 56, 57, 58) have also found that narrow rows generally out-yielded wide rows.

The results from location one and location two appear to be contradictory. Perhaps the better growing conditions at location one provided less inter- and intra-row competition than the conditions at location two. This could account for the better yield being produced in the wider row width at location one but the narrow row width at location two. Doss and Thurlow (20) concluded that the row width which resulted in maximum yields was dependent on environmental growing condition.

The LSD for detecting a difference between cultivars averaged over all row widths at location one at the 0.05 level of probability is 553.5 kg/ha (Table III). Douglas was the highest yielding cultivar across all row widths with 4232.9 kg/ha. This yield was significantly greater than the yield of Ransom, Essex, or Elf. The difference between Douglas and Forrest or Douglas and Gail approached significance at the 0.05 level. The mean grain yield of Elf was 2030.6 kg/ha which was significantly less than any of the other cultivars. The difference between any two of the cultivars Essex, Forrest, Gail, and Ransom was not significant.

The LSD at the 0.05 level of probability for comparison of cultivar yields is 283.1 kg/ha at location two (Table IV). The mean grain yield of Douglas was higher than the yield of any other cultivar except Elf. The mean grain yield of Ransom across all row widths was significantly less than the yield of any other cultivar. Forrest produced a significantly lower yield than any other cultivar except Ransom. The difference between Essex and Gail was not significant.

Elf was harvested late at location one and severe shattering resulted. However, this cultivar appears to have the genetic potential for higher yields especially in the higher yielding environment of location two. Douglas performed well at both locations; thus, it appears to be superior to the other cultivars under the environmental conditions present in 1981. Essex, Gail and Forrest were intermediate in yield at both locations. Essex and Gail appear to have excellent yield stability since their yields were relatively constant at location one and location two environments. The yield of Forrest was lower than expected especially at location two. Ransom yielded well at location one but was very poor at location two. The late maturity of this cultivar probably contributed to the very low yields under the less favorable environmental conditions of location two.

Plant Height

A highly significant difference at the 0.01 level of probability was found among cultivars for plant height at both locations (Table I, II). Plant height at the 0.01 level of probability was significantly affected by row widths at location one (Table I). No significant effect of row width on plant height was found at location two (Table II). No significant interaction between cultivars and row widths was found at either location.

The average height in centimeters for the six cultivars of soybeans at both locations is presented in Tables V and VI. The LSD at the 0.05 level of probability for detecting a difference between row widths at location one is 2.8 cm (Table V). The mean plant height of the six cultivars was significantly higher when they were grown in 100 cm rows than when grown in 25, 50 and 75 cm rows. Cultivars achieved their shortest height when grown in 25 cm rows. Table V shows that there is a significant difference in the height of plants grown in 25 cm rows and other row widths, but no significant difference between the 50 and 75 cm row widths. This increase in plant height in the 100 cm rows with high plant density within the row suggests that the intra-plant competition for light was greater in wider rows than in narrow rows. Several researchers (14, 17, 41, 50, 51) have also indicated either directly or indirectly the great influence of light on plant height and yield components of soybeans.

The LSD at the 0.05 level of probability for detecting a difference between row widths at location two is 2.2 cm (Table VI). Table VI shows that there was no difference between any row width when compared to any other row width. There was no significant effect of row width on plant height at this location. This result suggests that the within-row plant competition at this location was less than that of

TABLE V

AVERAGE EFFECT OF ROW WIDTH AND CULTIVAR ON PLANT HEIGHT OF SIX SOYBEAN CULTIVARS (LOCATION I)

Cultivar	Row Width (cm)				Mean Plant Height (cm)
	25	50	75	100	
Elf	27.0	29.0	31.5	34.5	30.5
Douglas	71.0	71.0	71.0	78.5	72.9
Essex	57.0	53.5	59.0	60.5	58.0
Forrest	69.8	75.0	78.5	76.5	74.9
Gail	65.0	69.0	67.3	73.5	68.7
Ransom	84.5	92.0	88.8	91.8	89.3
Mean Plant Height (cm)	62.4	65.3	66.0	69.2	

LSD(0.05) for Row Width = 2.8 cm
LSD(0.05) for Cultivars = 3.5 cm

TABLE VI

AVERAGE EFFECT OF ROW WIDTH AND CULTIVAR ON PLANT HEIGHT OF SIX SOYBEAN CULTIVARS (LOCATION II)

Cultivar	Row Width (cm) 25	50	75	100	Mean Plant Height (cm)
Elf	41.3	39.3	40.0	42.5	40.8
Douglas	91.0	94.5	93.0	94.8	93.3
Essex	72.3	67.0	68.5	69.8	69.4
Forrest	89.5	87.5	86.0	91.3	88.6
Gail	85.8	82.5	80.5	80.0	82.2
Ransom	98.5	97.5	98.8	94.0	97.2
Mean Plant Height (cm)	79.7	78.1	77.8	78.7	

LSD(0.05) for Row Width = 2.2 cm
LSD(0.05) for Cultivars = 2.7 cm

location one.

The LSD at the 0.05 level of probability for comparison of cultivar heights at location one is 3.5 cm (Table V). The mean plant height of Ransom was significantly higher than the height of any other cultivar. The mean plant height of Elf was significantly lower than the height of any other cultivar. There was no significant difference in the mean plant height of Douglas and Forrest, but there was a significant difference between Essex and Gail. All cultivars were significantly different in their height except Douglas and Forrest.

The LSD at the 0.05 level of probability for comparison of cultivar heights at location two is 2.7 cm (Table VI). The mean plant height of Ransom was significantly higher than the height of any other cultivar. The mean plant height of Elf was significantly lower than the height of any other cultivar. There was a significant difference in the mean plant height between any two cultivars at this location. Plant height was not significantly affected by row width at location two, while it was affected by row width at location one. The differences in the plant height between cultivars at both locations appear to be primarily due to the differences in the genetic potential of the cultivar rather than to the differences in row widths.

Shattering

The cultivar effect on shattering was highly significant at the 0.01 level of probability at location one (Table I), but no shattering occurred at location two. No effect of row width and no cultivar X row width interaction was found at location one. Table VII presents the average effect of row widths and cultivars on soybean shattering at location one. The LSD at the 0.05 level of probability (0.3) for detecting a difference between row widths at this location shows no significant difference in the shattering occuring in various row widths. Thus, the differential shattering appears to be due to the genetic potential of the cultivars studied.

The LSD at the 0.05 level of probability for detecting a difference between cultivars at this location is 0.3. The cultivar Elf averaged a higher shattering score than any other cultivar. Essex and Douglas ranked second and third in shattering score, respectively. Forrest, Gail and Ransom exhibited a low shattering score of 1.0. The high shattering score of Elf and Essex affected the total yield of these cultivars.

100-Seed Weight

The effect of cultivars on 100-seed weight at the 0.01 level of probability was statistically significant at both locations. Hundred seed weight was not affected by row

TABLE VII

AVERAGE EFFECT OF ROW WIDTH AND CULTIVAR ON SHATTERING SCORE OF SIX SOYBEAN CULTIVARS (LOCATION I)

Cultivar	Row Width (cm)				Mean Score Shattering (1-5)
	25	50	75	100	
Elf	5	5	5	5	5.0
Douglas	2	2	2	2	2.0
Essex	2	3	3	3	2.8
Forrest	1	1	1	1	1.0
Gail	1	1	1	1	1.0
Ransom	1	1	1	1	1.0
Mean Score of Shattering (1-5)	2.0	2.2	2.2	2.2	

LSD(0.05) for Row Width = .3
LSD(0.05) for Cultivars = .3

width (Tables I and II). The LSD at 0.05 level of probability for detecting a difference between row widths at location one is 0.5 g and does not show any significant difference in the 100-seed weight at this location (Table VIII). The LSD at the 0.05 level of probability for detecting differences in the 100-seed weight at location two is 0.4 g. There was no significant difference in the 100-seed weight across all row widths at this location.

The LSD at the 0.05 level of probability for detecting a difference between cultivars at location one is 0.6 g (Table VIII). There was a significant difference in the 100-seed weight between cultivars. Douglas averaged 17.2 g/100 seed. Elf, Essex, Forrest, Gail, and Ransom averaged 15.9, 12.2, 11.7, 17.8, and 15.1 g/100 seed, respectively, across all row widths at location one (Table VIII).

The LSD at the 0.05 level of probability for detecting a difference between cultivars at location two is 0.5 g (Table IX). There was a significant difference in the 100-seed weight between cultivars. Douglas averaged 15.8 g/100 seed. Elf, Essex, Forrest, Gail and Ransom averaged 16.6, 11.8, 11.0, 16.2, and 10.2 g/100 seed, respectively, across all row widths at location two.

Hundred seed weight was not affected by row width at either location. There was a significant difference in the 100-seed weight of all cultivars at both locations. The 100-seed weight of Ransom was low at location two which

TABLE VIII

AVERAGE EFFECT OF ROW WIDTH AND CULTIVAR ON 100 SEED WEIGHT OF SIX SOYBEAN CULTIVARS (LOCATION I)

Cultivar	Row Width (cm)				Mean 100 Seed Weight (g/100 Seed)
	25	50	75	100	
Elf	15.5	16.4	15.8	15.8	15.9
Douglas	17.2	17.0	16.8	17.7	17.2
Essex	12.9	12.0	12.3	11.7	12.1
Forrest	12.0	11.6	11.5	11.7	11.7
Gail	17.6	18.1	17.7	17.7	17.8
Ransom	14.7	15.3	15.7	14.8	15.1
Mean 100 Seed Weight (g/100 Seed)	15.0	15.1	15.0	15.0	

LSD(0.05) for Row Width = .5 g
LSD(0.05) for Cultivars = .6 g

TABLE IX

AVERAGE EFFECT OF ROW WIDTH AND CULTIVAR ON 100 SEED WEIGHT OF SIX SOYBEAN CULTIVARS (LOCATION II)

Cultivar	Row Width (cm)				Mean 100 Seed Weight (g/100 Seed)
	25	50	75	100	
Elf	17.0	16.7	16.3	16.3	16.6
Douglas	15.3	16.1	16.1	15.8	15.8
Essex	11.0	11.8	11.9	12.6	11.8
Forrest	10.9	10.9	11.0	11.0	11.0
Gail	16.1	16.4	16.2	16.1	16.2
Ransom	10.1	10.3	10.2	10.2	10.2
Mean 100 Seed Weight (g/100 Seed)	13.4	13.7	13.6	13.7	

LSD(0.05) for Row Width = .4 g
LSD(0.05) for Cultivars = .5 g

probably contributed to the low yield produced by this cultivar under the less favorable environmental conditions at location two. The 100-seed weights of the other cultivars were nearly constant at both locations. Probst (43), Lehman and Lambert (35), and Weber et al. (58), found that seed size is independent of row width. Also, variation in seed size is greater within cultivars rather than between spacings within cultivars.

Seeds Per Plant

The number of seeds per plant shows a highly significant response to the cultivars at the 0.01 level of probability at both locations. It was also significantly affected by row width at the 0.05 level of probability at location one (Table I), and at the 0.01 level of probability at location two (Table II). No cultivar X row width interaction was found at either location.

The average effects of row width and cultivar on the number of seeds per plant at both locations is presented in Tables X and XI. The LSD at 0.05 level of probability for detecting a difference between row widths at location one is 9.9 seeds (Table X). Table X shows that the mean number of seeds per plant was highest for all cultivars when they were grown in 100 cm rows. The lowest number of seeds per plant was obtained from 75 cm rows. There was a significant difference in the mean number of seeds per plant between the

TABLE X

AVERAGE EFFECT OF ROW WIDTH AND CULTIVAR ON THE NUMBER OF SEEDS PER PLANT OF SIX SOYBEAN CULTIVARS (LOCATION I)

Cultivar	Row Width (cm)				Mean Seeds Per Plant
	25	50	75	100	
Elf	43.3	52.8	42.3	50.3	47.2
Douglas	96.5	95.3	71.8	100.0	90.9
Essex	95.0	94.3	101.5	104.3	98.8
Forrest	113.0	127.5	113.0	115.5	117.3
Gail	88.0	80.3	61.3	77.3	76.7
Ransom	78.5	71.3	74.0	100.3	81.0
Mean Seeds Per Plant	85.7	86.9	77.3	91.3	

LSD(0.05) for Row Width = 9.9 seeds
LSD(0.05) for Cultivars = 12.2 seeds

TABLE XI

AVERAGE EFFECT OF ROW WIDTH AND CULTIVAR ON THE NUMBER OF SEEDS PER PLANT OF SIX SOYBEAN CULTIVARS (LOCATION II)

Cultivar	Row Width (cm) 25	50	75	100	Mean Seeds Per Plant
Elf	69.3	71.5	67.3	58.0	66.5
Douglas	76.8	74.5	69.8	70.3	72.9
Essex	86.5	84.3	76.0	77.0	80.9
Forrest	73.0	78.8	66.0	78.8	74.2
Gail	68.0	66.0	53.8	68.5	64.1
Ransom	50.5	64.3	50.8	58.8	56.1
Mean Seeds Per Plant	70.7	73.2	63.9	68.6	

LSD(0.05) for Row Width = 5.2 seeds
LSD(0.05) for Cultivars = 6.3 seeds

100 cm and 75 cm rows, but no significant difference between the 25, 50 and 100 cm rows for all cultivars at this location. Taylor (54), Lehman and Lambert (35) and Kantanka and Lawson (32) indicated that as row width increased, the number of seeds per plant increased. The plants in 100 cm row width consistently produced more seeds per plant than those in narrow row widths.

The LSD at the 0.05 level of probability for detecting differences between row widths at location two is 5.2 seeds (Table XI). Table XI shows that the highest number of seeds per plant was obtained when cultivars were grown in 25, 50 and 100 cm rows. The lowest number was obtained when cultivars were grown in 75 cm rows. A significant difference is presented in the mean number of seeds per plant between the 50 and 75 cm row widths. No significant difference was found between 25, 50 and 100 cm row widths. Also, no significant difference in the mean number of seeds per plant was found between the 75 and 100 cm row widths at this location. There was a small increase in the number of seeds per plant in the 50 cm rows compared to the 100 cm rows at this location. The cultivars studied showed an increase in the number of seeds per plant across all row widths at location one. The cultivars studied at location two also produced the highest number of seeds per plant in the 100 cm rows with a small unexpected increase from narrow row widths.

The LSD at the 0.05 level of probability for detecting a difference between cultivars at location one is 12.2 seeds (Table X). Table X shows that Elf, Douglas, Essex, Forrest, Gail and Ransom averaged 47.2, 90.0, 98.8, 117.3, 76.7, and 81.0 seeds per plant, respectively. Forrest produced the highest number of seeds and Elf produced the lowest number of seeds per plant. There was a significant difference between Forrest and all other cultivars. No significant difference was detected between Douglas and Essex or between Gail and Ransom. A significant difference did exist between the mean number of seeds of Elf and any other cultivar at this location.

The LSD at the 0.05 level of probability for detecting a difference between cultivars at location two is 6.3 seeds (Table XI). Table XI shows that Elf, Douglas, Essex, Forrest, Gail and Ransom averaged 66.5, 72.9, 80.9, 74.2, 64.1 and 56.1 seeds per plant, respectively across all row widths at this location. Essex produced the highest number of seeds and Ransom produced the lowest number of seeds per plant across all row widths. The difference in the number of seeds per plant was significant between Essex and any other cultivar. The difference was not significant between Douglas and Forrest or between Elf and Gail, but there was a significant difference between Gail and Ransom and between Elf and Ransom.

The results from location two shows that Elf produced a relatively large number of seeds which might contribute to the high yield produced by this cultivar at this location. Forrest produced the highest number of seeds per plant at location one but it was not reflected in its grain yield. The results from location one show that Ransom produced the lowest number of seeds per plant, and Essex produced the highest number of seeds. It appears that the difference in the mean number of seeds per plant is mainly due to the differences in the environmental conditions presented at both locations in 1981.

CHAPTER V

SUMMARY AND CONCLUSIONS

This study was conducted on the Agronomy Research Station, Perkins, Oklahoma, and on the Oklahoma Vegetable Research Station, Bixby, Oklahoma, in the 1981 growing season. The objectives of this study were to evaluate the effect of various row widths on six soybean cultivars and to determine which combination of treatments yielded the best at both locations. This study dealt with six soybean cultivars (Elf, Douglas, Essex, Forrest, Gail and Ransom) and four row widths (25, 50, 75, and 100 cm) at each location. Plant populations used were 27 plants/square meter at location one and 32 plants/square meter at location two. Cultivars and row widths were arranged in a factorial fashion. The experiment at both locations was layed out in a randomized complete block design with four replications.

Characters analyzed were grain yield, plant height, shattering, 100-seed weight, and seeds per plant. Statistical analysis was carried out for each character to provide information on the effects of cultivar and row width on these characters.

Grain yield was significantly affected by cultivars at the 0.01 level of probability, and by row spacings at the 0.05 level of probability at location one. The grain yield was significantly affected by row width and cultivar at the 0.01 level of probability at location two. The grain yield was highest for all cultivars grown in 100 cm rows at location one. The 75 cm row width was out-yielded by the 25 and 50 cm row width. Douglas yielded the best at this location and Elf yielded the lowest. Soybean cultivars yielded the highest when they were grown in 50 cm row width at location two. The 75 cm row width was out-yielded by 25 and 100 cm row width. Douglas also yielded the highest at this location, but Ransom yielded the lowest across all row widths. No cultivar X row width interaction was found at either location.

Plant height was significantly affected by various row widths at the 0.01 level of probability at location one, but no row width significant effect on plant height was found at location two. The mean plant height of the six cultivars was highest when they were grown in 100 cm rows, and was lowest in 25 cm rows at location one. The mean plant height of all cultivars was highest when they were grown in 25 cm rows, and was lowest in 75 cm rows at location two. Elf, Douglas, Essex, Forrest, Gail and Ransom averaged 30.5,72.9, 58.0, 74.9, 68.7 and 89.3 cm at location one, and they averaged 40.8, 69.4, 88.6, 82.2 and 97.2 cm at location two. No cultivar X row width interaction was found at either location.

The cultivars significantly affected shattering at the 0.01 level of probability at location one, but no shattering was recorded at location two. Elf averaged a higher score in shattering than did other cultivars. No effect of row spacing, and no cultivar X row width interaction was found.

The difference in 100-seed weight among cultivars was statistically significant at both locations, but no significant affect of various row spacings on 100-seed weight was found at either location. Elf, Douglas, Essex, Forrest, Gail, and Ransom averaged 15.9, 17.2, 12.2, 11.7, 17.8, and 15.1g/100 seeds, respectively, at location one, whereas they averaged 16.6, 15.8, 11.8, 11.0, 16.2, and 10.2g/100 seeds respectively at location two. No cultivar X row width interaction was found at either location.

The number of seeds per plant shows a significant response to the cultivars at the 0.01 level of probability at both locations. It was also significantly affected by row width at the 0.05 level of probability at location one, and at the 0.01 level of probability at location two. Elf, Douglas, Essex, Forrest, Gail and Ransom averaged 47.2, 90.9, 98.8, 117.3, 76.7, and 81.0 seeds per plant, respectively, at location one. Whereas they averaged 66.5, 72.9, 80.9, 74.2, 64.1, and 56.1 seeds per plant, respectively, across all row widths at location two. The mean seeds per plant was highest when cultivars were grown in 100 cm rows and was lowest when they were grown in 75 cm rows at location one. No significant difference in the number of seeds per plant was found between various row widths at location two, and no cultivar X row width interaction was found at either location.

In conclusion, this study indicates that the soybean yield is considerably affected by cultivars and by spacing of the plants. Not only by the distribution of the plants within the row, but also by the distance between rows. The yield response of soybean cultivars to row spacings was not the same at both locations. The short determinate cultivar Elf did not yield as well as the other determinate cultivars at location one, whereas it out-yielded all other determinate cultivars at location two. The yielding ability of the tall indeterminate cultivar Douglas at both locations suggests that it may be a desirable high yielding cultivar in soybean production areas in Oklahoma. This study also suggests that cultivars studied might respond well to wider rows (100 cm) under the adequate rainfall and better soil conditions at lccation one and they might respond better to narrow rows (25-50 cm) where the inter- and intra-plant competition was less than that of wider rows at location two.

Plant height was affected by row width at location one, but it was not affected by row width at location two. This indicates that the competition among plants for light was greater at location one than location two. The difference in plant height appears to be primarily due to the differences in the genetic potential of cultivars studied. The late harvesting of Elf and Essex resulted in a high shattering score of these cultivars. This might be an important factor which affected the yield of these cultivars.

The 100-seed weight was not affected by row width at either location. This result suggests that seed size is independent of row width and the variation in seed size is mainly due to the differences in genetic potential of different cultivars rather than to the differences in row widths. The number of seeds per plant was affected by row width. The highest number of seeds resulted from wider rows, and a small increase in the number of seeds resulted from 50 cm rows. This suggests that there is a linear relationship between row width and the number of seeds per plant. These results are from a one-year study and more intensive research needs to be done to determine the optimum row width for Oklahoma soybean growers.

LITERATURE CITED

1. Basnet, B., E. L. Mader, and C. D. Nickell. 1974. Influence of between and within-row spacing on agronomic characteristics of irrigated soybean. Agron. J. 66:657-659.

2. Beaver, J. S. and R. R. Johnson. 1981. Response of determinate and indeterminate soybeans to varying cultural practices in the northern U.S.A. Agron. J. 73:833-838.

3. Bello, A. B., W. A. Cerom-Diaz, C. D. Nickell, E. O. El Sherif, and L. C. Davis. 1980. Influence of cultivar, between row spacing, and plant population of fixation of soybeans. Crop Sci. 20:751-755.

4. Bernard, R. L. 1972. Two genes affecting stem termination in soybeans. Crop Sci. 12:235-239.

5. Beuerlein, J. E., J. W. Pendleton, M. E. Bauer, and S. R. Ghorasky. 1971. Effect of branch removal and plant populations at equidistant spacings on yield and light use efficiency of soybean canopies. Agron. J. 63:317-318.

6. Boerma, H. R. 1979. Comparison of past and recently developed soybean cultivars in maturity Groups VI, VII, and VIII. Crop Sci. 19:611-613.

7. Boone, Lester V. 1975. Producing Farm Crops. The Interstate Printers, and Publishers, Inc., Danville, Ill.

8. Brigham, Raymond D. 1979. Registration of Gail soybean. Crop Sci. 19:747.

9. Brim, C. A. and C. Elledge. 1973. Registration of Ransom soybeans. Crop Sci. 13:130.

10. Burnside, O. C. and R. S. Moomaw. 1977. Control of weeds in narrow-row soybeans. Agron. J. 69:793-796.

11. Burnside, O. C. and R. S. Moomaw. 1979. Soybean (Glycine max) growth as affected by weed removal, cultivar, and row spacing. Weed Sci. 27:562-565.

12. Caldwell, B. E. and Grant Vest. 1970. Effects of Rhizobium Japanicum strains on soybean yields. Crop Sci. 10:19:21.

13. Carter, T. E. and H. R. Boerma. 1979. Implications of genotype X planting date and row spacing interaction in double-cropped soybean cultivar development. Crop Sci. 19:607-610.

14. Caviness, C. E. and Charmras Prongsirivathana. 1968. Inheritance and association of plant height and its components in a soybean cross. Crop Sci. 8:221-224.

15. Cooper, Richard L. 1971. Influence of early lodging on yield of soybean. Agron. J. 63:449-450.

16. Cooper, Richard L., A. K. Walker, and M. H. Niehaus. 1978. Elf - a new type of soybean variety for Ohio growers. Ohio Report: 63 - May-June. Ohio Agric. Res. Develop. Center, Wooster, Ohio.

17. Costa, J. A., E. S. Oplinger, and J. W. Pendleton. 1980. Response of soybean cultivars to planting patterns. Agron. J. 72:153-156.

18. Delorit, Richard J., Louis J. Geub, and Henry L. Ahlgren. 1974. Crop Production. Prentice-Hall, Inc., Englewood Cliffs, N.J.

19. Dies, Edward J. 1943. Soybean: gold from the soil. The MacMillan Co., New York.

20. Doss, B. D. and D. L. Thurlow. 1974. Irrigation, row width, and plant population in relation to growth characteristics of two soy bean varieties. Agron. J. 66:620-623.

21. Doss, B. D., R. W. Pearson, and Howard T. Rogers. 1974. Effect of soil water stress at various growth stages on soybean yield. Agron. J. 66:297-299.

22. Egli, D. B. and J. E. Leggett. 1973. Dry matter accumulation patterns in determinate and indeterminate soybeans. Crop Sci. 13:220-222.

23. Fehr, W. R. and S. R. Rodriguez. 1974. Effect of row spacing and genotypic frequency on the yield of soybean blends. Crop Sci. 14:521-525.

24. Gedge, D. L., W. R. Fehr, and A. K. Walker. 1977. Intergenotypic competition between rows and within blends of soybeans. Crop Sci. 17:787-790.

25. Hartung, R. C., J. E. Specht, and J. H. Williams. 1980. Agronomic performance of selected soybean morphological variants in irrigation culture with two row spacings. Crop Sci. 20:604-609.

26. Hartwig, E. E. and C. J. Edwards, Jr. 1970. Effects of morphological characteristics upon seed yield in soybeans. Agron. J. 62:64-65.

27. Hartwig, E. E. and J. M. Epps. 1973. Registration of Forrest soybeans. Crop Sci. 13:287.

28. Hicks, D. R., J. W. Pendleton, R. L. Bernard, and T. J. Johnson. 1969. Response of soybean plant types to planting patterns. Agron. J. 61:290-293.

29. Hill, L. D. 1976. World Soybean Research. The Interstate Printers and Publishers, Inc., Danville, Ill.

30. Hoggard, A. L., J. Grover Shannon, and D. R. Johnson. 1978. Effect of plant population on yield and height characteristics in determinate soybeans. Agron. J. 70:1070-1072.

31. Horvath, E. A. 1939. The Soybean Industry. Chemical Pub. Co. of New York, Inc.

32. Kantanka, Osei Safo, and Norman C. Lawson. 1980. The effect of different row spacings and plant arrangements on soybeans. Can. J. Plant Sci. 60:227-231.

33. Lawn, R. J. and D. E. Byth. 1974. Response of soybeans to planting date in south eastern Queensland. II, Vegetative and reproductive development. Aust. J. Agric. Res. Part II:723-737.

34. Leffel, R. C. 1961. Plant lodging as a selection criterion in soybean breeding. Crop Sci. 1:346-349.

35. Lehman, W. F. and J. W. Lambert. 1960. Effects of spacing of soybean plants between and within rows on yield and its components. Agron. J. 52:84-86.

36. Lin, Chi-Chen and James H. Torrie. 1970. Inter-row competitive effects of soybean genotypes. Crop Sci. 10:599-601.

37. Leuschen, W. E. and D. R. Hicks. 1977. Influence of plant population on field performance of three soybean cultivars. Agron. J. 19:390-392.

38. Markley, Klare S. and Warren H. Goss. 1944. Soybean Chemistry and Technology. Chemical Pub. Co., Inc., Broclyn, N.Y.

39. Norman, A. G. 1963. The soybean: Genetics, Breeding, Physiology, Nutrition, and Management. Academic Press, New York. pp. 161-164.

40. Parker, M. B., W. H. Marchant, and B. J. Mullinix, Jr. 1981. Date of planting and row spacing effects of four soybean cultivars. Agron. J. 73:759-762.

41. Pendleton, J. W., D. B. Peters, and D. R. Hicks. 1969. Influence of supplemental light on apparent photosynthesis, yield, and yield components of soybeans. Crop Sci. 9:577-581.

42. Pendleton, J. W. and E. E. Hartwig. 1973. Management In B. E. Caldwell (ed.), Soybeans: Improvement, Production, and Uses. Amer. Soc. of Agron., Madison, Wis.

43. Probst, A. H. 1945. Influence of spacing on yield and other characters in soybeans. Jour. Amer. Soc. Agron. 37:549-554.

44. Reich, R. C., E. J. Kamprath, and L. A. Nelson. 1981. Soil management factors correlated with soybean yields in the southern U.S. coastal plain. Agron. J. 73:90-95.

45. Reiss, W. D. and L. V. Sherwood. 1964. Effect of row spacing, seeding rate and potassium and calcium hydroxide additions on soybean yields on soils of southern Illinois. Agron. J. 57:431-433.

46. Ryder, Gordon J. and J. E. Beuerlein. 1979. Part one, soybean production: a system approach. Crops and Soils, Feb., pp. 7-9.

47. Ryder, Gordon J. and J. E. Beuerlein. 1979. Part two, soybean production: a system approach. Crops and Soils, Mar., pp. 9-11.

48. Scott, W. O. and Samuel R. Aldrich. 1970. Modern Soybean Production. Sanda Publications, Champaign, Ill., pp. 53-56.

49. Shaw, R. H. and C. R. Weber. 1967. Effects of canopy arrangements on light interception and yield of soybeans. Agron. J. 59:155-159.

50. Shibles, R. M. and C. R. Weber. 1966. Interception of solar radiation and dry matter production by various soybean planting patterns. Crop Sci. 6:55-59.

51. Shibles, R. M. and D. E. Green. 1969. Morphological and physiological considerations in breeding for narrow rows. Dept. of Agron., Iowa State Univ., Ames, Iowa, pp. 1-8.

52. Smith, T. J. and H. M. Camper. 1973. Registration of Essex soybean. Crop Sci. 13:495.

53. Spilde, LeRoy A., Dean A. Whited, and R. J. Sletteland. 1980. The effect of row spacing on soybean yields. N. D. Farm Res., Dept. of Agron., N. D. State Univ., Fargo, N. D. 37:11-18.

54. Taylor, H. M. 1980. Soybean growth and yield as affected by row spacing and by seasonal water supply. Agron. J. 72:543-547.

55. Terman, G. L. 1977. Yields and nutrient accumulation by determinate soybeans as affected by applied nutrients. Agron. J. 69:234-265.

56. Timmons, D. R., R. F. Halt, and R. L. Thompson. 1967. Effect of plant population and row spacing on evapotransporation and water-use efficiency by soybeans. Agron. J. 59:262-265.

57. Wax, L. M. 1972. Weed control for close-drilled soybeans. Weed Sci. 20:16-19.

58. Weber, C. R., R. M. Shibles, and D. E. Byth. 1966. Effect of plant population amd row spacing on soybean development and production. Agron. J. 58:99-102.

59. Wiggans, R. G. 1939. The influence of space and arrangement on the production of soybean plants. Jour. Amer. Soc. Agron. 31:314-321.

60. Wilcox, J. R. 1974. Response of three soybean strains to equidistant spacings. Agron. J. 66:409-412.

VITA

Mahmoud Y. Sabbouh

Candidate for the Degree of

Master of Science

Thesis: RESPONSES OF SIX SOYBEAN CULTIVARS TO VARIOUS ROW SPACINGS

Major Field: Agronomy

Biographical:

Personal Data: Born in Ra's Al Aeim, Syria, January 1, 1954, the son of Yousef and Tamrah Sabbouh.

Education: Graduated from Bouka Agricultural Secondary School, Latakia, Syria, in 1972; received the Bachelor of Science degree in Agriculture from the University of Damascus in 1977; completed requirements for the Master of Science degree at Oklahoma State University in May, 1982.

Professional Experience: Teaching assistant at the College of Agriculture, Damascus University, 1978-80; graduate research assistant, Department of Agronomy, Oklahoma State University, 1980-82.

Professional Organizations: Member of the American Society of Agronomy and the Crop Science Society of America.