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To the Graduate Council:

I am submitting herewith a thesis written by V. Subbiah entitled "Varietal Responses of Soybeans to Different Row Spacings." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

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VARIETAL RESPONSES OF SOYBEANS TO
DIFFERENT ROW SPACINGS

A Thesis
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

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V. Subbiah
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CHAPTER I

INTRODUCTION

The soybean, Glycine max (L.) Merril, is a very ancient crop in the east Asian countries. In the United States large scale production of soybeans, chiefly as a forage crop, commenced in the beginning of the twentieth century. The acreage harvested for beans greatly increased from less than 6 million acres in 1941 to over 27 million acres in 1961 (1). Currently, soybeans rank fourth in value among the cash crops grown in the United States. The United States produces 57 per cent of the total world crop of soybeans (5). Soybeans are primarily produced for oil and protein for human foods and animal feeds (14). The development of improved varieties and the solution of several management problems through plant breeding and agronomic research have resulted in increased yields.

Soybeans are now normally planted in rows, while they are also planted either broadcast or in drills, particularly on sloping land to reduce soil erosion. The influence of spacing on yield seems to depend upon length of growing season, growth type of varieties in adapted areas, soil fertility, moisture status and date of planting. In the northern states soybeans in narrow rows of 18 to 28 inches generally produce the highest yields whereas in the southern states there has been little advantage of

planting in rows closer than 36 to 42 inches (13). Studies also show that there are varietal differences in the response to row spacing.

The yield of soybeans is determined by the size and number of seed per unit area. The latter is regulated by the number of fertile pods per plant, number of seeds per pod and the number of plants per unit area. The experiment reported herein was conducted to determine the influence of five different spacings between rows on the components of yield and other characteristics of three adapted varieties of soybeans.

CHAPTER II

REVIEW OF LITERATURE

The early methods of planting soybeans include broadcasting and drilling in rows with 7- or 8-inch spacing. In the past two decades planting soybeans in rows spaced so as to permit cultivation has gained favor over the two earlier methods. This change in method of planting allows greater efficiency in weed control. In the northern and southern growing areas representing widely different growing conditions, there have been several studies conducted to determine the optimum spacing.

The shift towards row planting gained popularity much earlier in the northern corn belt areas where low soil temperature is a great handicap in the destruction of weeds prior to planting (22).

Pendleton et al. (18), using several varieties of soybeans in spacing tests conducted in three geographically different locations in Illinois, found no difference in yield among varieties planted at different row spacings. All of the varieties yielded highest in 24-inch rows and the lowest yield was obtained from 40-inch rows. The yield for the 24-inch row spacing was 15 per cent higher than that for the 40-inch spacing. They suggested that the lower pod formation in the 40-inch spacing might further reduce yields if the crop was combined. While row spacing had a distinct

influence on yield, seeding rates of 60, 75, 90 or 105 pounds per acre did not result in appreciable differences in yield.

Lehman and Lambert (15), in Minnesota, conducted detailed studies with Blackhawk and Mandarin varieties on the effect of spacing of plants between and within rows on the components of yield, viz., number of seed and pods per plant, seed weight and seeds per pod. The row spacings studied were 20 and 40 inches and spacings in the row were 4, 8, 16 and 24 plants per foot of row. Seed yields tended to be higher in the narrower row spacing but the effect of spacing within the row was variable. Increasing the spacing between the rows increased the number of seeds and pods per plant but did not affect seed weight or number of seeds per pod. The number of branches increased consistently with increase in row spacing. A greater per cent of the total seed per plant was produced on branches at the 40-inch spacing than at the 20-inch spacing. The number of seed per pod on branches and on main stems were not greatly different.

Ohio results indicated a yield advantage for spacings of 21-to 32-inches over a 42-inch spacing (8). At Columbus, Ohio, early varieties of soybeans produced higher yields in rows of 21-to 32-inch spacing if sown early in the season, but if planting was delayed the yield advantage was for wider spacings (19). Calland (4), from a survey of principal soybean counties of north-western Ohio, found that the weed problem in solid plantings forced the farmers to resort to row plantings for easier weed control.

According to Hanway (9) the yield will increase as the distance between rows is decreased until the leaves of plants meet with those in adjoining rows and completely shade the ground. In tests in Lincoln, Nebraska, he found that 21-inch spaced rows yielded higher than row spacings of 28, 35 and 42 inches.

Wiggans (23) used row spacings of 8, 12, 16, 24 and 32 inches and spacings within the row of $1/2$, $1\ 1/8$, $1\ 1/2$, $2\ 1/4$, 3, $4\ 1/2$ and 6 inches in studies with the Cayuga variety of soybean. He consistently obtained higher yields in four years where the distance between rows and between the plants in the row was almost equal. He found the optimum spacing to be six plants per square foot of area for this variety. He suggested that optimum rates and spacings for soybeans should be determined not only for the various soybean producing regions but also for the varieties to be grown and that large, late maturing varieties would not be expected to require the same spacing for optimum yields as would small, early maturing varieties.

Indiana results indicate that there is higher yield advantage for close spacing of early maturing than for mid-season soybeans (2). Row spacings of 24 to 32 inches were usually found to produce the highest yield for erect growing early varieties but wider spacings were more desirable for late varieties.

In tests for a period of eleven years in Illinois, a row spacing of 24 inches yielded higher than a spacing of 8 inches between the drills. The number of pods set per plant was higher

in the 24-inch spacing as compared to the 8-inch drill planting. The number of immature pods per plant was higher in the drill planting than in the 24-inch spacing (3).

Spacing test results on weed free lands on southeastern Kansas (25) showed that the highest yield was obtained in 7-inch or 21-inch rows, and the lowest yield was obtained in 42-inch rows.

Hildebrand et al. (11), in Michigan, and Smith (19), in Ohio, are in agreement that solid planting does not allow good weed control, requires more seed, and usually make harvest operations difficult. Smith also found that frequently the stand in solid planting was poor and lodging severe.

Spain et al. (21), in North Carolina, found that broadcasting soybeans required aerial operations for chemical control of weeds and insects, whereas the row-planted beans performed better and were adapted to conventional methods of weed and insect control. They also found row spacings of 36 to 42 inches quite satisfactory in a normal planting season, but if planting was delayed there was yield advantage for narrower rows.

McClelland (16), reporting on tests conducted in Arkansas over a period of twelve years, showed the superiority of row planting over drill and broadcast methods. In drill and broadcast stands he obtained very frequent crop failures and low yields, which were attributed to inadequate soil moisture, lack of cultivation and competition of weeds.

In tests in Arkansas in 1956 and 1957 high yields were

obtained in spacings of 7 and 10 inches (7). This was believed to be due to the quicker shading of the soil in these narrow rows than was obtained in spacings of 36 to 42 inches. From tests conducted in Arkansas in 1950 and 1951, Hartwig (10) reported that 10-inch row spacings gave higher yields than 20 and 40-inch spacings.

Hartwig (10) reviewed in detail row spacing and rate of planting studies on soybeans in the south. The general findings were that the optimum rate within the row was 10 to 12 viable seeds per foot and that there was usually no yield advantage for planting in rows spaced closer than 36 to 40 inches. Planting fewer seeds than 10 to 12 per foot of row led to difficulty in early season weed control. When the seeding rate of 10 to 12 seeds per foot of row was exceeded it favored early season weed control but resulted in lodging. In the south higher yields are usually obtained in wider spaced rows than in the narrower spacings which have a yield advantage in the north. The southern adapted varieties have much more foliage than the northern varieties and are capable of filling the row middles of 36-and 40-inch rows.

Results in west Florida showed that row spacing had very little influence on yield where recommended rates of fertilizer and seed were used (20).

Mooers (17) studied the influence of row spacings of 18 inches to 36 inches on the yield of three different varieties of soybeans in Tennessee in 1907. He obtained the higher yield of

beans in the 18-inch row spacing. However, he recommended the 30-inch spacing.

Chandrasekaran¹ studied the influence of fertilizer and row spacing on the Ogden variety of soybeans. He reported somewhat higher yields for the 18-inch row spacing than for the 36-inch spacing and that the number of pods and branches per plant were less with the narrower spacing. He found that spacing did not influence number of seeds per pod, test weight per bushel or weight of 100 seeds.

Hinson and Hanson (12), conducted plant competition and spacing studies on four varieties of soybean in pure stands and in three different mixtures of the same four varieties at within row spacings of 2, 4, 8, 16, and 32 inches. They reported that the relative yield was influenced more by spacing than by plant competition due to changes in the phenotype of surrounding plants.

Caviness (6) studied the influence of moderate skips in the row of an otherwise complete stand and reported that a 4-foot skip in an 18-foot row barely reduced yields. With a 6-foot skip nearly 95 percent of the yield from optimum stands was obtained. This demonstrated the compensative ability of soybean plants.

¹Chandrasekaran, S. The effect of fertilization and spacing on the yield and composition of soybeans. Unpub. M. S. Thesis, The University of Tennessee, Knoxville, Tennessee, 1961.

CHAPTER III

MATERIALS AND METHODS

A split-plot field design was used in this experiment in which Hill, Ogden and Lee varieties were the main plots and spacings between rows of 18, 24, 30, 36 and 42 inches were the subplots. The treatments were replicated four times. Only three replications were used for obtaining the final yield data because of abnormal growth in the fourth replication. The Hill, Ogden and Lee represent early, mid-season and late type varieties. Descriptions of the varieties are given in Appendix A. The number of rows planted at each spacing in each plot was 8, 6, 4, 4 and 3 representing the spacings from the narrowest to the widest.

The field experiment was conducted on Huntington fine sandy loam. The soil was very high in available P, low to medium in available K and had a pH of 6.2. The field was fertilized with 17.6 pounds of P and 33.2 pounds of K per acre using 200 pounds of 0-20-20 fertilizer.

The experimental field received normal preparatory cultivations and soybeans were planted on May 9, 1963. The inoculated seeds were sown by means of a hand seeder in furrows made with a push plow. The seeding rate was 10 to 12 seeds per foot of row. Germination and subsequent stand were quite satisfactory. The soybeans were cultivated twice with a push plow 13 and 28 days

after seeding. There was no further need for cultivation to control weeds.

General observations on the date of first flowering, general flowering and cessation of flowering were made.

A few days prior to harvest five plants per plot were selected from the central rows in areas having a stand of 8 to 10 plants per foot of row. These selected plants were used to determine the influence of row spacing on plant height, node number on the stem at which lowest branches were formed, height at which lowest pod was set, the total nodes on main stem, the number of branches, number of nodes on all branches, the number of total pods, barren pods, two-seeded and three-seeded pods on the stem and branches, and weight of 100 seeds.

The plants were harvested by hand sickles after trimming the 20-foot rows to 19 feet. The center rows of the plots, either 4, 2, or 1 depending upon the spacing, were harvested to obtain plot yields. The beans were threshed by machine immediately after harvest. Hill, Ogden and Lee varieties were harvested 155, 161, and 173 days respectively from the date of seeding. The plot yield included the yield from the five plants sampled for plant measurements. Estimation of moisture content using the Steinlite moisture meter and the determination of test weight per bushel were made.

CHAPTER IV

RESULTS

I. PLANT GROWTH AND FLOWERING

The seedling emergence and subsequent stand of all the varieties were satisfactory. Lee showed more vigorous, early plant growth than did Ogden and Hill. It completely shaded the row middles of the 18-inch spacing in 39 days from seeding while Ogden and Hill required 54 to 65 days, respectively. The shading of row middles in the wider spacings occurred later.

Lee was the earliest to lodge. It lodged severely in the 18-inch spacing to the extent of about 80 % of the plants by 59 days from seeding, at which time plants in the 42-inch spacing were almost free from lodging. During the same period lodging was about 20 % in the 18- and 24-inch spacings of Hill variety while plants of Ogden variety showed no signs of lodging at any spacing. At the time of harvest all plots were severely lodged.

The data on plant height, number of branches and number of nodes on main stem and branches are summarized in Table 1. The plant height and the internodal length decreased with an increase in row spacing. The mean height of plants for the 18-inch spacing was 52.9 inches and 45.0 inches for the 42-inch spacing. The plant height averaged 39.5 inches in Hill while both Ogden and Lee averaged 51.8 inches. The number of

Table 1- Effect of row spacing on certain characteristics of 3 soybean varieties.*

Variety	<u>Row spacing, inches</u>					Variety mean
	18	24	30	36	42	
<u>Plant height in inches</u>						
Hill	42.2	40.2	38.4	38.4	38.4	39.5
Ogden	56.0	54.2	50.0	49.9	49.1	51.8
Lee	60.4	52.7	51.1	47.3	47.4	51.8
Spacing mean	52.9	49.0	46.5	45.2	45.0	—
<u>Number of nodes on main stem</u>						
Hill	15.1	15.4	15.9	15.6	15.5	15.5
Ogden	17.2	18.2	18.3	19.2	19.2	18.4
Lee	15.6	16.1	16.5	16.3	16.5	16.2
Spacing mean	16.0	16.6	16.9	17.0	17.1	—
<u>Number of branches per plant</u>						
Hill	6.0	7.9	8.4	7.8	9.0	7.8
Ogden	5.1	5.9	8.5	10.6	9.4	7.9
Lee	3.7	6.0	7.1	9.7	9.4	7.2
Spacing mean	4.9	6.6	8.0	9.4	9.3	—
<u>Number of nodes on branches</u>						
Hill	18.4	24.9	29.7	26.7	30.8	26.1
Ogden	26.4	28.9	42.0	46.4	46.2	37.9
Lee	19.2	21.7	28.6	33.9	33.5	27.4
Spacing mean	21.3	25.2	33.4	35.7	36.8	—

*Values are averages of 5 plants from each of 3 replications.

branches per plant increased with increase in spacing up to 36 inches, the 18-inch spacing averaging 4.9 and the 36-and 42-inch spacing averaging 9.4 and 9.3 branches per plant, respectively. The range in number of branches per plant among the varieties was 7.2 to 7.9. Row spacing had little influence on number of nodes on the main stem, increasing from 16 for the 18-inch spacing to about 17 for the 42-inch spacing. The number of nodes on the branches increased with row spacing and ranged from 21.3 to 36.8. Hill, Lee and Ogden had 26.1, 27.4 and 37.9 nodes on branches.

Table 2 shows the influence of row spacing on the node number on the stem at which the lowest branch occurred and on the height of the lowest pods on the stem. With increasing row spacing the node number of the lowest branch and the height of lowest pods were decreased. The average node number ranged from 5.5 to 4.7 and the height from 12.4 to 9.3 inches for the 18-inch to 42-inch spacings. The lowest branches and pods of Hill were nearer the ground than those of the other two varieties.

The influence of row spacing on flowering of the soybean varieties is given in Table 3. The average number of days to first flowering for the different spacing was 77 to 78, the number of days to general flowering 82 to 83, and the duration of flowering 18 to 20 days. There were varietal differences in the initiation and duration of flowering. Hill was the earliest to flower, 73 days as compared to 79 and 80 for Ogden and Lee.

Table 2 - Height from ground of lowest pods and branches of 3 soybean varieties as influenced by row spacing.*

Variety	<u>Row spacing, inches</u>					Variety mean
	18	24	30	36	42	
	<u>Node number on stem of lowest branch</u>					
Hill	5.4	5.1	5.0	4.4	4.2	4.8
Ogden	6.1	5.8	5.2	5.3	4.9	5.5
Lee	5.1	5.3	4.8	5.1	5.1	5.1
Spacing mean	5.5	5.4	5.0	4.9	4.7	—
	<u>Height in inches from ground of lowest pods</u>					
Hill	12.2	10.7	8.6	8.1	8.0	9.5
Ogden	12.4	10.4	10.5	10.7	10.1	10.8
Lee	12.5	11.1	9.9	10.5	9.7	10.7
Spacing mean	12.4	10.7	9.7	9.8	9.3	—

*Values are averages of 5 plants from each of 3 replications.

Table 3 - Effect of row spacing on the flowering of 3 soybean varieties.*

Variety	<u>Row spacing, inches</u>					Variety mean
	18	24	30	36	42	
<u>Number of days from seeding to first flowering</u>						
Hill	73	73	73	73	73	73
Ogden	79	79	79	78	78	79
Lee	81	80	81	80	79	80
Spacing mean	78	77	78	77	77	—
<u>Number of days from seeding to general flowering</u>						
Hill	79	78	79	78	78	78
Ogden	83	82	83	84	81	83
Lee	87	86	86	87	86	86
Spacing mean	83	82	83	83	82	—
<u>Number of days from seeding to cessation of flowering</u>						
Hill	94	94	93	91	95	93
Ogden	98	97	98	99	97	98
Lee	97	98	97	98	98	98
Spacing mean	96	96	96	96	97	—
<u>Duration of flowering in days</u>						
Hill	21	21	20	18	22	20
Ogden	19	18	19	21	19	19
Lee	16	18	16	18	19	17
Spacing mean	19	19	18	19	20	—

*Values are averages of observations on 3 replications.

Hill also had a slightly longer flowering period, 20 days compared to 17 and 19 days for Lee and Ogden, respectively.

II. POD AND SEED PRODUCTION

The number of pods on the main stem and branches is presented in Table 4. The total number of pods per plant increased with increase in spacing up to the 36-inch spacing and there was slight reduction at the 42-inch spacing. The range in the number of pods from narrowest to widest spacing was 66.1 to 116.6. The differences between spacings were highly significant except between the 36- and 42-inch spacings. The number of pods on both main stem and branches increased with increase in spacing in the same manner as did total pods per plant. The number of pods on the main stem and branches averaged 14.4 and 51.7, respectively, for the 18-inch spacing and 27.1 and 89.5 for the 42-inch spacing. There were no appreciable differences in the percentage of total pods that were borne on the branches at the different spacings; the percent ranged from 73 to 78. Lee produced significantly more total pods than did Hill, 115.5 compared to 87.6. The difference between Lee and Ogden was not significant. However, the differences due to varieties were not independent since there was a high variety x spacing interaction. This interaction was probably due to Hill producing relatively few pods in the 36-inch spacing and Ogden and Lee producing relatively few in the 42-inch spacing. The branches produced 71, 79 and 78 % of the total pods on Hill, Ogden and Lee,

Table 4 - Number of pods on main stem and branches of 3 soybean varieties as influenced by row spacing.*

Variety	Row spacing, inches					Variety mean
	18	24	30	36	42	
<u>Number of pods on main stem</u>						
Hill	19.3	23.0	28.9	28.1	27.9	25.4
Ogden	10.8	17.6	21.6	26.0	22.7	19.7
Lee	13.0	30.3	23.7	31.7	30.8	25.9
Spacing mean	14.4	23.6	24.7	28.6	27.1	—
<u>Number of pods on branches</u>						
Hill	42.2	61.6	69.3	60.3	77.5	62.2
Ogden	53.3	56.0	82.4	97.9	77.3	73.4
Lee	59.7	74.7	83.6	116.2	113.6	89.6
Spacing mean	51.7	64.1	78.4	91.5	89.5	—
<u>Number of pods per plant</u>						
Hill	61.5	84.6	98.2	88.4	105.4	87.6
Ogden	64.1	73.6	104.0	123.9	100.0	93.1
Lee	72.7	105.0	107.3	147.9	144.4	115.5
Spacing mean	66.1	87.7	103.2	120.1	116.6	—
L.S.D. pods per plant:						
			Spacing mean			Variety mean
	(.05)		8.2			26.4
	(.01)		10.9			N.S.

*Values are averages of 5 plants from each of 3 replications.

respectively.

The number of fertile pods is presented in Table 5. The change in fertile pods per plant due to spacing is very similar to total pods, in that the number increased with spacing up to 36 inches but with a slight reduction at the 42-inch spacing. The range was from 50.3 for the 18-inch spacing to 103.1 for the 36-inch spacing. The differences between fertile pods at the different spacings were highly significant except between the 36- and 42-inch spacings. The range of fertile pods on the main stem was 9.3 to 22.9 and on the branches it was 41.0 to 80.2 for the 18-inch to 36-inch spacings. The trend of increase of fertile pods was very similar to that of total pods. The percentage of total fertile pods produced on the branches ranged from 75 to 81.

The differences in fertile pods for varieties were not significant; however, there was a highly significant variety x spacing interaction which may be due to Hill producing a lower number of fertile pods in the 36-inch spacing than in the 42-inch spacing. Lee had the maximum number of fertile pods, 91.2 compared to 83.5 for Ogden and 70.9 for Hill. Of these fertile pods 79, 80 and 72 % were produced on the branches of Lee, Ogden and Hill varieties, respectively.

The number of 3-seeded, 2-seeded and aborted pods per plant is given in Table 6. The number of 3-seeded pods varied from 15.7 to 40.5, increasing with spacing up to the 36-inch

Table 5 - Number of fertile pods on main stem and branches of 3 soybean varieties as influenced by row spacing.*

Variety	Row spacing, inches					Variety mean
	18	24	30	36	42	
<u>Number of fertile pods on main stem</u>						
Hill	11.8	16.7	20.6	22.6	23.8	19.1
Ogden	8.4	13.7	18.9	21.6	19.3	16.4
Lee	7.6	21.4	17.6	24.4	24.3	19.1
Spacing mean	9.3	17.3	19.0	22.9	22.5	—
<u>Number of fertile pods on branches</u>						
Hill	33.2	50.3	57.7	54.0	63.8	51.8
Ogden	46.4	52.4	75.1	92.5	69.1	67.1
Lee	43.4	56.8	71.3	94.3	94.7	72.1
Spacing mean	41.0	53.1	68.0	80.2	75.8	—
<u>Number of fertile pods per plant</u>						
Hill	45.0	67.0	78.3	76.6	87.6	70.9
Ogden	54.8	66.1	94.0	114.1	88.4	83.5
Lee	51.0	78.2	88.9	118.7	119.0	91.2
Spacing mean	50.3	70.4	87.0	103.1	98.3	—
L.S.D. fertile pods per plant:						
			Spacing mean			Variety mean
	(.05)		6.9			N.S.
	(.01)		9.2			—

*Values are averages of 5 plants from each of 3 replications.

Table 6- Number of 3-seeded, 2-seeded and aborted pods per plant as influenced by row spacing.*

Variety	Row spacing, inches					Variety mean
	18	24	30	36	42	
<u>Number of 3-seeded pods</u>						
Hill	11.8	20.1	20.8	23.2	23.2	19.8
Ogden	9.3	12.2	22.9	26.0	19.0	17.9
Lee	26.0	44.5	48.2	72.2	66.1	51.4
Spacing mean	15.7	25.6	30.6	40.5	36.1	—
<u>Number of 2-seeded pods</u>						
Hill	33.2	46.9	57.5	53.4	64.4	51.1
Ogden	45.6	53.9	71.1	88.1	69.4	65.6
Lee	25.0	33.7	40.7	46.5	52.9	39.8
Spacing mean	34.6	44.8	56.4	62.7	62.2	—
<u>Number of aborted pods</u>						
Hill	16.5	17.6	19.9	11.8	17.8	16.7
Ogden	9.2	7.5	9.9	9.8	11.6	9.6
Lee	21.7	26.8	18.4	29.2	25.4	24.3
Spacing mean	15.8	17.3	16.1	16.9	18.3	—
<u>Number of total pods</u>						
Hill	61.5	84.6	98.2	88.4	105.4	87.6
Ogden	64.1	73.6	104.0	129.9	100.0	93.1
Lee	72.6	105.0	107.3	147.9	144.4	115.5
Spacing mean	66.1	87.7	103.1	120.1	116.6	—

*Values are averages of 5 plants from each of 3 replications.

spacing. The range of 3-seeded pods was from 23.7 to 33.7% of the total pods formed. There was little effect of spacing on the number of aborted pods; however, the percent aborted pods decreased with increase in spacing. The percent of total pods that were aborted from the narrowest to the widest spacing was 24, 20, 16, 14 and 16. Varietal differences in the percentage of 3-seeded and aborted pods were evident. Of the total pods formed Lee had 45% 3-seeded and 21% aborted, Ogden had 19% and 10% and Hill had 23% and 19%.

The average number of seeds per pod is given in Table 7. There were no appreciable differences in seeds per pod at the different spacings. The seeds per pod from the narrowest to the widest spacing were 2.3, 2.4, 2.3, 2.4 and 2.4. There were some varietal differences; Lee, Hill and Ogden had 2.6, 2.3 and 2.2 seeds per pod. There were no differences between number of seeds per pod borne on the main stem and branches.

The data on the number of seeds borne on the main stem and branches are summarized in Table 8. There were highly significant differences in number of seeds per plant at the different spacings. The average number of seeds produced from the narrowest to the widest spacing were 116.2, 166.5, 204.6, 246.7 and 232.8. The number of seeds on the main stem and branches at the different spacings followed the same trend as pods per plant. The number of seeds produced on the main stem and branches were 21.8 and 54.3, 94.4 and 178.5, respectively, for the 18-inch and 42-inch spacings.

Table 7-Number of seeds per pod of 3 soybean varieties as influenced by row spacing.*

Variety	<u>Row spacing, inches</u>					Variety mean
	18	24	30	36	42	
<u>Number of seeds per pod on main stem</u>						
Hill	2.4	2.3	2.4	2.4	2.4	2.4
Ogden	2.2	2.2	2.3	2.2	2.3	2.2
Lee	2.5	2.6	2.5	2.6	2.6	2.6
Spacing mean	2.4	2.4	2.4	2.4	2.4	—
<u>Number of seeds per pod on branches</u>						
Hill	2.2	2.3	2.2	2.4	2.2	2.3
Ogden	2.2	2.2	2.2	2.2	2.2	2.2
Lee	2.5	2.6	2.5	2.6	2.5	2.5
Spacing mean	2.3	2.4	2.3	2.4	2.3	—
<u>Number of seeds per pod per plant</u>						
Hill	2.3	2.3	2.3	2.3	2.3	2.3
Ogden	2.2	2.2	2.2	2.2	2.2	2.2
Lee	2.5	2.6	2.5	2.6	2.6	2.6
Spacing mean	2.3	2.4	2.3	2.4	2.4	—

*Values are averages of 5 plants from each of 3 replications.

Table 8- Number of seeds on main stem and branches of 3 soybean varieties as influenced by row spacing.*

Variety	Row spacing, inches					Variety mean
	18	24	30	36	42	
<u>Number of seeds on main stem</u>						
Hill	28.2	38.8	48.6	53.8	56.4	45.2
Ogden	18.3	29.7	43.8	48.1	43.9	36.8
Lee	18.9	55.4	44.7	63.1	62.8	49.0
Spacing mean	21.8	41.3	45.7	55.0	54.3	—
<u>Number of seeds on branches</u>						
Hill	73.8	115.3	128.7	122.7	142.0	116.5
Ogden	100.5	114.8	166.5	205.8	152.2	147.9
Lee	108.9	145.5	181.6	246.6	241.4	184.8
Spacing mean	94.4	125.2	158.9	191.7	178.5	—
<u>Number of seeds per plant</u>						
Hill	102.0	154.1	177.3	176.5	198.4	161.7
Ogden	118.8	144.5	210.3	253.9	195.8	184.7
Lee	127.8	200.9	226.3	309.7	304.2	233.8
Spacing mean	116.2	166.5	204.6	246.7	232.8	—
L.S.D. seeds per plant:						
			Spacing mean			Variety mean
	(.05)		6.3			63.4
	(.01)		8.4			N.S.

*Values are averages of 5 plants from each of 3 replications.

There was little influence of spacing on the percent of total seeds borne on the branches, the range being 75 to 81%. Lee produced a significantly greater number of seeds per plant than did Hill but the difference between Lee and Ogden was not significant. Lee produced an average of 233.7 seeds per plant while Ogden and Hill produced 184.7 and 161.7, respectively. A variety spacing interaction was due to the varieties Hill, Ogden and Lee not showing a consistent response to spacing.

There was no appreciable difference in seed weight at the different spacings, as may be seen in Table 9. However there were slight varietal differences. The weights for 100 seed were 16.2, 15.3 and 13.7 grams for Ogden, Lee and Hill, respectively.

III. YIELD OF BEANS

The yields of the soybean varieties at the different row spacings are shown in Table 10. The acre yields for the spacings from 18 to 42 inches were 35.7, 39.1, 40.9, 37.2 and 38.7 bushels. Yields at the different row spacings were not significantly different. Differences in yield among varieties were not great, with Ogden yielding 40.7 bushels per acre, Hill, 37.9 bushels and Lee, 36.3 bushels. The varietal differences were independent of spacing as there was no significant variety x spacing interaction. The only great difference observed in variety response to spacing was the low yield of 29.6 bushels for Lee at the 18-inch spacing.

Table 9 -Seed weight of 3 soybean varieties as influenced by row spacing.*

Variety	Weight of 100 seeds, g.					Variety mean
	Row spacing, inches					
	18	24	30	36	42	
Hill	13.8	13.5	13.9	13.8	13.4	13.7
Ogden	16.0	16.1	16.4	16.5	16.0	16.2
Lee	15.1	15.0	15.4	15.5	15.4	15.3
Spacing mean	15.0	14.9	15.2	15.3	15.3	—

*Values are averages of 3 samples from each of 3 replications.

Table 10-Yield of 3 soybean varieties as influenced by row spacing.*

Variety	Yield, bu./Acre					Variety mean
	Row spacing, inches					
	18	24	30	36	42	
Hill	37.3	37.9	40.3	37.2	36.6	37.9
Ogden	40.1	40.1	41.6	41.0	40.8	40.7
Lee	29.6	39.3	40.7	33.4	38.6	36.3
Spacing mean	35.7	39.1	40.9	37.2	38.7	—
L.S.D.	(.05)		Spacing mean N.S.			Variety mean 3.7

*Values are averages of 3 replications.

CHAPTER V

DISCUSSION

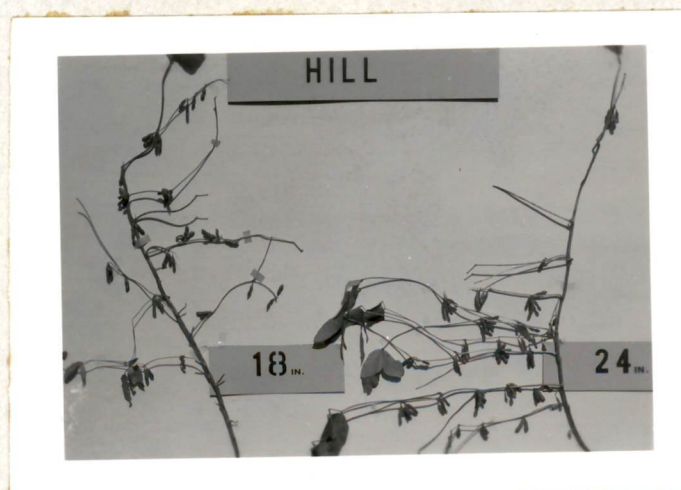
The early development of a canopy over the row middles at the 18-inch spacing was seen in all varieties. The early shading resulted in less weed growth at this spacing. Probably greater plant height in these narrow rows and early canopy development caused the crop to lodge to a greater extent in them than in the wider row spacings. The quicker shading of row middles and increased lodging observed at this narrow row spacing is in agreement with earlier reports. Lee lodged severely while Ogden showed considerable resistance in the early period of growth.

Increasing the row spacing exposed the plants to more light which evidently resulted in an increased number of branches, a reduced plant height and an increase in number of nodes. Lehman and Lambert (15) and Chandrasekaran in Tennessee also found an increase in number of branches with increase in row spacing. Pendleton (18) found that pods formed lower on the stem of plants in a 40-inch spacing than were formed in narrower spacings. This study also indicated some reduction in the height of the lowest branches and pods as the spacing increased. Varietal differences were observed in plant height and number of nodes. Hill was shorter than the other two varieties. Ogden had the maximum number of nodes. Hill formed pods and branches lower than did the other two varieties. The influence of row

spacing on plant growth of the three varieties are shown in Figures 1 to 3. It may be seen from the photographs that there is an increase in the number of branches and pods on the branches with an increase in the spacing. Row spacing did not greatly influence flowering except for a slight lengthening of duration of flowering in the wider spacings.

In this study the increase in the number of pods and seeds per plant with an increase in spacing was evident and is in general agreement with findings of earlier workers such as Chandrasekaran and Lehman and Lambert (15). The increases in the number of total pods, fertile pods and seeds were similar, increasing with wider spacings up to 36 inches and slightly less at the 42-inch spacing. The cause of the decreases at the 42-inch spacing is not known.

Varietal differences in the number of pods and seeds per plant were significant, but there was no significant difference for fertile pods. However, the varietal influence was not independent of spacing because there was a high interaction between them. The branches produced more pods and seeds at all spacings than did the main stem. Branch to stem ratios for pods and seeds were calculated to indicate their relative productivity. In the 18-inch spacing the branch to stem ratios were 3.6, 4.4 and 4.3 for number of pods, fertile pods and seeds per plant, whereas for the 42-inch spacing they were 3, 3, 3.4 and 3.0, respectively. Lehman and Lambert (15) reported a branch-stem

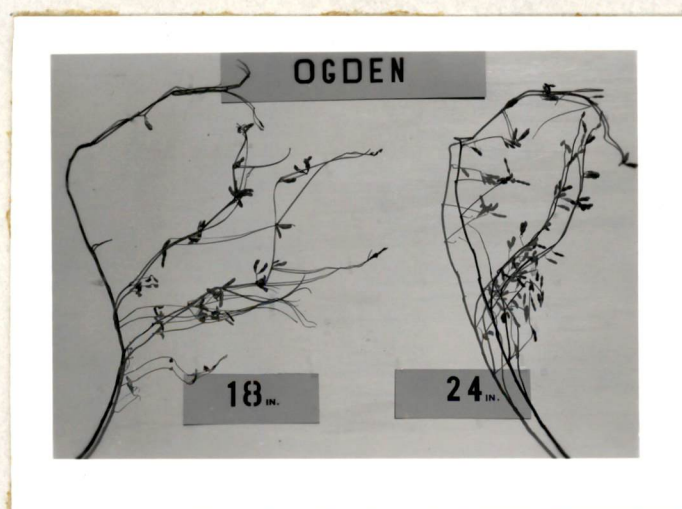


(a)

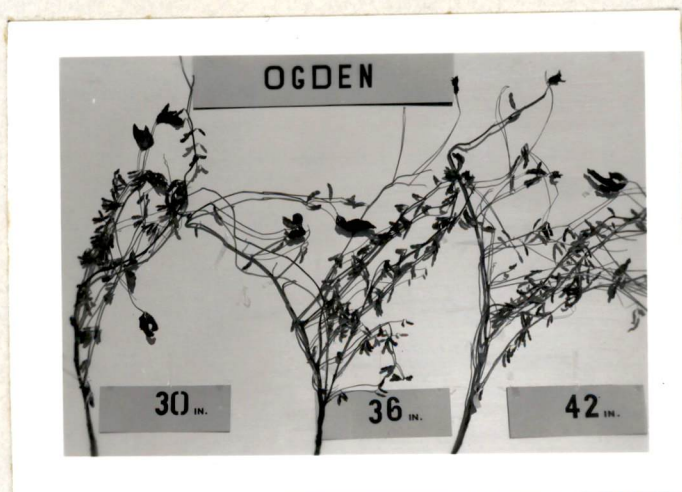


(b)

Figure 1-Photographs of the Hill variety of soybeans used in this study showing plant characteristics at maturity for the different row spacings.

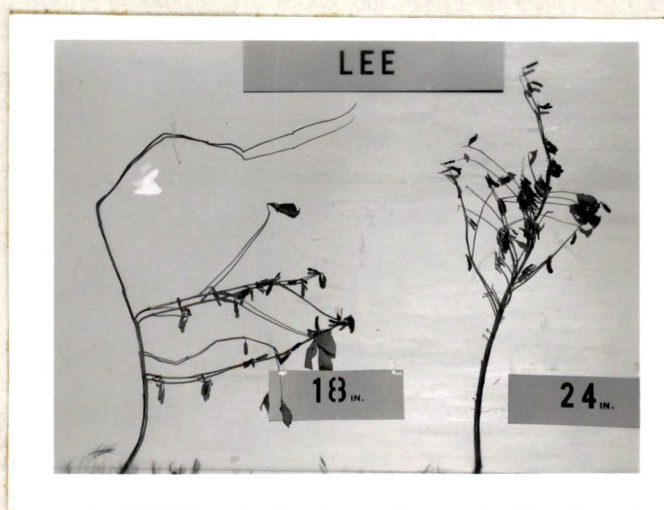


(a)

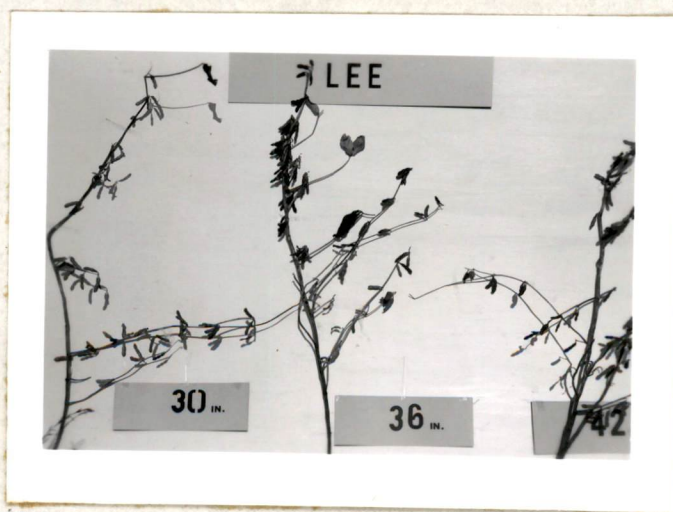


(b)

Figure 2-Photographs of the Ogden variety of soybeans used in this study showing plant characteristics at maturity for the different row spacings.



(a)



(b)

Figure 3-Photographs of the Lee variety of soybeans used in this study showing plant characteristics at maturity for the different row spacings.

ratio of less than one in their studies, indicating that the northern varieties they used were more dependent on the main stem for production of pods and seeds than are the southern varieties used in this study. Hill was somewhat more dependent on the main stem for production than was either Ogden or Lee. The branch-stem ratios for total pods for the varieties Hill, Ogden and Lee were 2.4, 3.7 and 3.4 and the ratios for seeds 2.6, 4.0 and 3.8.

The absence of any influence of row spacing on number of seeds per pod is in agreement with other workers. Also from data not reported here it was found that row spacing did not influence the test weight per bushel. It was also found that row spacing did not greatly influence the weight of 100 seeds.

There was some varietal differences in number of seeds per pod. Lee had considerably more 3-seeded pods and a higher average seeds per pod than the other two varieties. Woodworth (24) found that certain of the varieties he tested had predominantly 3-seeded pods. Spacing had some influence on production of 3-seeded pods.

The differences in yield per acre at the various spacings were not significant. However, all varieties yielded the highest at the 30-inch spacing. The yields for Lee at the 18- and 36-inch spacing were lower than those for the other treatments. The reasons for these differences are not known. Ogden produced the highest yield of beans. From the results it can be seen that Ogden had the lowest percentage of aborted pods and had the

highest unit seed weight. Woodworth (24), studying factors associated with yield of soybeans, found that only a low percentage of aborted seeds and a high unit seed weight were highly correlated with yield.

The yields obtained from the harvested rows were different from yields one might expect from a study of the plant sample data. This indicates that the size of the sample or the sampling technique did not give representative samples of the populations.

The yield of soybeans is determined by the average seed size, number of seeds per pod, number of pods per plant and number of plants per unit area. The results of this study show that the yield components, weight per 100 seed and seeds per pod, were not greatly affected by changes in spacing. On the other hand, the plants of the varieties studied were able to adjust to different spacings by changes in number of pods and seeds per plant. The increase in branching of these varieties with an increase in spacing is probably responsible in part for the higher seed production per plant and high yields at low plant populations. Although varietal response to row spacing was not always the same, Ogden, Hill and Lee reacted similarly to changes in spacing. There seems to be no advantage for narrow row spacing for these branching southern varieties.

CHAPTER VI

SUMMARY AND CONCLUSIONS

A split plot experiment with soybeans is reported with varieties as the main plots and different row spacings as the sub-plots. Hill, Ogden and Lee were the varieties and the row spacings were 18, 24, 30, 36 and 42 inches. General observations on seedling emergence, crop growth, lodging and flowering were made. Detailed studies on certain growth and fruiting characteristics were made on five plants from each treatment in each of the three replications. Plants from central rows of each treatment were harvested to obtain plot yields.

The following conclusions were drawn from the study:

1. Increase in row spacing reduced the plant height and height from ground of lowest branch and lowest pods on the plant.
2. The number of branches per plant and the number of nodes on the branches increased with increases in row spacing.
3. Plants in the narrow spacings tended to shade the row middles much earlier than in the wide spacings.
4. Lodging was much earlier and more severe in the narrow row spacings.
5. Row spacing did not influence the time and duration of flowering to a great extent.

6. Significant increase in the number of total pods, fertile pods and seeds per plant was obtained from increases in row spacing to 36 inches. However, the number of seeds per pod, seed weight per 100 and test weight per bushel were not influenced by row spacing. There was some reduction in percentage of aborted pods with increase in spacing.
7. A high percent of the pods and seed for all varieties and spacings were produced on the branches. Based on the branch to stem ratio for pods and seeds the branches seemed to be somewhat more important for production in the narrow spacings than in the wide spacings.
8. Hill variety was shorter than the other varieties and was intermediate in lodging. It flowered earlier and had the longest duration of flowering. The branches seemed to be somewhat less important for production for Hill than for Ogden and Lee.
9. Ogden showed considerable resistance to lodging. It was intermediate to Hill and Lee in flowering time. It largely depended on the branches for production and had the least percentage of aborted pods. The weight of 100 seeds was higher than the weight for the other varieties.
10. Lee showed the least resistance to lodging. It flowered late and had the shortest duration of flowering. It had the largest percentage of aborted and 3-seeded pods. The seed size was intermediate to that for Ogden and Hill.

11. The yields of soybeans obtained from the harvested rows were different from the yields calculated from the plant sample data. This indicates that the size of the sample or the sampling technique did not give a representative sample of the populations.

12. Row spacing did not significantly influence the yield.

The plants of all varieties were able to adjust to differences in row spacing by changes in the number of branches, pods and seed per plant. There seems to be no yield advantage for narrow row spacing for these branching varieties.

LITERATURE CITED

LITERATURE CITED

1. Anonymous. The soybean situation, production and research in our nation and states. National Soybean Crop Improvement Council. 1961.
2. Beeson, K. E., and Probst, A. H. Soybeans in Indiana. Indiana Agr. Ext. Bul. 231 (Revised) 1955.
3. Burlison, W. L., Van Doren, C. A., and Hackleman, J. C. Eleven years of soybean investigations. Illinois Agr. Exp. Sta. Bul. 462. 1940.
4. Calland, J. W. Cultural practices in Ohio. The Soybean Dig. 6 (6): 14-16. 1946.
5. Cartter, J. L., and Hartwig, E. E. The management of soybeans. Advances in Agronomy XIV: 359-412. Academic Press, Inc., New York. 1962.
6. Caviness, C. E. Effect of skips in soybean rows. Arkansas Farm Res. 10 (4): 12. 1961.
7. Frans, R. E. Effect on soybean yields of herbicides and narrow row width combinations. Arkansas Agr. Exp. Sta. Rept. Series 84, 1-9. 1959.
8. Glenn, F. S. Soybean research in Ohio. The Soybean Dig. 19 (7): 18-19. 1959.
9. Hanway, D. G. Growing soybeans in Nebraska. The Soybean Dig. 14 (10): 19-20. 1954.
10. Hartwig, E. E. Row width and rates of planting in the southern states. The Soybean Dig. 17 (5): 13-16. 1957.
11. Hildebrand, S. C., White, R. G., Potter, H. S., and Porter, J. A. Soybean production in Michigan. Michigan Agr. Ext. Bul. 362. 1959.
12. Hinson, K., and Hanson, W. D. Competition studies in soybeans. Crop Sci. 2 (2): 117-123. 1962.
13. Johnson, H. W., Cartter, J. L., and Hartwig, E. E. Growing soybeans. U. S. D. A. Farmers Bul. 2129. 1959.

14. Johnson, H. W., and Bernard, R. L. Soybean genetics and breeding. *Advances in Agronomy XIV*: 149-221. Academic Press, Inc., New York. 1962.
15. Lehman, W. F., and Lambert, J. W. Effects of spacing of soybean plants between and within rows on yield and its components. *Agron. J.* 52:84-86. 1960.
16. McClelland, C. K. Methods and rates of planting soybeans. *Arkansas Agr. Exp. Sta. Bul.* 390. 1940.
17. Mooers, C. A. The soybean--A comparison with the cowpea. *Tennessee Agr. Exp. Sta. Bul.* 82. 1908.
18. Pendleton, J. W., Bernard, R. L., and Hadley, H. H. For best yields grow soybeans in narrow rows. *Illinois Agr. Exp. Sta. Illinois Res.* 2 (1), 3-4. 1960.
19. Smith, P. E. Growers should watch row width, planting date for soybeans. *Ohio Agr. Exp. Sta. Farm and Home Res. Bul.* 311 (43):27. 1958.
20. Smith, R. L. Soybean production in western Florida. *The Soil and Crop Sci. Soc. of Florida Proc.* 19:226-231. 1959.
21. Spain, G. E., Wells, J. C., and Jones, G. Producing soybeans in North Carolina. *North Carolina Agr. Ext. Cir.* 381 (revised). 1961.
22. Weiss, M. G. Soybeans. *Advances in Agronomy I*: 77-157. Academic Press, Inc., New York. 1949.
23. Wiggans, R. G. The influence of space and arrangement on the production of soybean plants. *J. Amer. Soc. Agron.* 31:314-321. 1939.
24. Woodworth, C. M. Genetics of the soybean. *J. Amer. Soc. Agron.* 25:36-51. 1933.
25. Zahnley, J. W. Soybean production in Kansas. *Kansas Agr. Exp. Sta. Bul.* 306. 1942.

APPENDIX

APPENDIX

SOYBEAN VARIETAL DESCRIPTIONS

- Hill An early variety averaging about 21-28 days earlier than Lee. Hill has medium plant height and heavy foliage and is similar to the Lee variety in general appearance. It is also similar to Lee in resistance to seed shattering. It has white flowers, tawny pubescence, a light-colored pod wall and the seeds are yellow with a light brown hilum.
- Ogden A variety intermediate in maturity to Hill and Lee but heavier and coarser in foliage. It is less resistant to shattering than either of the other two varieties. Ogden has purple flowers, gray pubescence and the seed have a green coat and a brownish hilum.
- Lee This variety averages about 10 days later in maturity than Ogden. Plants are of medium height and highly resistant to shattering. It has purple flowers, tawny pubescence, a light tan pod wall. Seeds are yellow with a black hilum.