Effect of plant population and row width on the performance of soybeans

Freddy Hernan Quintero

Follow this and additional works at: https://trace.tennessee.edu/utk_gradthes

Recommended Citation

This Thesis is brought to you for free and open access by the Graduate School at TRACE: Tennessee Research and Creative Exchange. It has been accepted for inclusion in Masters Theses by an authorized administrator of TRACE: Tennessee Research and Creative Exchange. For more information, please contact trace@utk.edu.
To the Graduate Council:

I am submitting herewith a thesis written by Freddy Hernan Quintero entitled "Effect of plant population and row width on the performance of soybeans." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant, Soil and Environmental Sciences.

Laurence N. Skold, Major Professor

We have read this thesis and recommend its acceptance:

N. S. Hall, C. R. Graves

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)
To the Graduate Council:

I am submitting herewith a thesis written by Freddy H. Quintero entitled "Effect of Plant Population and Row Width on the Performance of Soybeans." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant and Soil Science.

Laurence N. Skold, Major Professor

We have read this thesis and recommend its acceptance:

[Signatures]

Accepted for the Council:

L. Evan Pott
Vice Chancellor
Graduate Studies and Research
EFFECT OF PLANT POPULATION AND ROW WIDTH ON THE PERFORMANCE OF SOYBEANS

A Thesis
Presented for the Master of Science Degree
The University of Tennessee, Knoxville

Freddy H. Quintero
August 1978
ACKNOWLEDGMENTS

The author wishes to express his sincere gratitude and appreciation to those who gave encouragement and assistance during the course of this project. Special thanks go to:

Professor Laurence N. Skold, my major professor, for his sound judgement in planning and directing this research, helpful suggestions and useful criticisms in writing the thesis. Also, for his untiring interest in students.

Dr. N. S. Hall of the Graduate Committee who gave advice and constructive criticism during the preparation of this manuscript and for his help, interest, understanding, and encouragement throughout the course of this study.

Professor C. R. Graves for serving on the Graduate Committee, and for kindly scrutinizing the manuscript and giving useful suggestions.

The Plant and Soil Science Department staff for their help and encouragement during the course of study.

I am also indebted to the Government of Venezuela for giving this opportunity of undergoing training at The University of Tennessee under the Gran Mariscal de Ayacucho Scholarship program.

Special thanks to my understanding wife and family whose willingness to sacrifice made the achievement of this goal possible.
ABSTRACT

The effect of genotype, row width and plant population on the growth of soybeans (Glycine max (L) Merr.) was investigated in 1977 on a Sequatchie Loam soil at the Plant Science Farm, Knoxville, Tennessee. Six genotypes, three row widths, and three plant populations were used.

Genotype had the greatest influence on plant height. The final plant heights of the two tall genotypes were 14 cm greater than the two mid-tall genotypes, and 36 cm greater than the two short genotypes. The tallest plants of each genotype were at the highest plant population. The shortest plants of each genotype were at the lowest plant population in 50 cm row widths. Differences in plant height within genotypes were observed at 5 percent level of probability. All six genotypes showed an increase in plant height with higher plant population and narrower row width.

Lee 74 and Forrest were the most susceptible genotypes to lodging. Essex, M-Sk and M6-103 were the least. Lodging was increased as row width decreased and plant population increased.

There was no major difference in seed size at the different combinations of row width and plant population studied. Essex had the largest seed and M-Sk and M6-103 the smallest. Forrest and M-Sk observed a direct relationship between plant population and seed size.

Yield of Forrest and Essex were not significantly affected by either row width or plant population. In general, higher yield for each genotype was obtained at the closest row width and high plant population.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>II. REVIEW OF LITERATURE</td>
<td>3</td>
</tr>
<tr>
<td>III. MATERIALS AND METHODS</td>
<td>13</td>
</tr>
<tr>
<td>IV. RESULTS AND DISCUSSION</td>
<td>16</td>
</tr>
<tr>
<td>V. SUMMARY AND CONCLUSIONS</td>
<td>29</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>31</td>
</tr>
<tr>
<td>APPENDIX</td>
<td>37</td>
</tr>
<tr>
<td>VITA</td>
<td>39</td>
</tr>
</tbody>
</table>
## LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Row Widths and Plant Spacing Treatment Combinations Evaluated for Each Genotype</td>
<td>14</td>
</tr>
<tr>
<td>2. Soybean Plant Height as Influenced by Genotype, Row Width, and Plant Spacing</td>
<td>17</td>
</tr>
<tr>
<td>3. Soybean Lodging Score as Influenced by Genotype, Row Width, and Plant Spacing in the Row</td>
<td>19</td>
</tr>
<tr>
<td>4. Seed Size (g/100 Seeds) among Soybean Genotypes as Affected by Row Width and Plant Spacing</td>
<td>21</td>
</tr>
<tr>
<td>5. Soybean Seed Yield (kg/ha) as Influenced by Genotype, Row Width, and Plant Spacing</td>
<td>24</td>
</tr>
<tr>
<td>6. Some General Characteristics of Genotypes Studied</td>
<td>38</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Seed Weight of Seven Genotypes at Three Plant Populations</td>
<td>22</td>
</tr>
<tr>
<td>2. Yield of Seed of Lee 74 and Forrest at Various Row Widths and Plant Spacings</td>
<td>25</td>
</tr>
<tr>
<td>3. Yield of Seed of Essex and M2634 at Various Row Widths and Plant Spacings</td>
<td>26</td>
</tr>
<tr>
<td>4. Yield of Seed of M-Sk and M6-103 at Various Row Widths and Plant Spacings</td>
<td>27</td>
</tr>
</tbody>
</table>
CHAPTER I

INTRODUCTION

The soybean is one of the oldest of cultivated crops. Its early history is lost in antiquity. The first record of the plant in China dates back to 2838 B.C. (45). The cultivated soybean probably was derived in China from a wild type, Glycine ussuriensis (L) with small seeds that grew in eastern Asia (45, 69).

Among the agricultural crops of the United States soybeans, [Glycine max (L) Merrill], rank second in value. The rapid increase in the acreage devoted to the soybean is unique among the current major crops in the United States. The acreage harvested for beans increasing from only 190,000 acres in 1920 to over 59.1 million acres in 1977. The United States now produces about 68 percent of the total world crop.

An important management decision facing soybean producers is how far apart to space soybean rows. This may seem trivial to some for it is difficult to imagine that a few inches one way or the other could influence bean yields very much. Even when soybean row spacings had been narrowed to a favorable recommended range for the plant possessing average varietal characteristics for that region, the knowledge of why yield fluctuations occur was usually left to some loose assumption concerning light and moisture relationships.

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. Planting too much seed is probably more common than planting too little. The soybean has a tremendous ability to compensate for variation in population. Therefore, the penalty for over or underplanting is relatively small (54). As row width is narrowed, planting rate should be adjusted. Use of the smaller or larger plant populations should depend on the fertility level of the field, lodging resistance of the variety, and the comformation of the variety to be used.

Previous studies have shown that row spacing and plant density may affect yield. The objective of this investigation was to determine the effect of row width and plant population on the yield of six different genotypes.
CHAPTER II

REVIEW OF LITERATURE

A survey of literature over the past several decades indicates that there has been considerable interest in determining row width and plant population that should be used to give maximum yields. Much of this work has shown that the effects of these factors are related to plant type, growth habit, and growing conditions.

Until the mid twenties, soybeans were cultivated in the United States primarily as a hay crop. The average yield in the United States for the five year period 1935-1939 was 18.9 bushels per acre (42). Most of the plantings were broadcast or drilled solid and weed control was a major problem in obtaining good quality hay.

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 (69).

Some of the advantages of growing soybeans in rows for seed production were: higher seed yield; lower seeding rate; more uniform stands; less lodging; and improved access for weed control (42). As the demand for soybeans increased in the United States, row widths ranging from 18 to 28 inches were used in the Midwest when soybeans were seeded in fertile soils under favorable conditions, while on less fertile soils the rows were spaced 28 to 36 inches apart. As farming became more mechanized, row width had to be expanded to fit the 22-inch tire or to meet favorably with the axle length of farm implements. Until
1966, tractors, planters, cultivators, sprayers, and harvesters that were being sold to farmers in the United States were designed for a 36 to 42-inch row width. In figuring the cost of converting to a 30-inch row system, expenses could range from two to thirty thousand dollars (57).

Spain et al. (61), 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 widths of 36 to 42 inches quite satisfactory in a normal planting season, but if planting were delayed there was yield advantage for narrower rows.

The yield increase associated with narrow-row culture is largely due to increased light interception and photosynthesis that allows more pods and seeds to develop to maturity, rather than aborting. In wide rows, much of the sunlight strikes the soil between rows and is wasted during early pod and seed set, a crucial period when 70 to 75 percent of the flowers may abort and never form pods. Scientists have found, for example, that soybeans planted in 10-inch rows intercept 98 percent of the available light at beginning of pod set, while those planted in 40-inch rows intercept only about 87 percent of the light.

Response to either population or row width is closely correlated with the ability of the crop to intercept most of the incoming radiation without so much growth that lodging occurs.

Wiggans (70) and Probst (51) suggested that optimum rates and widths 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 width for optimum yields as would small, early maturing varieties.

Most research over a considerable number of years in the northern soybean producing areas of the United States has shown that soybean yields are higher in rows narrower than the traditional 102 cm. However, rows narrower than 102 cm usually do not show higher yields in conventional soybean production in southern areas of the United States (49).

Row-to-row spacing of 50 to 60 cm have frequently been demonstrated to result in higher yields than when wider widths are used. Pendleton et al. (48) reported that in Illinois 61 cm rows consistently gave about 15 percent yield advantage over 102 cm rows. Calland (7) found, on the average, that narrow rows, spaced 18 to 28 inches, gave the highest yields; medium width rows, 30 to 36 inches, yielded slightly less, and wide rows, 38 to 42 inches, gave the lowest yields. Yield advantages for even narrower row widths have been reported. Timmons et al. (64) reported that yields generally increased as row width decreased from 102 to 20 cm. Weber et al. (68) found a significant linear increase in yield as row width decreased from 102 to 13 cm. Graves and McCutcheon (23) reported that 7-inch width yielded significantly more than the 20 inch and both outyielded the 30- and 40- inch widths which were not significantly different from each other when soybeans were planted July 1.

The yield advantage of row width of 25 cm or less conflicts with early reports. Burlison et al. (3), McClelland (44), and Zahnley (72)
obtained smaller yields from drilled plantings. Wiggans (70) obtained increased yield as distance between rows was decreased even with drilled plantings. The lack of weed control measures in close-drilled rows may have decreased yields in these early experiments.

Yield will increase as the distance between rows is decreased until the leaves of plants in adjoining rows meet and completely shade the soil (26). He suggests, as a rule of thumb, that if a short, early variety is being grown, or the fertility level is such that the vegetative growth is limited, spacing rows as close as available equipment will handle will usually result in higher yields than for wider rows.

Wiggans (70) concluded in 1939 that the ideal planting pattern for maximum yield was one in which the distance between the rows was equal to the distance between plants within the row. An equidistant planting pattern minimizes interplant competition and provides a plant canopy that will intercept a maximum of the incident radiation. Shibles and Weber (58), working with four populations and four row widths, were able to demonstrate that the combination that more nearly approached an equidistant spacing reached 95 percent light interception first.

In tests for a period of 11 years in Illinois, a row width of 24 inches yielded higher than a width of 8 inches between the drills. The number of pods set per plant was higher in the 24-inch width 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 width (3). Indiana results indicate that there is higher yield advantage with close spacing
of early maturing than with mid-season soybeans (2). Row width 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.

Pendleton et al. (48) using several varieties of soybeans in width tests conducted in three geographically different locations in Illinois, found no difference in yield among varieties planted at different row widths. 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 width was 15 percent higher than that for the 40-inch width. While row width 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.

Cooper (15), in Illinois, based on three years' data, established that there is a potential 10-20 percent yield advantage of 7-inch rows over 20-inch or 30-inch rows, provided weeds are effectively controlled. Graves and McCutchen (25) reported no consistent yield increase on the yields of soybeans on three soil types at the different row spacings.

Thurlow (63) published results of some experiments done at Auburn in which he indicated that with changing varieties and increased double cropping, which caused delayed planting, closer rows have resulted in increased yields even in the South. Thurlow indicated that the highest yields could be expected from 13-inch rows. However, the average of seven late plantings indicated that the greatest yield increases come from reducing row widths from 36 to 30 inches. Leffel and Barber (36) found that yield was highest at the row width of two feet in the south at late planting dates.
McClelland (44), 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.

Smith (60) in west Florida showed that row width had very little influence on yield where recommended rates of fertilizers and seed were used.

Lehman and Lambert (37), in Minnesota, found seed yields tended to be higher in the widths with 20 inches between rows than in 40-inch rows, but the effect of spacing within the row was variable. Increasing the width 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 width. Roger (53) reported higher yields in Alabama from close spacing if the beans were planted late, weeds controlled, and the seeding rate per acre was not increased.

The row width which will result in maximum yield is dependent upon length of growing season, growth type of varieties, and fertility level of the soil (8). If post-emergence cultivation is necessary for weed control, then it appears that row width cannot be reduced below 28 to 30 inches.

Trials in the southern United States have produced results similar to those in the Midwest with respect to population but not row width. Johnson and Harris (33) found that for Bragg, an optimally adapted
variety at their location, significant yield responses were not obtained for increases in population above 66 plants per meter in 91-cm rows. Two early and one late variety required 26 plants per meter of row to produce maximum yield. No yield reduction resulted from population above the optimum.

Chandrase Karan (12) studied the influence of fertilizer and row spacing on the Ogden variety of soybean. He reported somewhat higher yields for the 18-inch row spacing than for the 36-inch spacing. The number of pods and branches per plant were less with the narrower spacing. He found that spacing did not influence the seed size, seed per pod, ow weight of 100 seeds.

Caviness (9) 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 stand was obtained. Parks et al. (47) reported that in a plant one row-skip one, and a plant two-skip one system, the plant exposure to the sun was 180 degrees and 110 degrees respectively. Also the plant canopy exposure in 38-inch rows is further reduced to only 55 degrees. The plant one-skip one system gave highest yield.

Hinson and Hanson (31) conducted plant competition and spacing studies on four varieties of soybean in pure stands and in three different mixtures of the same four varieties of soybean in pure stands and in three different mixtures of the same four varieties at row widths of 2, 4, 8, 16, and 32 inches. They reported that the relative yield was influenced more by width than by plant competition due to changes in the phenotype of surrounding plants.
In the soybean-producing area of the midwestern United States, the yield of adapted soybean varieties is stable over a range of plant population. Probst (51) reported that maximum yields of well adapted varieties in 76-cm rows could be obtained with 13 to 20 plants per meter of row. Yield differences over the range of populations studied (8 to 39 plants per meter of row) averaged only 11 percent. Weber et al. (68) studied populations from 64,000 to 516,000 plants per hectare in row widths of 12.7, 25.4, 50.8, and 101.6 cm. Maximum yields occurred at either 128,000 or 257,000 plants per hectare. Yield differences between plant population were least in the widest rows.

Experiments have shown that soybeans usually produce the same yield over wide variations in populations. One strain that Wilcox (71) tested showed no measurable difference in yield when populations varied from 83,000 to 582,000 plants per hectare in equidistant spacings.

Results for planting rates within the row are, in general, similar for all producing areas. Planting rates of 6 to 12 viable seed per foot usually give most satisfactory results (8). As row width is narrowed planting rate should be adjusted. Results of studies in the regions where narrow rows are used indicate that optimum populations are six to eight plants per foot of row at harvest time in 30-inch rows, four to six in 20-inch rows, three to four in rows 10-inches or narrower (54). High seeding rates are frequently associated with increased lodging (14). Plants seeded at low rates often develop pods so low on the plant that significant losses may occur during harvest (32).

Hildebrand et al. (30), in Michigan, and Smith (59), in Ohio, are in agreement that solid planting does not allow good weed control,
requires more seed, and usually makes harvest operation difficult. Smith also found that frequently the stand in solid planting was poor and lodging severe.

Hartwig (27) reviewed in detail row width 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.

Cooper (17), in Illinois, based on his results of six years of research with soybeans, suggested a planting rate of 13.5 viable seeds per square meter is near optimum for all three row widths, 17-, 50-, and 75-cm. Also he reported that earlier maturing cultivars tend to be more responsive to 17-cm rows with yield advantages as much as 30-40 percent under very high yield conditions, with irrigation, over full season cultivars.

Increasing the population within the row tends to increase the plant height and lodging. However, the number of branches, pods, and seeds per plant usually decreases as population increases (54).

Several workers have shown that as population increases lodging increases (27, 28, 41, 62). Generally, density within row and not row width is the prime factor in lodging prior to harvest. Probst (51) reported lodging to increase with increasing density in the row,
while height, seed size, and maturity were generally unaffected. When population was increased in narrow row spacings, seeds were slightly heavier in some instances. Graves and McCutchen (25) reported that Essex soybean responded to close row spacing and higher plant population only when planting was delayed.

Cooper (14) has demonstrated that early lodging in highly productive environments reduced yield by as much as 23 percent when compared to plants that were artificially maintained in an upright position. Weber and Fehr (66) and Johnston et al. (34) obtained yield increases of 13 percent and 10 percent respectively, where natural lodging was prevented.

Basnet et al. (1) reported that their results do not agree with the results reported by Hinson and Hanson (31) and Johnson and Harris (33) that "an inverse relationship exists between seed size and plant population." Basnet et al. (1), Probst (51), and Lehman and Lambert (37) found that plant spacing in the row had no effect on seed weight.
CHAPTER III
MATERIALS AND METHODS

The experiment reported here was conducted on a Sequatchie Loam soil at the Knoxville Plant Science Farm during the 1977 growing season. A conventional seedbed was prepared by plowing the previous fall and disk ing and harrowing prior to planting in the spring. The experimental area was fertilized with 20 kg of P and 37 kg of K per ha which was broadcast and incorporated into the soil by disk ing.

Bean planting was made on May 16 at double rate using a hand planter and thinned to the desired stand in the seedling stage. During the cropping season the rainfall was not well distributed and a period of drought occurred which resulted in lower than normal yields.

A split plot design was used in this experiment in which six soybean genotypes were the main plots and seven combinations of row widths and plant populations (treatments) were the split plots. Of the six genotypes, two were tall, and cultivars 'Lee 74' and 'Forrest', two were mid-tall, the cultivar 'Essex' and the breeding line M2634, and two were short, the breeding lines M-Sk and M6-103. Table 1 shows the seven treatments evaluated for each genotype. In the 100 cm row width, plants were 6 or 3 cm apart. In the 50 cm row width, plants were 12, 6, or 3 cm apart, and in the 25 cm row width plants were 12 or 6 cm apart. This gave plant populations of $16.7 \times 10^4$ and $33.3 \times 10^4$ plants per ha in 100 cm rows, $16.7 \times 10^4$, $33.3 \times 10^4$, and $66.7 \times 10^4$ in 50 cm rows and $33.3 \times 10^4$ and $66.7 \times 10^4$ in 25 cm rows.
Table 1. Row widths and plant spacing treatment combinations evaluated for each genotype.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Row width, cm</th>
<th>Rows per plot*</th>
<th>Plants per ha ((\times 10^4))</th>
<th>Plant spacing, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>100</td>
<td>4</td>
<td>33.4</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>100</td>
<td>4</td>
<td>16.7</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>50</td>
<td>7</td>
<td>66.7</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>50</td>
<td>7</td>
<td>33.4</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>50</td>
<td>7</td>
<td>16.7</td>
<td>12</td>
</tr>
<tr>
<td>D</td>
<td>25</td>
<td>13</td>
<td>66.7</td>
<td>6</td>
</tr>
<tr>
<td>E</td>
<td>25</td>
<td>13</td>
<td>33.4</td>
<td>12</td>
</tr>
</tbody>
</table>

*Rows 3.6 meters long.
Each plot measured 3.6 meters long with either 4, 7, or 13 row per plot depending on the width between rows. Each treatment was replicated three times.

The beans were hand hoed once when they were about 40 cm in height to control weeds. Later cultivation was unnecessary because of a rapid development of a canopy which shaded out most of the weeds.

The following field data were collected and analysed:

**Plant height.** Centimeters from ground level to tip of main stem. Two height measurements were taken from the central two rows of each plot. Height measurements were taken on August 10, August 23, and September 20. The second one was used for analysis.

**Lodging.** Scored at maturity on a scale of 1 to 4, estimated visually according to the following criteria: 1 = most plants erect; 2 = most plants leaning slightly or a few plants down; 3 = 50-80 percent of plants down; 4 = 80 percent or more of plants down.

**Seed yield.** Plants were harvested by hand. A 2.4 m section of center rows of the plots, either 5, 3, or 2 depending upon the spacing, were harvested to obtain plot yields. The beans were threshed on a stationary thresher immediately after harvest. The yield of the genotypes is reported as kilogram per hectare at 13 percent moisture.

**Seed size.** Grams per 100 seeds from a randomly selected sample of clean, whole seed.

**Statistical analysis.** Calculated using an analysis of variance. L.S.D. at 5 percent level of probability was used to test significant difference among treatments and among genotypes.
CHAPTER IV

RESULTS AND DISCUSSION

Plant Height

Plants made normal, early seedling growth on all plots and varied little in height during the first month after planting. After the first month of growth, plants of the higher population plots tended to grow slightly faster than those on low population plots, primarily because of longer internodes in plants in high population plots.

The data on plant height are summarized in Table 2. Genotype had the greatest influence on plant height. The final plant heights of the two tall genotypes, Lee 74 and Forrest, were 14 cm greater than the two mid-tall genotypes 'Essex' and M2634, and 36 cm greater than the two short genotypes M-Sk, and M6-103.

The tallest plants of each genotype were at the highest plant population, which agrees with data from previously reported populations studies with soybeans (29, 68, 71).

The shortest plants of each genotype, were at the lowest population in 50 cm row width. Differences in plant height within genotypes were observed at 5 percent level of probability. Lee 74 plants were significantly shorter when plants were spaced 12 cm apart than when spaced 3 or 6 cm apart in 50 cm row widths. Essex plants were shorter at the widest plant spacing in 25 or 50 cm row widths than at closer plant spacings in 100 cm row widths.
Table 2. Soybean plant height as influenced by genotype, row width, and plant spacing.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Row width and plant spacing, cm</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>3</td>
<td>6</td>
<td>50</td>
<td>3</td>
<td>6</td>
<td>12</td>
<td>25</td>
<td>6</td>
<td>12</td>
<td>Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lee 74</td>
<td>104</td>
<td>101</td>
<td>106</td>
<td>106</td>
<td>97</td>
<td>106</td>
<td>104</td>
<td>103.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forrest</td>
<td>109</td>
<td>103</td>
<td>104</td>
<td>98</td>
<td>94</td>
<td>107</td>
<td>95</td>
<td>101.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Essex</td>
<td>91</td>
<td>88</td>
<td>83</td>
<td>86</td>
<td>81</td>
<td>83</td>
<td>79</td>
<td>84.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M2634</td>
<td>100</td>
<td>94</td>
<td>98</td>
<td>94</td>
<td>79</td>
<td>96</td>
<td>88</td>
<td>92.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M-Sk</td>
<td>74</td>
<td>69</td>
<td>78</td>
<td>70</td>
<td>60</td>
<td>76</td>
<td>66</td>
<td>70.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M6-103</td>
<td>70</td>
<td>61</td>
<td>66</td>
<td>60</td>
<td>54</td>
<td>64</td>
<td>59</td>
<td>62.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>91.3</td>
<td>86.0</td>
<td>89.1</td>
<td>85.6</td>
<td>77.6</td>
<td>88.6</td>
<td>81.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

L.S.D. 7.1 cm (.05) (treatments)

L.S.D. 21.5 cm (.05) (genotypes)
Forrest, M2634, M-Sk, and M6-103 were shorter at wide plant spacings in all row widths than at closer spacings although not significantly so in all cases.

All six genotypes showed an increase in plant height with higher plant population and narrower row width, which agrees with the results of Wilcox (71).

Lodging

Lodging is affected by numerous characters of the plant and by environmental conditions. Lodging which does not exceed a score of 2 by the system used in this study is not considered serious. Table 3 summarizes the data of lodging score as influenced by genotype, row width and plant population. Through an oversight, lodging notes were not recorded for Lee 74, although it is the most susceptible to lodging of the cultivars evaluated. Of those evaluated, Forrest was the most lodging susceptible to the seven combinations of row width and population tested. There were no appreciable differences in lodging of Forrest among for the seven treatments. Essex, M2634, M-Sk, and M6-103 genotypes showed variation in lodging score for each of the seven treatments tested. The data show that the genotypes used may be classified as susceptible to lodging. Lodging increased as row width decreased and plant population increased. Increased lodging is a characteristic response of soybean to increases in plant population (29, 52, 9).

According to Dornhoff and Shibles (18), the youngest leaves that develop in the highest light intensity have a much higher photosynthetic
Table 3. Soybean lodging score as influenced by genotype, row width, and plant spacing in the row.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>100</th>
<th>50</th>
<th>25</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Lee 74</td>
<td>-</td>
<td>*</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Forrest</td>
<td>2.3</td>
<td>2.0</td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Essex</td>
<td>1.3</td>
<td>1.0</td>
<td>1.6</td>
<td>1.0</td>
</tr>
<tr>
<td>M2634</td>
<td>2.6</td>
<td>1.0</td>
<td>3.0</td>
<td>2.0</td>
</tr>
<tr>
<td>M-Sk</td>
<td>1.3</td>
<td>1.0</td>
<td>3.0</td>
<td>1.0</td>
</tr>
<tr>
<td>M6-103</td>
<td>1.3</td>
<td>1.0</td>
<td>2.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Mean</td>
<td>1.5</td>
<td>1.2</td>
<td>2.4</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Lodging score of 1 = erect, 4 = prostrate

*Through an oversight, lodging notes were not recorded for Lee 74.
rate potential than do older shaded leaves. When lodging occurs at early pod set there is a complete disruption of this highly organized canopy. Older leaves become exposed to the light and many younger, more photosynthetically active leaves become shaded. Another way that lodging may inhibit yield is through stimulation of terminal growth and excessive branching at the expense of seed set (14).

The results presented herein agree with Cooper (17) that above a certain population level lodging becomes the more important factor, and yield gained from increasing population is smaller than the losses from lodging.

Seed Size

There was no major difference in seed size at the different combinations of row width and populations studied, as may be seen in Table 4. However, there was genotype difference, Essex having the largest seed and M-Sk and M6-103 the smallest.

There were differences at 5 percent level of significance in seed size, in some combinations of row width and plant populations, within genotypes. Lee 74 and Forrest showed significant difference in seed size for variation in plant population in 100 and 50 cm row widths.

Essex and M2634 and M-Sk showed differences with plant population changes in 25 cm row widths.

M6-103 was the only genotype that did not show any significant difference in seed size with changes in row width and plant population.

Forrest and M-Sk were the only genotypes for which there was a direct relationship between plant population and seed size (Figure 1).
Table 4. Seed size (g/100 seeds) among soybean genotypes as affected by row width and plant spacing.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>100</th>
<th>50</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Lee 74</td>
<td>10.5</td>
<td>11.1</td>
<td>10.4</td>
</tr>
<tr>
<td>Forrest</td>
<td>11.5</td>
<td>11.0</td>
<td>11.8</td>
</tr>
<tr>
<td>Essex</td>
<td>11.9</td>
<td>12.0</td>
<td>11.9</td>
</tr>
<tr>
<td>M2634</td>
<td>10.3</td>
<td>10.9</td>
<td>10.8</td>
</tr>
<tr>
<td>M-Sk</td>
<td>10.0</td>
<td>9.5</td>
<td>10.6</td>
</tr>
<tr>
<td>M6-103</td>
<td>7.4</td>
<td>7.6</td>
<td>7.6</td>
</tr>
</tbody>
</table>

Mean       | 10.3|10.4|10.5|10.3|9.8 |10.7|10.4|

L.S.D. 0.5 g (.05) (treatments)

L.S.D. 1.8 g (.05) (genotypes)
Figure 1. Seed weight of seven genotypes at three plant populations.
Essex and Forrest produced the largest seed and M-Sk and M6-103 produced the smallest.

Seed Yield

The effects of genotype, row width, and plant population level on bean yields are given in Table 5. The average yields for individual treatments ranged from 1900 to 3100 kg/ha.

The yield effect of plant population and row width for each genotype tested is given in Figures 2, 3, and 4. Forrest produced the highest yield and M6-103 the lowest.

Yield of Lee 74, as it can be seen in Table 5, is affected significantly by plant population change in 100 cm row width. Also, decrease of row width from 100 to 25 cm produced a significant increase in yield. According to the results of this study it seems that a good plant population for Lee 74 should be $66.7 \times 10^4$ plants per ha in 50 cm to 25 cm row width.

Yield of Forrest and Essex were not significantly affected by either row width or plant population.

Yield of M2634 was affected by plant population changes in the 100 cm row width. Also, its yield was affected significantly when row width was changed from 100 to 50 cm at plant population of $33.4 \times 10^4$ plants per ha. Plant population for this genotype should be $33.4 \times 10^4$ plants per hectare in 25 cm row width.

Yield of M-Sk genotype is affected greatly by row width and plant population. Plant population should be $66.7 \times 10^4$ plants per ha in 25 cm rows.
Table 5. Soybean seed yield (kg/ha) as influenced by genotype, row width, and plant spacing.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>100 Row width and plant spacing, cm</th>
<th>50</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Lee 74</td>
<td>2300</td>
<td>2700</td>
<td>2700</td>
</tr>
<tr>
<td>Forrest</td>
<td>2900</td>
<td>2900</td>
<td>2800</td>
</tr>
<tr>
<td>Essex</td>
<td>2100</td>
<td>2400</td>
<td>2200</td>
</tr>
<tr>
<td>M2634</td>
<td>2000</td>
<td>2500</td>
<td>2300</td>
</tr>
<tr>
<td>M-Sk</td>
<td>2000</td>
<td>2000</td>
<td>2700</td>
</tr>
<tr>
<td>M6-103</td>
<td>2000</td>
<td>1900</td>
<td>2300</td>
</tr>
<tr>
<td>Mean</td>
<td>2200</td>
<td>2400</td>
<td>2500</td>
</tr>
</tbody>
</table>

L.S.D. 340 Kg (.05) (treatments)
L.S.D. 890 Kg (.05) (genotypes)
Figure 2. Yield of seed of Lee 74 and Forrest at various row widths and plant spacings.
Figure 3. Yield of seed of Essex and M2634 at various widths and plant spacings.
Figure 4. Yield of seed of M-Sk and M6-103 at various row widths and plant spacings.
In general, highest yield for each genotype was obtained at the narrowest row width and high plant population.
CHAPTER V

SUMMARY AND CONCLUSIONS

A split plot design with soybeans is reported with genotypes as the main plots and different row width and plant population as subplots. Lee 74, Forrest, Essex, M2634, M-Sk and M6-103 were the genotypes and row widths were 100, 50, and 25 cm, and plants were 12, 6, or 3 cm apart in the row.

The field experiment was conducted in the summer of 1977 at the Knoxville Plant Science Farm, Knoxville, Tennessee. This research was carried on to determine the effects of plant population and row width on the performance of soybeans. Observations on plant height, lodging, seed size and seed yield were made. Plants from central rows of each treatment were harvested to obtain plot yields. During the growing season the rainfall was not well distributed and periods of drought occurred.

The following conclusions, based on one year data, were drawn from the study:

1. Genotype had the greatest influence on plant height. All six genotypes showed an increase in plant height with higher plant population and narrower row width.

2. The tallest genotypes, Lee 74 and Forrest, were the most susceptible to lodging. Mid-tall and dwarf genotypes were the least. Lodging was increased as row width decreased and plant population increased.
3. There was no major difference in seed size at the different combinations of row width and plant population studied. Essex had the largest seed and M-Sk and M6-103 the smallest. Forrest and M-Sk observed a direct relationship between plant population and seed size.

4. Higher yield for each genotype was obtained at the closest row width and high plant population.
BIBLIOGRAPHY


APPENDIX
Table 6. Some general characteristics of genotypes studied.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Plant Height Avg-cm</th>
<th>Blossom Color</th>
<th>Pubescence Color</th>
<th>Maturity Group&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Hilum Color&lt;sup&gt;2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lee 74</td>
<td>104</td>
<td>Purple</td>
<td>Tawny</td>
<td>VI</td>
<td>Black</td>
</tr>
<tr>
<td>Forrest</td>
<td>102</td>
<td>White</td>
<td>Tawny</td>
<td>V</td>
<td>Black</td>
</tr>
<tr>
<td>Essex</td>
<td>85</td>
<td>Purple</td>
<td>Gray</td>
<td>V</td>
<td>Buff</td>
</tr>
<tr>
<td>M2634</td>
<td>91</td>
<td>Purple</td>
<td>Tawny</td>
<td>V</td>
<td>Black</td>
</tr>
<tr>
<td>M-Sk</td>
<td>71</td>
<td>Purple</td>
<td>Tawny</td>
<td>V</td>
<td>Black</td>
</tr>
<tr>
<td>M6-103</td>
<td>62</td>
<td>Purple</td>
<td>Tawny</td>
<td>V</td>
<td>Black</td>
</tr>
</tbody>
</table>

<sup>1</sup>Varieties have been divided into ten maturity groups, 00 through VIII.

<sup>2</sup>All varieties studied had yellow seed coats.
VITA

Freddy Hernan Quintero was born in the district of Junin, Tachira, Venezuela, on November 10, 1951. He attended elementary school in the city of Rubio and graduated from Carlos Rangel Lamus High School in 1970.

In March 1970 he entered the Instituto Universitario de Technology Agro-Industrial Region los Andes at San Cristobal, Tachira, Venezuela, and was graduated in December, 1974, with a major in Agronomia. In January of 1974 he started to work as a crop researcher for the Venezuelan government. In August of 1975 he received a scholarship from the Venezuelan government, through the Gran Mariscal the Ayacucho program, to work toward the Master of Science degree in Plant and Soil Science.

In the fall of 1976 he entered Graduate School at the University of Tennessee and received his Master of Science degree with a major in Plant and Soil Science in August 1978.

He is married to the former Daisy Nohemi Hidalgo, and they have two sons and one daughter.