# EFFECT OF SPACING ON TWO SOYBEAN PLANT TYPES



by

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A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1973

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# INTRODUCTION

In the early history of soybean production in Kansas most of the area was planted with horse drawn planters, in 36 to 40 inch rows. Wide spacings were used for ease of using existing machinery and to allow post-emergence cultivation. With the availability of chemicals for satisfactory weed control and evolution of new varieties which have a better yield response, determination of optimum plant population and planting pattern is important.

Several studies have shown that soybeans planted in narrow rows have produced higher yields, especially in the northern states. Studies with narrow rows in Kansas and in some southern states have also given some encouraging results.

Plant spacing relates to both row spacing and within the row spacing. Plants may respond differently to variations in both row and within the row spacings, at the same density per unit area.

The spacing that will result in the maximum yield depends on many factors including the growth type of the varieties. Soybean plant types in northern U. S. have an indeterminate growth habit. Determinate plant types have been developed with the same background as some leading varieties.

This study was carried out to compare two plant types, namely an indeterminate and a tall determinate ($Dt_2$) plant type with the common genetic background of Clark soybean variety, at nine plant spacings.

## REVIEW OF LITERATURE

According to Wiggans (25) highest yield can be obtained from a uniform planting pattern, especially equidistant spacing. There is an optimum plant density beyond which there will be no further yield increase. He also observed that soybean plant, like other plants, has the ability to adjust to space, and optimum rates and spacings for soybeans should be determined for different varieties.

Buttery (2), Johnson and Harris (10), Nelson and Roberts (18), and many others have found that plant height increased at higher plant densities. Probst (19) found that varying the distance between the plants within the row had little influence on plant height, though plants spaced farther apart were generally shorter.

Buttery (2), using four populations with a row width of 30.5 cm, found that high plant density resulted in small plants but high dry weight per unit area, and low density produced larger plants with a lower dry weight per unit area. Intermediate densities produced intermediate plant size and yield. He noted that shoot/root, bean/shoot ratio, and leaf area index decreased as density increased.

Studying the effect of planting date and row width on three soybean varieties, Kilgore (14) observed that plants in 50 cm rows produced an average of 6 percent more than the plants in the 76 cm rows, and the 76 cm rows produced 8.4 percent more than the plants in the 100 cm rows.

Lehman and Lambert (16) reported that seed yields tended to be higher at the narrow row spacings, but the effects of spacing within the row were variable. The relative importance of branches varied with spacing for seed and pod number but had little or no effect on seed weight and seeds per pod.

For an average of four seeding rates, Reiss and Sherwood (20) found that plants in 60 cm rows produced the highest yields, followed by plants in 40, 20, 80, 100 cm rows.

Advantage of narrow rows has not been great in the south, (3) but in some cases yield advantages have been reported. In North Carolina, Clapp (4) noted that by narrowing the rows, a better ground cover could be obtained, especially with late planting, thus resulting in a better utilization of light and other factors.

Yields in Minnesota and Illinois in 45 to 60 cm rows have been up to 15 per cent greater than in 90 to 100 cm rows (3). In southeastern Kansas 50 cm rows produced higher yields than 100 cm rows, 75 Kg/Ha seeding rate was found to be superior in 50 cm rows, while 45 Kg/Ha was the optimum rate in 100 cm rows (3).

In Florida, in a study of the effects of date of planting and row width on yields, Smith (21) found that early and mid-season varieties, for an average of three years, produced the highest yields at row widths of 15 and 30 cm, when planted on May 15 and June 15. Yield for the late variety at the same dates and spacings was equal to or better than the yields from wider rows.

Lodging has been considered a major barrier to higher yields. Cooper (5) concluded that early lodging was very detrimental to yields in a highly productive environment, with rapid early growth resulting in severe lodging. He studied the effects of two levels of populations at two row widths and found that lodging increased and yield decreased as population in both 17 and 30 cm rows was increased. Plants in the 17 cm rows lodged more but gave better yields. In a comparison of lodged and non-lodged plants, significant yield increases were observed in both row widths, where lodging was prevented by using wire grids.

Upright soybean plants yielded 10 percent more than naturally lodged plants. Johnston and Pendleton (12) found that defoliation treatments applied to the upper, middle, and lower third of individual soybean plants, growing in natural ecosystems reduced their yield by 17, 22, and 4 percent respectively, compared to non-defoliated plants.

Johnson and Harris (10) reported that lodging generally increased with increase in population for the early and intermediate maturity varieties, but late maturing varieties lodged severely at low population and decreased as population was increased.

Probst (20) noted that lodging decreased with increasing within the row spacing. He observed that varieties classified as susceptible to lodging when planted close together may appear as being resistant to lodging when spaced farther apart.

Leffel (15) found that interaction of lodging with seed yield and quality was complex. He suggested concentration upon selection for combine harvestable yields rather than selection for lodging resistance.

According to Luellen (17), the major effect of lodging is reduced light efficiency due to increased mutual shading. In experiments to evaluate the photosynthetic contribution of leaves at different canopy levels, Johnston, et al. (13) found that adding light increased yields of the bottom, middle and top canopy positions of soybean plants by 30, 20, and 2 percent respectively. Light rich plants were found to have more seeds, nodes, pods, branches, pods per node, seeds per pod, and a higher oil content than the normal plants. Seed size and protein content, however, decreased.

As spacings between plants increased, more number of branches per plant have been noticed by Hanway (7), Beuerlin, et al. (1), and Weber and Weiss (23), and others. Beuerlin, et al. (1), in a study of the effect of branch removal found that the seed yield of normal plants increased with increased spacing, but decreased with the increased spacing of plants without branches. A population of 155,000 plants per hectare of plants without branches produced the highest yield of 4,397 kg per hectare (65.5 bu/A). They also observed that plant height, lodging, stem weight, and leaf area were greater in plants with branches. Seed weight and leaf density were greated in plants without branches.

According to Probst (19), close spacing within the row delayed maturity by 2 to 4 days. Weber, Shibles, and Byth (24) reported that maturity date was relatively unaffected by row width. They also noted that plants grown at higher density were taller, more sparsely branched, lodged more and set fewer pods and seeds than those at lower densities. Kilgore (14) reported that plants with the largest seeds gave the highest yield, and height to the first pod decreased, while the seeds per plant and branches per plant increased with an increase in row width.

In a spacing study with the genotypes of 'Clark' and 'Harosoy' soybean varieties, Shannon, Wilcox, and Probst (22) found that yield increased consistently as spacing between the hills increased for all genotypes, except the short determinate types. In general, the determinate, tall determinate, and the indeterminate genotypes of each variety matured earlier and lodged least at the intermediate plant spacing between the hills. Plants were taller when closely spaced and seed weight of all the genotypes increased as distance between the hills increased. Comparison of the genotypes within each variety revealed few significant differences for any character.

Hicks, et al. (9) compared four plant types in both 'Harosoy' and 'Clark' genetic backgrounds, in various planting patterns. They found that as plant population increased, plant height increased in narrow rows and lodging increased as row spacing decreased. Plants of the short determinate type did not lodge. Row spacing and seeding rate did not effect seed yield significantly, though the tall determinate ($Dt_2$) plants yielded 4.6 per cent more than the normal types.

In a study of two soybean plant types with a common genetic background, Hartwig and Edwards (8) found that plants with determinate growth type had a mean height of 86 cm and had a four year average yield of 2,660 kg per hectare, and the height of the indeterminate plants was 142 cm but the yield was only 80 percent of the determinate plants. The difference in yield was significant in each year of study. Excessive lodging was considered as the major factor contributing to the lower yield of the indeterminate plants. Weight per 100 seeds or seeds per pod was not changed.

Johnson and Harris (11) are of the opinion that normal soybean yields are possible even with poor stands, if the variety used is adapted to a particular location. After studying the effects of planting date, row spacings, and seeding rate on lodging and seed yield of seven soybean varieties, Cooper (6) concluded that excess seeding rates may be more deleterious to yields in narrow rows because less efficient natural thinning occurs with more the uniform plant distribution.

# MATERIALS AND METHODS

Tall determinate and indeterminate plant types with the genetic background of Clark soybeans were tested at K. S. U. Agronomy Farm at Manhattan, to evaluate the effects of nine plant spacings. The spacings used were 15.2 x 15.2 cm, 7.6 and 15.2 cm within 30.4 cm rows, 5 and 10 cm within 45.7 cm rows, 3.8 and 7.6 cm within 60.9 cm rows, and 3 and 6 cm within 76.2 cm rows. (6 x 6, 3 and 6 inches within 12 inch rows, 2 and 4 inches within 18 inch rows, 1.5 and 3 inches within 24 inch rows, and 1.2 and 2.4 inches within 30 inch rows). Two spacings factors were included which gave 231 $cm^2$ and 462 $cm^2$ per plant and populations of 430,000 and 215,000 plants per hectare.

A split-plot design was used with spacings as the main plots and plant types as sub-plots. The experiment was replicated four times.

Plots were 6.4 x 3.04 m (21 x 10 ft.) and had four 76.2 cm, five 60.9 cm, six 45.7 cm, ten 30.4, and twenty 15.2 cm rows. Planting was done with a nursery plot planter on May 25, 1972. Thinning and gap filling was done three weeks after emergence. Good weed control was obtained by the application of Treflan before planting and little hand weeding was necessary during the growing season. Three weeks before the date of maturity, the plots were trimmed to 4.88 m (16 ft.) in length. Two, three, four, five, and ten rows were respectively harvested from the 76.2, 60.9, 45.7, 30.4, and 15.2 cm rows from which yield per hectare was computed. Plots in the first replication were harvested on October 17 and unfavorable weather delayed the harvest of the rest of the plots until December 26, 1972.

Ten-plant samples were taken from each plot after all plots reached maturity to compute yield components and to measure other variables. Characters evaluated from the plant samples were pods per plant, seeds per pod, seed yield per plant, number of nodes, number of branches, shoot/bean ratio, seed size and height to first pod. Characters were evaluated for each plot as follows:

Seed Size: Weight in grams of 100 whole seeds for each plot.

Date of Maturity: Number of days after September 30 when 95 to 100 percent of the pods had ripened and most of the leaves had dropped.

Height: Height in cm from ground level to the top of matured plants.

Lodging: Each plot was assigned a visual score on a 1 to 5 scale as follows:

1 - All plants erect.

2 - Either all plants leaning slightly, or a few plants down.

3 - Either all plants leaning moderately, or 25 to 50 percent of the plants down.

4 - Either all plants leaning considerably, or 50 to 80 percent of the plants down.

5 - All plants down.

Date of maturity, height, and lodging were noted in the field at the time of maturity.

Seed Yield: Weight of air dried seed from each plot, converted from grams per plot to kilograms per hectare.

All variables were subjected to analysis of variance and compared by L. S. D. procedure at 0.05 level of probability.

# RESULTS AND DISCUSSION

## Number of Nodes

Indeterminate plants produced 2.5 nodes per plant more than the determinate plants (Table 1). This difference due to plant types was highly significant but no differences existed due to spacings (Table 7).

Table 1. Effect of plant type on number of nodes, plant height, lodging, and date of maturity.

| Plant type | No. of Nodes | Pl. Height (cm) | Lodging[1] | Maturity[2] |
|---|---|---|---|---|
| Determinate | 16.8 | 98.0 | 3.6 | 7.7 |
| Indeterminate | 19.3 | 131.4 | 3.4 | 9.8 |
| L. S. D. (0.05) | 0.9 | 3.0 | 0.1 | 0.8 |

[1]Lodging score was given on the basis of visual observation; 1 = all plants erect and 5 = all plants lodged.

[2]Date of maturity was taken as the number of days after September 30.

## Height to First Pod

Height to first pod was not effected by plant types or spacing x plant type interaction. Significant differences existed between spacings (Table 7). At all the row widths, height to first pod was greater at the higher density. Plants at the higher density in 30.4 cm rows had the pods formed highest, but plants at the lower density in the 30.4 cm rows had the pods formed closest to the ground

(5.3 cm) and these were significantly different (Table 2).

Table 2. Effect of spacing on number of nodes, height to first pod, and plant height.

| Spacing (cm) | No. of Nodes | Ht to 1st pod (cm) | Pl Height (cm) |
|---|---|---|---|
| 15.2 x 15.2 | 17.75 | 8.1 ab | 119.0 ab |
| 30.4 x 7.6 | 17.50 | 9.5 a | 118.8 ab |
| 30.4 x 15.2 | 19.25 | 5.3 c | 111.8 cde |
| 45.7 x 5.0 | 18.87 | 8.8 a | 122.5 a |
| 45.7 x 10.0 | 18.00 | 6.2 bc | 108.1 e |
| 60.9 x 3.8 | 17.12 | 7.2 abc | 117.1 abc |
| 60.9 x 7.6 | 18.37 | 6.1 bc | 110.0 de |
| 76.2 x 3.0 | 18.25 | 5.7 c | 115.6 bcd |
| 76.2 x 6.0 | 18.12 | 5.5 c | 109.7 de |
| L. S. D. (0.05) | N.S. | 2.5 | 6.4 |

## Plant Height

There were highly significant differences for plant height due to plant types and spacings (Table 7). Determinate plants were 33 cm shorter than the indeterminate plants (Table 1). With 45.7 cm between the rows, plants at the higher density resulted in the tallest plants (122 cm) and plants at the lower density in the same row width resulted in the shortest plants (108.1 cm). The difference due to plant density was the least in the 76.2 cm rows (5.9 cm), and it was not significant. The difference was significant at the other row widths.

## Number of Branches

Number of branches was significantly effected by spacing but there was no significant difference due to plant types. The highest number of branches, 1.47, was produced on plants at the lower density, spaced 76.2 and 45.7 cm between rows (Table 3). Plants at the higher density, spaced 30.4 and 15.2 cm between the rows resulted in 0.21 and 0.40 branches per plant, respectively. The difference in branching due to plant density was significant for 30.4 and 45.7 cm rows, but it was least in 76.2 cm rows.

Table 3. Effect of spacing on number of branches, lodging, and date of maturity.

| Spacing (cm) | No. of Branches | Lodging | Date of Maturity |
|---|---|---|---|
| 15.2 x 15.2 | 0.40 de | 3.26 d | 9.7 ab |
| 30.4 x 7.6 | 0.21 e | 3.48 cd | 10.2 a |
| 30.4 x 15.2 | 1.38 ab | 3.34 cd | 8.0 bcd |
| 45.7 x 5.0 | 0.83 bcd | 3.29 d | 9.3 abc |
| 45.7 x 10.0 | 1.47 a | 3.38 cd | 7.2 d |
| 60.9 x 3.8 | 0.48 cde | 3.76 ab | 10.2 a |
| 60.9 x 7.6 | 1.04 abc | 3.99 a | 8.5 abcd |
| 76.2 x 3.0 | 1.26 ab | 3.59 bc | 8.2 bcd |
| 76.2 x 6.0 | 1.47 a | 3.76 ab | 7.7 cd |
| L. S. D. (0.05) | 0.60 | 0.27 | 1.8 |

## Lodging

Highly significant differences were found for lodging between plant types and spacings (Table 8). Determinate plants lodged more than the indeterminate plants but the difference was only 0.2

(Table 1). Lodging score was given on the basis of visual observation, on a 1 to 5 scale, and statistical significance for an actual difference of 0.2 may be disregarded.

Plants spaced 60.9 x 7.6 cm were lodged most severely, with a lodging score of 3.99, followed by plants spaced 60.9 x 3.8 and 76.2 x 6 cm, with a score of 3.76 (Table 3). Lodging in plants spaced 60.9 x 7.6 (3.99) was significantly higher than observed in all other spacings. The 15.2 x 15.2 cm spacing resulted in the lowest lodging score.

Lodging notes were taken at the time of maturity. Though most of the lodging was observed after a heavy rainfall of over 5 cm in the last week of August, lodging was noticeable to varying degrees in the earlier stages.

## Date of Maturity

Date of maturity was recorded as the number of days after September 30, as none of the plots matured before that date. Indeterminate plants matured two days later than the determinate plants (Table 1) and the difference was highly significant (Table 8). Highly significant differences also existed between spacings. Plants at the higher density, spaced 30.4 and 60.9 cm between the rows, required 10.2 days (after Sept. 30) to mature. Plants spaced 45.7 x 10.0 cm (lower density) required the shortest time to mature. Maturity was delayed at the higher density at all the row spacings.

## Yield Components

1. Pods per plant:

There were no significant differences due to plant types or spacing x plant type interaction for number of pods per plant, but highly significant differences existed due to spacings (Table 9). Plants in 30.4 cm rows, at the lower density produced 57.9 pods per plant and plants at the higher density with the same row spacing produced the lowest number of pods with 39.5 (Table 4). Plants spaced 15.2 x 15.2 cm produced 40.7 pods per plant.

At all row spacings lower plant density resulted in a higher number of pods per plant, but on per unit basis, the higher density resulted in more number of pods per hectare.

2. Seeds per pod and Seed size:

There were no significant differences for seeds per pod and seed size due to plant types, spacings or plant type x spacing interaction (Table 9).

## Shoot/bean Ratio

Analysis of variance for shoot/bean ratio shows no significant difference between plant types but the shoot/bean ratio was significantly affected by spacings (Table 9). Plants spaced 60.9 x 7.6 cm had the highest ratio of 2.40. It was significantly higher than the ratio for all the spacing treatments except the 60.9 x 3.5 cm spacing which had a ratio of 2.23.

Table 4. Effect of spacing on number of pods per plant, seeds per pod and seed size (100 seed weight).

| Spacing (cm) | Pods/plant | Seeds/pod | Seed size (100 seed wt) (g) |
|---|---|---|---|
| 15.2 x 15.2 | 40.7 bc | 2.03 | 20.8 |
| 30.4 x 7.6 | 39.5 c | 2.07 | 21.1 |
| 30.4 x 15.2 | 57.9 a | 2.01 | 20.1 |
| 45.7 x 5.0 | 50.1 a | 2.04 | 20.9 |
| 45.7 x 10.0 | 53.7 a | 2.41 | 19.4 |
| 60.9 x 3.8 | 49.3 ab | 1.88 | 20.9 |
| 60.9 x 7.6 | 50.6 a | 2.21 | 21.3 |
| 76.2 x 3.0 | 51.6 a | 1.97 | 19.8 |
| 76.2 x 6.0 | 56.0 a | 2.37 | 20.3 |
| L. S. D. (0.05) | 9.0 | N.S. | N.S. |

Seed Yield per Plant

Ten-plant samples were taken from each plot from the rows that were later harvested for yield and the seed yield was added to the total plot yield. Plant types did not significantly effect the yield per plant but differences among spacings were highly significant (Table 10). Plants in 76.2 cm rows at the lower density produced the highest amount of seed, giving 24.5 g per plant (Table 5). The equidistant spacing resulted in the lowest amount of seed, with 15.7 g per plant.

Based on seed yield per plant, hypothetical plot yields were computed (Table 5). The 76.2 x 6 cm spacing which gave the highest seed weight per plant of 24.5 g, would hypothetically yield

3.92 kg per plot. The equidistant spacing, which resulted in the lowest seed yield per plant, would hypothetically yield 5.02 kg per plot. Lowest hypothetical yield was from the 60.9 x 7.6 spacing.

Table 5. Effect of spacing on shoot/bean ratio, seed yield per plant, and hypothetical plot yield.

| Spacing (cm) | Means for both plant types for Shoot/bean ratio | Seed wt. per plant (gm) | Hypothetical plot yield (Kg)[1] |
|---|---|---|---|
| 15.2 x 15.2 | 2.13 a | 15.7 d | 5.02 |
| 30.4 x 7.6 | 2.20 a | 15.9 d | 5.08 |
| 30.4 x 15.2 | 2.18 a | 23.3 ab | 3.72 |
| 45.7 x 5.0 | 2.08 a | 20.4 abc | 6.52 |
| 45.7 x 10.0 | 2.17 a | 22.9 ab | 3.66 |
| 60.9 x 3.8 | 2.23 ab | 17.6 cd | 5.63 |
| 60.9 x 7.6 | 2.40 b | 19.3 bcd | 3.08 |
| 76.2 x 3.0 | 2.17 a | 21.6 abc | 6.91 |
| 76.2 x 6.0 | 2.19 a | 24.5 a | 3.92 |
| L. S. D. (0.05) | 0.16 | 4.4 | - |

[1]Computed from seed weight per plant, assuming perfect stand (320 and 160 plants per harvested area x seed wt per plant). Not analysed.

## Yield

Analysis of variance for yield showed that difference between plant types was not significant but highly significant differences existed due to spacings (Table 10). Plant types x spacing interactions were not significant.

Equidistant spacing of 15.2 x 15.2 cm resulted in the highest yield of 3217 Kg/Ha (Table 6). Plants spaced 7.6 cm within 60.9 cm rows produced 2229 Kg/Ha, which was significantly lower than the yields obtained from plants in all other row spacings.

Table 6. Effect of plant types and spacings on yield and means for spacings and row widths.

| Spacing (cm) | Plant types: Determinate Kg/Ha | Plant types: Indeterminate Kg/Ha | Means for: Spacings[1] Kg/Ha | Means for: Row Width Kg/Ha |
|---|---|---|---|---|
| 15.2 x 15.2 | 3285 | 3150 | 3217 a | 3217 |
| 30.4 x 7.6 | 2837 | 2886 | 2862 ab | 2821 |
| 30.4 x 15.2 | 3067 | 2472 | 2779 b | |
| 45.7 x 5.0 | 2893 | 2894 | 2894 ab | 2891 |
| 45.7 x 10.0 | 2931 | 2847 | 2889 ab | |
| 60.9 x 3.8 | 2611 | 2541 | 2576 bc | 2403 |
| 60.9 x 7.6 | 2157 | 2301 | 2229 | |
| 76.2 x 3.0 | 2798 | 3059 | 2928 ab | 2882 |
| 76.2 x 6.0 | 2785 | 2888 | 2836 ab | |

[1] L. S. D. (0.05) = 412

Trends observed from the yield components were not consistent with the final yields. Differences due to spacings were significant for pods per plant and seed yield per plant, based on which hypothetical plot yields were computed, assuming perfect stand. There was no relationship of these variables to yield. However, the 60.9 x 7.6 cm spacing which resulted in the lowest final yield, also had the lowest hypothetical plot yield. The shoot/bean ratio was the highest for this spacing. A final stand count was not made but varying degrees of natural thinning may have occurred due to the competition resulting from different plant spacings. This may have caused the inconsistency with the trends observed from the yield components.

Studies in the past have indicated that early lodging is a major barrier to higher yields. Yield from plants spaced 60.9 x 7.6 and 60.9 x 3.8 was 2229 and 2576 Kg/Ha. The lodging scores for these spacings were 3.99 and 3.76, compared to 3.26 for plants with the equidistant spacing of 15.2 x 15.2 cm, which produced the highest yield. This apparent suggest some relationship but relatively high yields produced by plants spaced 3 and 6 cm within the 76.2 cm rows, with a lodging score of 3.59 and 3.76, does not agree with this. In this study there may have been some differences in the time of lodging. Heavy rains in the last week of August, and the first week of September, 1972, (Table 12) caused an appreciable amount of lodging. But lodging was also noticeable to varying degrees, prior to that, especially after the rains in mid- and late July. Lodging notes were taken only at the time of maturity and there is no evidence to show the effect of early lodging, if any, or if it was in agreement with earlier findings about effects of early lodging on yield.

The design of the experiment allowed analysis of variance with only two factors, namely, plant types and spacings. However, after the means were averaged, highest yield was from the 15.2 cm rows (Table 6). The data were further analysed, eliminating the 15.2 cm spacing, for row width and plant density effects. Thus, there were three factors, namely, plant types, row widths, and plant density. Analysis of variance for yield with these three factors showed significant differences due to row widths, but there were no significant differences due to plant types, densities, or any interactions among them (Table 11). The 60.9 cm rows width produced 2403 Kg/Ha and this was significantly lower than the yields for other row widths (L. S. D. at 0.05 level = 283 Kg/Ha).

## SUMMARY AND CONCLUSIONS

There were no differences in yield due to plant types or density, though the determinate plants and the higher density generally resulted in higher yields.

There were significant differences in yield due to spacings. The equidistant spacing (15.2 x 15.2 cm) resulted in the highest yield while the lowest yield was from plants spaced 7.6 cm within 60.9 cm rows (at the lower density). Trends observed from the yield components were not consistent with the final yields. Varying degrees of natural thinning may have been responsible for this. The spacing which resulted in the lowest yield had the highest lodging and shoot/bean ratio. There may have been differences in the time of lodging for different spacings, and studies in the past have indicated that early lodging may be a barrier to higher yields.

Plant competition is very complex. The response of plants in various planting patterns may influence plant competition differently for different variables and combining these to produce the highest yield is the main task before research workers. Certain trends could be observed by varying certain factors. Determinate plant types may produce higher yields at wider within row spacings as shown in Table 6 for the narrow row widths. A similar test, observing the time of lodging and final stand count may be helpful.

## ACKNOWLEDGEMENTS

I wish to express my appreciation and thanks to Dr. E. L. Mader, my major professor and professor of Agronomy, K. S. U., for his help with my research work and writing the thesis. Many thanks also to Dr. R. L. Vanderlip, associate professor of Agronomy, from whom I have learned a lot, and to Dr. R. H. Mattson, assistant professor of Horticulture for serving as members of my advisory committee.

I want to thank my parents, Dr. and Mrs. M. Channa Reddy, of Secunderabad, India, for helping me through school at K-State. I want to express my fond appreciation to my wife, Indira, who was here when I started my research and was a great help and who has always inspired me. And thanks to my little son, Adithya, whose birth in India, in October 1973, helped me to work on my thesis expeditiously (so I can go back and get to see him soon).

Finally I want to thank all my friends and fellow graduate students who helped me with my research and thesis.

# LITERATURE CITED


1. Beuerlin, J. E., J. W. Pendleton, M. E. Bauer, and S. R. Ghorashy. 1971. Effects of branch removal and plant population at equidistant spacings on yield and light use efficiency of soybean canopies. Agron. J. 63: 317-19.

2. Buttery, B. R. 1967. Effects of plant population and fertilizer on the growth and yield of soybeans. Can. J. Pl. Sci. 49: 659-73.

3. Carter, J. L. and E. E. Hartwig. 1962. The management of soybeans. Adv. Agron. 14: 359-412.

4. Clapp, John. 1971 As quoted in Soybean Digest. 31(7): 14.

5. Cooper, R. L. 1970. Early lodging-a major barrier to higher yields. Soybean Digest 30(3): 12-13.

6. Cooper, R. L. 1971. Influence of soybean production practices on lodging and seed yield in highly productive environment. Agron. J. 63: 490-93.

7. Hanway, D. G. 1954. Growing soybeans in Nebraska. Soybean Digest 14: 19-20.

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

9. Hicks, D. R., J. W. Pendleton, R. L. Bernard, and T. J. Johnston. 1969. Response of soybean plant types to planting patterns. Agron. J. 61: 290-93.

10. Johnson, B. J. and H. B. Harris. 1967. Influence of plant population on yield and other characteristics of soybeans. Agron. J. 59: 447-49.

11. Johnson, B. J. and H. B. Harris. 1968. Normal soybean yields possible even with poor stands. Crops and Soils 20(4): 24.

12. Johnston, T. J. and J. W. Pendleton. 1968. Contribution of leaves at different canopy levels to seed production of upright and lodged soybeans. Crop Sci. 8: 291-92.

13. Johnston, T. J., J. W. Pendleton, D. B. Peters, and D. R. Hicks. 1969. Influence of supplemental light on apparent photosynthesis, yield, and yield components of soybeans. Crop Sci. 9: 577-81.

14. Kilgore, G. L. 1966. The effect of planting date and row width on three soybean varieties. Master's thesis, Kansas State University.

15. Leffel, R. C. 1961. Plant lodging as a selecting criterion in soybean breeding. Crop Sci. 1: 346-49.

16. 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.

17. Luellen, W. R. Lodging barrier to higher soybean yields. Crops and Soils. 22(7):8-9. 1970.

18. Nelson, C. E. and S. Roberts. 1962. Effects of plant spacing and planting date on six varieties of soybeans. Washington Agr. Exp. Sta. Bull. 639.

19. Probst, A. H. 1945. Influence of spacing on yield and other characters in soybeans. J. Am. Soc. Agron. 37: 549-54.

20. Reiss, W. D. and L. V. Sherwood. 1965. Effect of row spacing, seeding rate, and potassium and calcium hydroxide additions on soybean yields on soils of southern Illinois. Agron. J. 57: 431-33.

21. Smith, R. L. 1968. Effect of date of planting and row width on yield of soybeans. Crop Sci. Soc. Florida Proc. 28: 130-33.

22. Shannon, J. G., J. R. Wilcox, and A. H. Probst. 1971. Plant response of soybeans in hill-plots. Crop Sci. 11: 477-79.

23. Weber, C. R. and M. G. Weiss. 1948. Lets push up soybean yields. Iowa Farm Science. 2: 10-12.

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

25. Wiggans, R. G. 1939. The influence of space and arrangement on the production of soybean plants. J. Am. Soc. Agron. 31: 314-21.

# APPENDIX

Table 7. Analysis of variance table for number of nodes, height to first pod, and plant height.

| Source of Variation | d. f. | Mean aquares for<br>No. of Nodes | Ht. to first pod | Pl. Height |
|---|---|---|---|---|
| Replications | 3 | 12.09 | 40.64 | 192.56 |
| Plant types (A) | 1 | 112.50** | 3.55 | 20100.06** |
| Error (a) | 3 | 5.4 | 2.66 | 165.86 |
| Spacings (B) | 8 | 3.4 | 18.86** | 199.51** |
| A x B | 8 | 1.0 | 4.18 | 37.37 |
| Error (b) | 48 | 3.7 | 6.25 | 11.21 |

Table 8. Analysis of variance table for number of branches, lodging, and date of maturity.

| Source of Variation | d. f. | Mean squares for<br>No. of Branches | Lodging | Maturity |
|---|---|---|---|---|
| Replications | 3 | 2.00 | 0.27 | 4.2 |
| Plant types (A) | 1 | 0.48 | 0.82** | 78.1** |
| Error (a) | 3 | 0.05 | 0.02 | 4.7 |
| Spacings (B) | 8 | 1.92** | 0.51** | 9.9** |
| A x B | 8 | 0.40 | 0.06 | 1.2 |
| Error (b) | 48 | 0.35 | 0.07 | 3.2 |

Table 9. Analysis of variance table for pods per plant, seeds per pod, and seed size.

| Source of variation | d. f. | Mean squares for Pods/plant | Seeds/pod | Seed size |
|---|---|---|---|---|
| Replications | 3 | 183.0 | 0.53 | 9.31 |
| Plant types (A) | 1 | 60.5 | 0.19 | 7.73 |
| Error (a) | 3 | 10.0 | 0.03 | 8.40 |
| Spacings (B) | 8 | 313.2** | 0.25 | 3.37 |
| A x B | 8 | 54.0 | 0.11 | 3.14 |
| Error (b) | 48 | 80.3 | 0.11 | 3.37 |

Table 10. Analysis of variance table for shoot/bean ratio, seed yield per plant, and yield.

| Source of variation | d. f. | Mean squares for Shoot/bean ratio | Seed yield per plant | Yield |
|---|---|---|---|---|
| Replications | 3 | .220 | 49.8 | 1109733 |
| Plant types (A) | 1 | .005 | 32.6 | 20909 |
| Error (a) | 3 | .040 | 7.1 | 183750 |
| Spacings (B) | 8 | .060* | 83.2** | 589269** |
| A x B | 8 | .018 | 5.9 | 113028 |
| Error (b) | 48 | .028 | 19.3 | 166442 |

Table 11. Analysis of variance (with three factors) for yield.

| Source of variation | d. f. | Mean squares |
|---|---|---|
| Replications | 3 | 1454038 |
| Plant types (A) | 1 | 7439 |
| Error (a) | 3 | 137101 |
| Row widths (B) | 3 | 870800** |
| Density (C) | 1 | 275625 |
| B x C | 3 | 88710 |
| A x B | 3 | 138010 |
| A x C | 1 | 107092 |
| A x B x C | 3 | 120176 |
| Error (b) | 42 | 157628 |

Table 12. Daily precipitation at Manhattan, Kansas for the period May through December, 1972.

| Date | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|
| 1 | .88 | | | .01 | 1.39 | | .88 | |
| 2 | | | | .04 | .38 | | .05 | |
| 3 | | | | .85 | | T | | |
| 4 | .04 | T | .03 | T | | .54 | | T |
| 5 | .01 | T | | .10 | | | T | T |
| 6 | | | | | T | | T | .01 |
| 7 | .66 | | | | 3.40 | | .07 | |
| 8 | T | | .08 | | T | | | T |
| 9 | | | T | | T | | T | |
| 10 | T | | | | .02 | .18 | 1.16 | .16 |
| 11 | .26 | | .04 | | | | T | T |
| 12 | T | | .18 | | | | | .73 |
| 13 | .31 | T | | | | .24 | .72 | T |
| 14 | .04 | 2.49 | | | .46 | .14 | .28 | |
| 15 | | .11 | .05 | | | | | |
| 16 | | | .14 | | | | .23 | |
| 17 | | | T | | | | | |
| 18 | | | 1.22 | | | T | | |
| 19 | | .15 | | | | .02 | .05 | |
| 20 | | .15 | | | | .02 | | |
| 21 | | .03 | | .01 | .14 | .24 | T | |
| 22 | .01 | .07 | | .02 | | .07 | T | |
| 23 | .39 | | | | | .52 | | |
| 24 | .06 | | .23 | .14 | | | | T |
| 25 | | | | 2.54 | | | .24 | |
| 26 | | | | .01 | T | | | |
| 27 | T | | T | | | | | |
| 28 | .27 | | 1.19 | | | | | |
| 29 | T | | .10 | | | | | |
| 30 | T | | T | T | T | .03 | | .78 |
| 31 | | | | .32 | | .21 | | T |
| Total | 3.02 | 3.00 | 3.26 | 4.04 | 5.79 | 2.21 | 3.73 | 1.85 |
| ± Normal | -1.35 | -2.11 | -0.74 | -0.14 | 2.08 | -0.11 | | |

# EFFECT OF SPACING ON TWO SOYBEAN PLANT TYPES

by

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1973

To study the effect of spacing on soybean plant types, tall determinate ($Dt_2$) and normal indeterminate plant types with the genetic background of Clark variety were tested at nine plant spacings. Spacings used were 15.2 x 15.2 cm, 7.6 x 15.2 cm within 30.4 cm rows, 5 and 10 cm within 45.7 cm rows, 3.8 and 7.6 cm within 60.9 cm rows, and 3 and 6 cm within 76.2 cm rows. A split plot design was used with spacings as the main plots and plant types as sub-plots. The experiment was replicated four times.

Variables measured were number of nodes, height to first pod, plant height, number of branches, lodging, date of maturity, yield components, shoot/bean ratio and seed yield.

Determinate plants were shorter, produced fewer nodes, lodged more and matured two days earlier than the indeterminate plants.

There were significant differences among spacings for height to first pod, plant height, number of branches, lodging, date of maturity, pods per plant, seed yield per plant, shoot/bean ratio, and final seed yield. Number of nodes per plant, seed size, and seeds per pod were not affected by spacing.

Averaged over both the plant types, plants at the higher density, at the equidistant spacing of 15.2 x 15.2 cm produced the highest yield (3217 Kg/Ha). The lowest yield (2229 Kg/Ha) was produced by the plants at the lower density, spaced 7.6 cm within the 60.9 cm rows and this was significantly lower than the yield produced by plants grown in all other row widths. This spacing also had the highest lodging and shoot/bean ratio.

Pods per plant and seed yield per plant, which were significantly affected by spacings, were not correlated with final yield. Varying degrees of natural thinning and differences in the time of lodging may have been responsible for this.