

VARIETAL RESPONSE OF SOYBEANS TO PHIZOBIVM JAPONICUM,
ROW WIDTH, AND DATE OF PLANTING AS EXPRESSED BY
NODULATION AND SEED YIELD

by 683

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INTRODUCTION

The soybean, (Glycine max (L) Merrill, now ranks fourth among the cash crops in the United States, and first among oilseed crops of the Western Hemisphere. Soybeans supply about 35 percent of the total fats and oils produced in this country while soybean meal supplies nearly 56 percent of the protein concentrates. Soybean oil, classed as a semi-drying oil, is used for food purposes and also in several industrial products.

Soybeans will succeed on nearly all soil types except extremely deep sands. The crop can tolerate considerable low soil acidity much more than other legumes like alfalfa, clover and field peas. While soybeans can be grown under soil acidity of pH range of 4.5 to 7.5, for best results, soils should be limed to pH 6.0 to 6.5 and soils of low fertility should be supplied with those mineral elements in which they are deficient. Generally, phosphorus, potassium and calcium have been noted as the most important among the mineral nutrients required for normal growth and development. Good soil tilth and adequate moisture, among the many other environmental factors, play a major role in the establishment and production of soybeans.

It is important that the appropriate strain of nitrogen-fixing bacteria (Rhizobium japonicum) of soybean cross-inoculation group is present in the soil to supply the bulk of the nitrogen needed by the crop, and this is usually achieved by inoculation of the seed with a suitable culture. This may be very necessary especially on land not previously planted to soybeans. However, application of adequate nitrogen fertilizer to soils devoid of the nitrogen-fixing bacteria may be as productive as soils with the bacteria.

Although soybean is not the foremost farm crop in Kansas, the high demand for the meal as an excellent protein supplement in feeds on the farm

and the high cost of the concentrate, both of which stimulate rapid increase in the acreage of soybeans, also justify research toward increasing the efficiency of production of the recommended varieties in the eastern quarter of Kansas.

The object of this research was to study the response of four varieties of soybean (Clark 63, Hill, Kent and Wayne) to Rhizobium japonicum strain U.S.D.A. 7, to 3 row widths (10, 20, and 30 inch) and five dates of planting (May 16, May 28, June 7, June 20, and July 1) as expressed by nodulation and seed yield. An understanding of varietal performance with a promising bacteria (Rhizobium) strain at various planting dates and with different spacings is important for making recommendations to growers and for the integration and interpretation of results obtained from experiments of this type. The research of this study was conducted at Kansas State University in Manhattan, in 1968.

LITERATURE REVIEW

Strain Variation and Host Specificity

That legume bacteria (*Rhizobium*) are of different kinds has been known for a long time. For example, the bacteria that work on alfalfa and sweet clover will not function on field peas, beans, soybeans and other legumes, Erdman (19). This has led to the recognition of the cross-inoculation groups of leguminous plants. A cross-inoculation group refers to a collection of leguminous plant species which develop nodules when exposed to bacteria from the nodules of any member of that particular plant group.

As reported by Alexander (2) more than 20 cross-inoculation groups have been established, but only seven have achieved prominence, and no more than six have been sufficiently well delineated for the bacterium responsible, to have attained species status. It should be noted, however, that certain bacterial strains invade legumes outside their cross-inoculation group to effect nodulation. This phenomenon is termed symbiotic promiscuity which increases in hosts possessing a greater degree of cross-pollination, Wilson (66).

Strains of *Rhizobium* species may be distinguished in their behavior in symbiosis by their ability to infect a given host plant as well as by nodules' effectiveness in benefiting the host through nitrogen fixation. Erdman (21), Johnson and Means (31) and Alexander (2) have reported that a particular strain may be highly effective on one host and ineffective on closely related species or even varieties of the same species. It is noted generally that large nodules are more effective while small nodules may lack effectiveness.

However, a non-nodulation response may not be due to ineffectiveness of a strain but genetic differences in the host species. William and

Lynch (65) and Clark (16) reported that the hereditary factor associated with the failure to nodulate in soybean lines (Glycine max (L.) Merrill) behaves as a single recessive. Tanner and Anderson (57) grafted root tips from genetic non-nodulating lines to roots of normal plants when the roots were 1 cm. long. The resulting root systems were partly nodulating and partly non-nodulating. In every case the nodulation pattern was determined by the genotype of the root segment. In red clover, Nutman (46) found that resistant plants were generally less vigorous, more chlorotic and displayed floral abnormality.

Nodulation and Nitrogen Fixation

Nodulation and nitrogen fixation are almost inseparable since nitrogen fixation depends on formation of effective nodules. In most legumes the primary invasion by the bacteria occurs through the root hair. Chailachyan and Megrabyan (15) reported that plant-excretion products stimulatory to the nodule bacteria are undoubtedly the cause of increased number of rhizobia in immediate proximity of the leguminous root. It has also been demonstrated that a nodule is in fact a metamorphosed lateral root in development. Nutman (46) reported that plants eventually forming the larger number of nodules produce a more extensively branching root system, thus having a greater total length of root exposed to random infection.

Bergersen's study (8) on Lincoln soybeans showed that nodules can be formed within nine days after planting and that nitrogen fixation can begin as early as two weeks after the appearance of the first formed nodule. Bergersen (8) also indicated how long active nitrogen fixation continues. He used winter-grown plants which flowered in two to three weeks

after germination and found that the total plant nitrogen increased at essentially a constant rate from the time nitrogen fixation began until four weeks later, when nodule decay began. By 58 days after planting or seven weeks after the first nodule was formed nitrogen fixation had ceased.

Aprison and Burris (5) were the first to report nitrogen fixation by excised nodules. Aprison et al.(6) reported substantial fixation by nodules excised from Hawkeye soybeans 80 days after planting. Excised nodules rapidly lose their ability to fix nitrogen. Fixation takes place in water and is not enhanced by addition of a number of common respiratory substrates and cofactors.

Magee and Burris (37) observed that the nitrogen fixation by excised nodules "increased roughly with increasing size of the nodules from young, actively growing plants," but declined as the growth rate slowed with blooming. Bond (10a) on the other hand, reported the highest daily rate of nitrogen fixation per plant during the pod set and development. As to the cessation of nodule formation, Ebertova (18) reported that new pink active nodules originated continuously throughout the life of the plant and also found nitrogen fixation continuing until the seeds were nearly ripe.

Johnson et al.(30) and Erdman et al.(20) have established the fact that some strains of Rhizobium induce chlorosis. That vigorous nitrogen fixation is required for the development of chlorosis has been confirmed by Johnson and Means (31). The chlorosis inducing power and effectiveness in nitrogen fixation has been used in studying competitive relationship of strains of Rhizobium by Johnson and Means (32). The relative competitiveness of Rhizobium strains should be an important consideration in their selection because strains applied in inoculum must compete with strains already present

in the soil. Johnson and Means (32) reported that competition among strains of nodulating bacteria for nodule site on legume roots is general and not a simple function of the relative number of cells of strains to which the roots are exposed.

Nutman (47) reported that when few nodules were present on the roots only a small proportion was borne laterally. As total number of nodules increases, the proportion of laterally borne nodules also increases and tends toward a value of 50 percent. Allen and Allen (1) observed that the size of nodules on a particular host is highly correlated with the nitrogen-fixing potentiality of the strain. In general, effective nodules have pink or reddish interiors, are clustered along the upper tap root and primary laterals and tend to be large, often with irregular contours. Ineffective nodules on the same plant are comparatively much smaller, white or greenish, and exist singly and are widely scattered. The functional periods of effective nodules of field peas, soybeans and clover are 2, 4, and 6 times longer, respectively, than those of ineffective ones as reported by Allen and Allen (1).

Three nodule pigments have been identified, namely, leghemoglobin (red), leghoolegoglobin (green) and legmethemoglobin (brown). Leghemoglobin is found only in mature effective nodules during the active state of nitrogen fixation, and in the youngest lobes of perennial nodules, Allen and Allen (1), and is considered indispensable to the symbiotic nitrogen fixation process. Leghoolegoglobin is found in ineffective nodules while legmethemoglobin is characteristic of the degeneration stage of effective nodules.

The common explanation for the senescence and degeneration of nodules concomitant with natural plant growth conditions are plant fruition, sudden changes from drought to excessive moisture, clipping of the plant tops

and lack of adequate photosynthesis.

Field measurements of symbiotic nitrogen fixation by legumes is difficult because nodulated legumes use both soil and elemental nitrogen. Weber (60) measured soybean nodulation and what it means in terms of seed production and fixed nitrogen. He used two soybean lines that are identical, except one forms nodules on its roots and the other does not. He compared nodulated and non-nodulated soybeans with varying rates of applied nitrogen on each and with the following: (a) with and without drought conditions; (b) ample moisture and with nitrogen partially immobilized with 20 tons of corncobs per acre. When cellulose such as corncobs is applied, normally available soil nitrogen is partially immobilized.

Soybeans with drought stress yielded about half as much as those without drought. Adequate moisture not only increased seed yield but more than doubled the percentage of nitrogen fixed by symbiosis. Added fertilizer nitrogen greatly decreased the amount of nitrogen fixed by the nodulating line, because increasing nitrogen in the soil decreased nodulation. The non-nodulating line increased in yield with added fertilizer nitrogen. The results of Weber's study indicated that under good growth conditions, fixed nitrogen in nodulated soybeans may approach 40 percent of the total nitrogen produced.

Mekee (40b) also reported that the dry weight of legume tops is a reasonably good estimate of total nitrogen in the plant while combined weight of tops and roots is a better estimate.

Factors Influencing Nodulation and Nitrogen Fixation

The formation of root nodules requires not only specific rhizobium

strain but also adequate conditions of the environment. Sironval et al (55) reported that under long days, the nodules on soybeans, for example, were heavy, numerous, effective and red colored, but in short days they remained rare and very small with whitish insides—possibly due to lack of adequate production of leghemoglobin, under short photoperiod. McKee's (40a) results also agree with Sironval et al.(55). It has been reported also that shading tends to depress nodule weight, whereas high but not excessive light intensifies, and high CO₂ levels increase nodule number.

Sironval (54) stated that nodule formation appears to be parallel and related to chlorophyll formation which varies in relation to photoperiod. Bach et al (7) showed the dependence of nitrogen fixation on photosynthesis, or in case of sliced nodules, an external supply of sugar; and Kamata (34) showed that nodulation is promoted by foliar application of sugars. The amount or supply of available carbohydrate reaching the roots is considered the chief influence that affects nodulation under variations in photosynthesis and in the presence of either free nitrogen or varying quantities of combined nitrogen as reported by Allison and Ludwig (3), Allen and Allen (1), Gibson and Nutman(24), Weber (60), and Munns (42).

The decrease in nodulation in the presence of soluble nitrogenous salts is due to an inadequate carbohydrate supply in the roots. Where nitrogen is abundant, the carbohydrates synthesized is used for the top growth and little is available for the growth of roots or nodules. Allison and Ludwig (3) reported that under winter conditions, growth is slow; very small additions of nitrogen are sufficient to stop all nodule formation while in summer much larger rates of application are required to cause reduction in nodule formation.

Nitrogen fixation resembles nodulation in its dependence upon the

carbohydrate-nitrogen ratio within the host tissue. A widening of the ratio stimulates the fixation of nitrogen, but excessively high carbohydrate levels resulting from high light intensities retard the process, Alexander (2). Scars and Lynch (52), and Weber (60) found that nodule number, weight and size were directly related to increased nitrogen fixation and inversely related to increased increments of applied nitrogen. However, small quantities of applied nitrogen can benefit the plant before adequate nitrogen fixation is in progress, as there may be nitrogen deficiency after the immobilization of the seed reserves--about two weeks after planting, McAlister et al. (39).

Many climatic, edaphic and biotic factors affect nodulation and nitrogen fixation. McKee (40b) observed that nodulation was retarded and depressed more than top or root growth by inadequate soil moisture and concluded that within limits, as the moisture content of the soil increases, so does the growth of the plant and the adequacy of nodulation increases to reach a maximum at or near field capacity.

There is a varying degree of resistance to high temperatures by strains of Rhizobium. Marshall (38) working with sandy soils, demonstrated the ability of rhizobia to withstand high temperatures was influenced by soil physical properties. Temperature for rhizobia survival are much lower in moist soils than in air-dry soils, he noted.

For many legumes, nodulation does not occur much below pH 5.0 as reported by Thornton (59) and Alexander (2). Soybeans and its infective bacterium are notable exceptions and nodules are formed in highly acid environments, though for best results, soils should be limed to pH 6.0 to 6.5. Toxicity resulting from iron and aluminum is most pronounced at low pH, and one or both of these may cause poor nodulation and legume stand.

Low pH also affects greatly the availability of molybdenum which is essential in the incorporation of nitrogen into fixed form. Bernstein and Ogata (9) in their study of salinity effect on nodulation, found that nodulation was strongly decreased by 130 meg. per litre of added sodium chloride (NaCl), and that the dry-weight percentage of nodules decreased significantly with increasing salinity.

Occasionally inoculation failure may result from a microbiological competition that suppresses the desired microsymbiont and prevents initiation of infection. Damirgi and Johnson (17) investigated the infectivity of rhizobia on the soybean variety Kent in the presence of selected Actinomycetes isolates. They found 35 to 53 percent reduction in nodule numbers in the autoclaved soil, when the Actinomycetes was introduced into the soil at the time of planting and 28 days before planting respectively.

The influence of some nutrient elements on the effective nodulation of legumes and particularly soybeans have been reported by a number of workers. Wilson (66) found chlorides and phosphate stimulate nodule production. Sulfates had harmful effects as did the use of ammonia. Alexander (2) noted that phosphorus and potassium through their role as essential macro-nutrients exert a direct influence on nitrogen gains and legume yields.

Gupta and Sfn (26) reported a marked variation in the amounts of phosphorus utilized by the strains from a single legume. They observed that strains of high efficiency utilize large quantities of phosphorus. Wilson (66) also reported phosphorus application cultures with soil increased nodule production. The number of nodules on 30-day-old soybean plants was doubled by application of 962 pp2m monosodium--or monopotassium-phosphate.

Feller (23), Norris (44), Alexander (2), and Nelson (43) all reported increases in both yields of soybeans and increase nodulation with

the use of lime. Experimental evidence shows that small applications of lime gives just as good results as large applications and a tremendous excess of lime decreases yield. Calcium application decreases soil acidity, which hinders the development of *Rhizobium*. Norris (45) found that manganese deficiency may show on soybeans grown in soils above pH 7.0.

Influence of Planting Date on Yield and Other Characteristics of Soybeans

Burlison et al. (11) obtained the highest soybean yields from May 20 plantings at Urbana, Illinois. Feaster (22) at Southern Missouri reported that planting date had considerable effects upon the yields of different varieties. He found that for maximum yields, short season varieties should be planted somewhat later than long season varieties; this is in agreement with Osler and Cartter (49). Weiss et al. (63), Torrie and Briggs (58), and Leffel (35) have reported that their earliest varieties did not differ significantly at various planting dates while yields of the latest varieties decreased progressively with delay in planting.

Cartter and Hopper (14) observed variation in seasonal environment was an important factor in modifying bean size and that oil and iodine number appeared to be critically influenced by the temperature prevailing during the period of seed development. Smith et al. (56) reported that seed produced from later planting in Virginia were usually smaller than seed from earlier dates of planting with the relative size of the different varieties remaining fairly constant. Osler and Cartter (49), however, found no appreciable difference in seed size with delayed planting except differences between varieties.

Green's (25) review on previous work on seed quality by Feaster (22),

Leffel (35), Smith et al. (56) and Torrie et al. (58) showed that visual ratings of seed lots have indicated that an early planting of early maturing varieties produced poorer seed quality than late seedings in most years. Planting date had less effect on the seed quality of varieties of later maturity, with seed quality just somewhat lowered by delayed plantings.

Feaster (22) stated that apparently the development of soybean seed under hot, dry weather conditions was conducive to poor quality. Green et al. (25) using laboratory germination as a measure of seed quality found that soybean plants from early dates of planting which matured during hot, dry weather conditions produced seed with lower laboratory germination and field emergence. Seeds from later date of planting which reached maturity after the hot, dry weather conditions had ended generally exhibited higher laboratory germination and field emergence.

Weiss et al. (63) reported that maturity of genetically early varieties was retarded more by delayed planting than that of later varieties. The report of Osler and Cartter (49) also agrees with this. Feaster (22) showed that early maturity can be obtained only by planting early maturing varieties at an early date, whereas early planting of full-season varieties results in only slightly advancing the maturity date.

The results of Weiss et al. (63) indicated no appreciable effect of planting date on lodging with delay in planting and found maximum height of plants at the first date (May 1) and decreased progressively with delay in planting. Leffel (35) also reported decrease in plant height with delay in planting, but that lodging of plants was not affected consistently with delay in planting.

Cartter and Hopper (14) working on ten varieties of soybeans at five locations found that the oil and protein content are largely varietal

characteristics which are influenced by environmental conditions. Feaster (22) reported that date of planting had little effect on oil content except for the latest date. Osler and Cartter (49) reported that when all varieties they used were considered, highest oil content of the seeds was attained at the first date and decreased progressively with later plantings. However, the decrease was not consistent for all varieties.

Feaster (22) reported that protein content had a tendency to vary inversely with the oil content as observed earlier by Cartter and Hopper (14). Weiss et al. (63), Torrie and Briggs (58) reported no effect of date of planting on protein content. Feaster (22) also found that the iodine number of the five varieties he studied showed a tendency to increase with lateness in planting. This is in agreement with results of Torrie and Briggs (58). On the contrary, Osler and Cartter (49) reported slight, but progressive, decrease in iodine number of oil with delay in planting, but that the decrease was not consistent for all varieties.

Effect of Row-Spacing on Development and Yield of Soybeans

Wiggins (64) reported that within population levels, seed yields increased as the inter and intra-row spacings approached a uniform (square) distribution pattern. Lehman and Lambert (36) found that soybeans planted in 20-inch rows generally outyielded those planted in rows spaced 40 inches, while yield differences due to intra-row spacings were inconclusive. Hanway (27) reported higher yields from 21-inch rows than from wider row spacings and postulated that yields will increase as rows are narrowed until the leaves of plants in adjoining rows meet and completely shade the soil. He also reported better emergence with close spacing if the soil is crusted. Reiss and Sherwood (51) reported that the yield results from the 24-inch row

spacings was better than any of the other four spacings—8, 16, 32, and 40-inch row widths they investigated. There was always varietal differences, though.

However, when the inter-row and intra-row become too closely spaced, the seed yield reduction results, suggesting more severe plant competition at higher densities. As reported by Johnson and Harris (33), Cartter and Hartwig surveyed the literature on within-row seeding rate studies and concluded that the highest yields (above which there were no further significant increases) were obtained from seeding rates of 19.7 to 39.4 seed per meter row (6-12 seed per foot) in all major soybean production areas of the United States, 39.4 seed per meter row being the upper limit.

Lehman and Lambert (36) found that seed weight and seeds per pod were not affected appreciably by spacing or population change whereas the number of seeds, pods and branches per plant decreased with increased plant population. Oba'et al. (48) had similar results.

Hinson and Hanson (29), Probst (50), and Johnson and Harris (33) reported increased lodging with increasing density for inter and intra-row spacings and that lodging is conducive to delayed maturity. They also reported increased height with close spacings and reduced number of branches. Weber et al. (62) also found that increased lodging contributed to decrease in yield at higher plant density. Weber and Pehr (61) reported an increase of 13 percent over the control when plants were staked to prevent lodging in seven varieties of soybeans. They noted that the increase in seed yield was primarily due to an increased number of pods and seeds in the staked varieties.

Weber et al. (62), Hinson and Hanson (29) observed that chemical composition of the seed was variable with spacing. However, protein percent

decreased slightly in the wider rows and with lower populations, while percent of oil showed an inverse relationship to protein.

MATERIALS AND METHODS
(Experimental Procedure)

Greenhouse Rhizobium Strain Variation Study

This study was conducted in the greenhouse in Spring, 1968, to evaluate the effectiveness of nine strains of Rhizobium to cause nodulation on five varieties of soybean. Six of the strains--USDA 7, USDA 71a, USDA 110, USDA 122, USDA 123, and USDA 135 were obtained from the United States Department of Agriculture, Agriculture Research Service, Beltsville, Maryland. Two strains, 61A65 and 61A69, were obtained from the Nitragin Company, Milwaukee, Wisconsin. One strain, 5566, came from the Nodogen Laboratory, Princeton, Illinois. All of the cultures were in humus. The varieties of soybean used were: Amsoy, Clark 63, Hill, Kent and Wayne.

The soil used was taken from the site selected for field planting on the Agronomy farm and tested for pH (6.6), available phosphorus (92 lbs/A), available potassium (900+ lbs/A) and percent organic matter content (2.3%) from which nitrifiable nitrogen was estimated to be 53 lbs/A. The soil test was done by the Soil Testing Laboratory, Agronomy Department, Kansas State University.

One hundred and fifty (150) 6-inch plastic pots were filled with the soil. Twelve adequately inoculated seeds with each of the nine inoculants were planted in each pot and later thinned to five evenly spaced plants eleven days after planting. Each variety with ten treatments, including the control, was replicated three times. The varieties were randomized within the strains which represent main plots with varieties as sub-plots in the split-plot design used. The pots were placed on a table covered with sand in the greenhouse.

In order to prevent early flowering, light break was applied daily

for two hours (11:30 p.m. - 1:30 a.m.) from the time the unifoliate leaves completely unfolded until the night before the termination of the experiment (39 days after emergence). Five 100-watt bulbs were arranged along the table above the plants at a distance of about 3.5 feet at the beginning and adjusted subsequently as the development of the plants progressed. Adequate moisture was supplied throughout the study duration.

At the termination of the experiment, the tops of the five plants in each pot were cut and put into already labeled paper bags and kept in the oven for drying. The roots were removed and carefully washed. The nodules were counted and the fresh-weight was determined. The nodules and the roots were then put in labeled paper bags and kept in the oven for drying. When the plant materials became very dry, the total dry matter per five plants was determined.

Field Experimental Design

The greenhouse study was conducted for appropriate selection of a strain to be used for inoculation of seeds for the field study. After putting the results of the greenhouse study into statistical analysis, strain USDA 7, from the United States Department of Agriculture, Agriculture Research Service, Beltsville, Maryland, was selected and used in treating the seeds of all varieties planted in the field experiment.

About eight grams of humus inoculant was placed in a quart jar and mixed into a slurry with 35 ml. of water. The seeds were thoroughly mixed with the slurry in the seed container and plantings were made soon after inoculating the seeds. Each variety received this same treatment for all the five dates of planting: May 16, May 28, June 7, June 20, and July 1. All plots were planted with hand planter, and the seeds were spaced about one

inch (252 seeds per 21-foot row) within the row.

There were sixty treatments randomized in 4 replicates. The plots were in a 5 x 3 x 4 split-split-plot design, i.e. five dates of planting, 3 row widths (10, 20, and 30-inches), and four varieties. The varieties were Wayne, Clark 63, Kent, and Hill (in order of maturity). Treflan was applied (1 qt. per acre) and disked into the soil ten days before the first date of planting. This was done to control weeds during growth of soybeans.

Plantings were made in 4-row plots for the 20, and 30-inch spacings and 6-row plots for the 10-inch row spacing. All plots were 21 feet long and harvested plot rows were 16 feet long. Weeding was done by hand hoeing. The design of experiment and layout of the plots for the four replicates are shown in Appendix I.

Sampling Methods

In order to establish the time nodule formation began, i.e. when first formed nodules become visible with the aid of a hand lens, seedlings were dug up with the soil from the outer rows of each plot, kept in labeled brown envelopes and quickly carried to the laboratory, washed and examined for nodules, starting from the fourth day after emergence. Date of emergence was the day when 50 percent of the seeds in each plot have germinated.

Three samplings were made for nodule counts for each date of planting at 6, 9, and 12 weeks after nodule initiation. For each plot the tops of ten plants of fairly uniform size were severed from the edges of the middle rows from which yield data would be taken. The roots were carefully dug, washed and kept in 5 percent formalin solution for counting of nodules in the laboratory the same day. The soil core (10 by 6 by 6 inches) of the roots in each plot was also carefully examined for nodules that might have

been lost to the core in the process of removing the plants. After each plot count, the nodules were dried with paper towel and the fresh-weight of the nodules recorded.

Date on ground cover was taken as number of days after planting when the soil between rows was completely or almost completely shaded by the plants.

Data on plant height--inches from ground level to tip of main stem, and nodes per plant were collected from each plot. Five uniformly spaced plants were selected for both observations at the time when 90 - 95% of the leaves had turned yellow, i.e. when the vegetative growth had ceased.

Lodging notes were taken at maturity on each plot and were scored from one to five:

- 1 = Almost all plants erect.
- 2 = All plants leaning slightly, or a few plants down.
- 3 = All plants leaning moderately (45°), or 25 to 50% of plants down.
- 4 = All plants leaning considerably, or 50 to 80% of plants down.
- 5 = Almost all plants down, or 80% or more of the plants down.

Maturity was recorded as days after emergence when approximately 95 percent of the pods were ripe and most of the leaves had dropped.

Harvest and Yield Determination

When the pods were adequately dry for threshing, the rows to be harvested were tagged with the proper label designation. Two middle rows were harvested from each of the 20-inch and 30-inch row spacings while the four middle rows of the 10-inch spacing were harvested. Each plot was harvested separately with a hand mower and threshed with a nursery thresher.

The seed weight in grams per plot was determined and this was later converted into bushels per acre.

Seed size was determined and expressed in grams per 100 seeds. The seed lots used were taken from each harvested plot seed yield. Seed quality was rated one to five. Seed characteristics used for the visual rating score for seed quality: purple seed stain, mottling, damage, wrinkled seedcoat and seed development.

1 = very good

2 = good

3 = fair

4 = poor

5 = very poor

RESULTS AND DISCUSSION

Greenhouse Nodulation Study

The nine strains of Rhizobium japonicum were evaluated in the greenhouse study for their relative ability to cause nodule formation on the roots of the five varieties of soybeans (Glycine max). The results of average number of nodules per plant are shown in Table 1. It is a well-established concept that a particular strain may be highly effective in nodulation on one host and ineffective on closely related species or even varieties of the same species as regards Rhizobium: Legume symbiotic relationship. This concept has prompted preliminary study of strains on varieties of soybeans under greenhouse conditions.

Statistical analysis showed that two strains, USDA 7, and USDA 71a produced significantly more nodules per plant than the control as well as the other seven strains used in the study—USDA 110, USDA 122, USDA 123, USDA 135, 61A65, 61A69 and 5566. There were no significant differences among these seven strains and the control. The control produced two more nodules per plant than strains USDA 110, 61A65 and 5566. These three strains produced the lowest average nodule number per plant (23.0) among all the other strains tested. Strains USDA 123, USDA 135, and 61A69 had 1.5 to 2 more nodules per plant than the control. The results are shown in Table 1 and Fig. 1.

The variation in varietal response in nodule formation upon infection by the strains of R. japonicum was as follows: Hill produced significantly more nodules per plant than other varieties (Amsoy, Wayne, Clark 63 and Kent). Amsoy produced significantly more nodules per plant than Clark 63, Wayne and Kent but there were no significant differences between the nodules produced per plant by Wayne, Clark 63 and Kent (Table 1 & Fig. 2).

Table 1. Comparative ability of nine strains of Rhizobium japonicum to cause nodulation on five varieties of soybean (Glycine max).

Average number of nodules per plant						
Rhizobial		Variety				Strain Mean
Strain	Amson	Clark 63	Wayne	Hill	Kent	
USDA 7	29.4	27.8	32.3	48.7	30.9	33.9
USDA 71a	35.8	25.4	31.2	46.0	28.7	33.4
USDA 110	27.2	21.6	16.3	33.3	16.7	23.0
USDA 122	30.8	18.4	23.3	34.6	16.3	24.7
USDA 123	32.4	24.5	18.4	40.5	20.1	27.2
USDA 135	33.4	23.6	23.7	35.4	21.9	27.6
61A65	21.3	16.8	16.2	32.4	21.7	23.0
61A69	29.0	23.3	17.6	39.9	23.2	26.6
5566	26.8	17.8	18.9	35.7	16.3	23.1
Control	29.2	23.0	15.6	37.7	19.9	25.1
Variety Mean	29.5	22.2	21.4	39.0	21.1	26.8

L.S.D. (.05) Between strain and control means = 5.4

L.S.D. (.05) Between variety means = 2.7

The nodule fresh-weight was considered as a measure of nodulation in this study as well. The analysis of variance, Table 34, Appendix II, shows that there was interaction between strains and varieties for nodule fresh-weight. Amsoy inoculated with strains USDA 123 and USDA 71a produced significantly more nodule fresh-weight than when inoculated with strains USDA 122, 61A65, 61A69, and 5566. But there were no significant differences between the effect of strains USDA 123, USDA 71a, USDA 110, USDA 135 and the control on nodule fresh-weight. Nodule fresh-weight from control was significantly greater than inoculation with strain 61A65. The results are shown in Table 2.

When Clark 63 was inoculated with strains USDA 71a, USDA 110, and USDA 135, it produced more nodule fresh-weight than when inoculated with strains 61A65 and 5566. It produced significantly lower fresh-weight with 61A65 inoculation than inoculation with strains USDA 7, USDA 122, USDA 123,

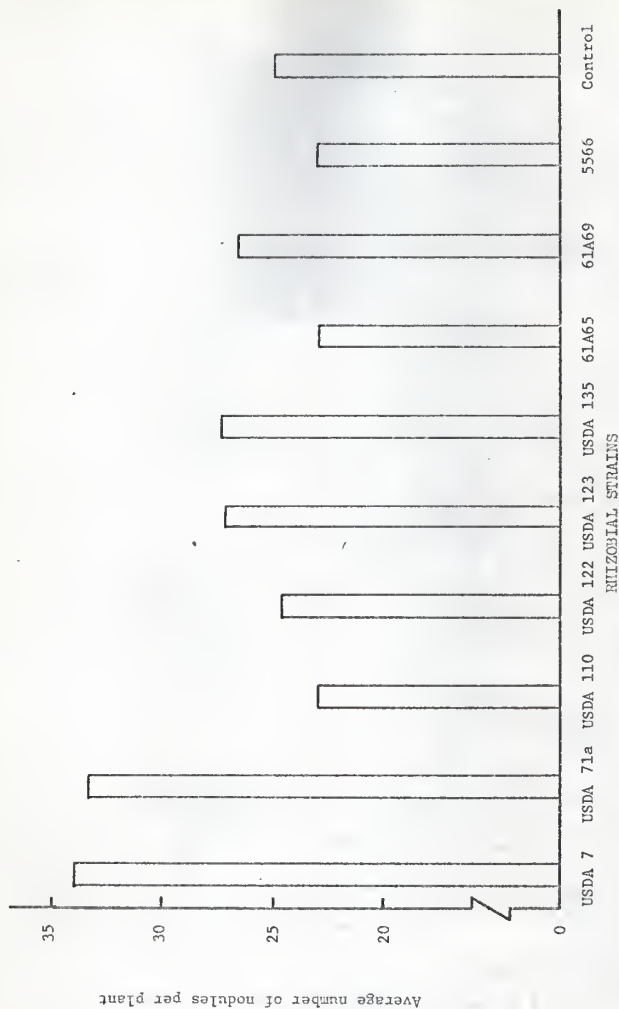


Fig. 1. Relative effectiveness of nine Rhizobial strains in nodulating the roots of Amsoy, Wayne, Clark 63, Kent, and Hill soybeans.

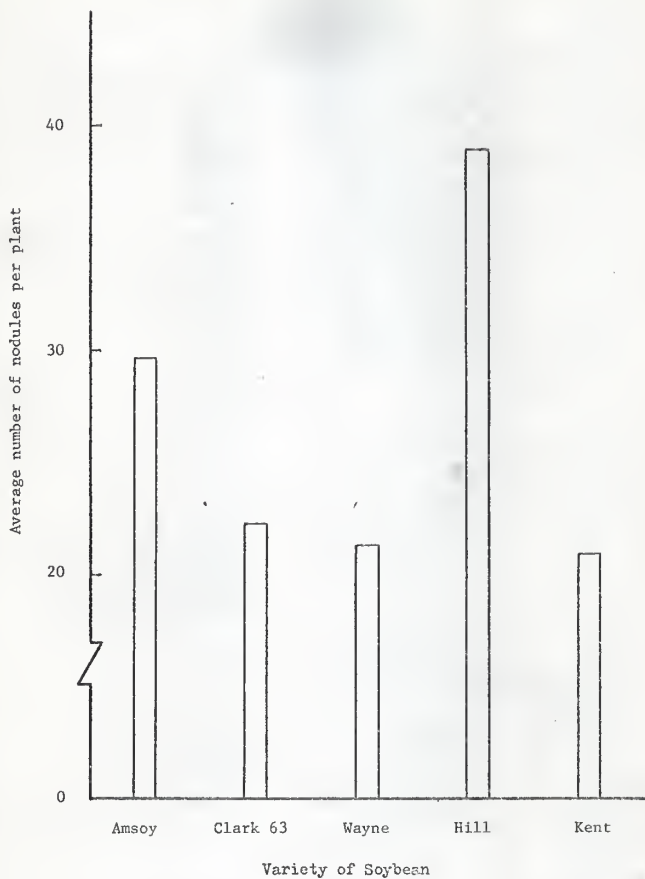


Fig. 2. Nodulation response of Amsoy, Clark 63, Wayne, Hill and Kent soybeans upon inoculation with nine strains of Rhizobium japonicum.

61A69 and the control. There were no significant differences among strains USDA 7, USDA 71a, USDA 110, USDA 122, USDA 123, USDA 135, 61A69 and the control in their effect on nodule fresh-weight.

When Wayne was inoculated with strains USDA 135, and USDA 7 it produced significantly more nodule fresh-weight than when inoculated with strains 61A65, 61A69, and 5566. The control also produced significantly more nodule fresh-weight than inoculation with strain 61A65. There were no significant differences between the effects of strains USDA 7, USDA 71a, USDA 110, USDA 122, USDA 123, USDA 135, and the control, on nodule fresh-weight.

Table 2. Comparative effect of nine strains of Rhizobium japonicum on nodule fresh-weight.

Rhizobial Strain	Average nodule fresh weight*: Variety x Strain					
	Variety					Strain Mean
	Amsoy	Clark 63	Wayne	Hill	Kent	
USDA 7	1.70	1.90	2.21	2.28	2.45	2.11
USDA 71a	2.02	2.22	1.82	1.88	2.15	2.01
USDA 110	1.72	2.20	1.95	1.48	1.82	1.83
USDA 122	1.52	1.94	1.89	1.94	1.69	1.79
USDA 123	2.06	1.92	1.94	1.97	1.62	1.90
USDA 135	1.87	2.29	2.27	1.97	2.11	2.10
61A65	1.12	1.42	1.59	1.50	1.74	1.48
61A69	1.52	1.87	1.69	1.81	1.66	1.71
5566	1.45	1.76	1.73	1.59	1.59	1.63
Control	1.74	2.27	2.10	2.12	2.12	2.11
Variety Mean	1.69	1.98	1.94	1.86	1.89	1.86

L.S.D. (.05) Between two strains within the same variety = 0.40

L.S.D. (.05) Between two varieties within the same strain = 0.35

* grams per 5 plants

When Hill was inoculated with strain USDA 7, it produced significantly more nodule fresh-weight than when inoculated with strains USDA 110, 61A65, and 5566. Inoculation with strains USDA 122, USDA 123 and USDA 135 resulted in significantly more nodule fresh-weight production than inoculation with strains USDA 110, and 61A65, but there were no significant differences in nodule fresh-weight produced from inoculation with strains USDA 7, USDA 71a, USDA 122, USDA 123, USDA 135, 61A69 and the control. Nodule fresh weight from control was significantly greater than nodule weight from inoculation with strains USDA 110 and 61A65.

When Kent was inoculated with strains USDA 7 and USDA 71a, it produced significantly more nodule fresh-weight than when inoculated with strains USDA 122, USDA 123, 61A65, 61A69 and 5566. Inoculation with strain USDA 7 also resulted in significantly more nodule weight than inoculation with strain USDA 110. There were no significant differences in nodule weight produced by Kent when inoculated with strains USDA 7, USDA 71a, USDA 135 and the control. Nodule weight from control was significantly greater than inoculation with strains USDA 122 and USDA 123.

Inoculation with strain 61A65 resulted in consistent and significant lower nodule weight than the control for all varieties. Inoculation of Kent and Hill with strain USDA 7 resulted in the greatest amount of nodule weight production as compared to effects of other strains on nodule weight. Inoculation with strain USDA 135 resulted in greatest amount of nodule weight in varieties Wayne and Clark 63 but there was no significant difference between the effects of strain USDA 135 and USDA 7 on both varieties for nodule weight. Inoculation of Amsoy with strain USDA 123 resulted in greatest amount of nodule weight but there was no significant difference between the

effects of USDA 123 and USDA 7 on nodule weight in Amsoy. The relatively high nodule weight from the control could be assumed to be due to the presence of effective nodulating strains of R. japonicum in the soil used for the experiment. The strains means for nodule weight showed that strains USDA 7, USDA 71a and USDA 135 contributed greatly to nodule weight. Varietal means showed that the lowest nodule weight was obtained from Amsoy and greatest from Clark 63.

Statistical analysis for total dry matter per five plants (Table 3) showed that Amsoy produced significantly more dry matter when inoculated with strain USDA 7 than when inoculated with strains 61A65 and 5566. It also produced significantly more dry matter when inoculated with strains USDA 110, USDA 122, USDA 123 and 61A69 than when inoculated with strain 61A65, but there were no significant differences between the effects of USDA 7, USDA 71a, USDA 110, USDA 122, USDA 123, USDA 135, 61A69 and the control on total dry matter production.

There were no significant strain effects on dry matter production of Clark 63 and Wayne. Hill produced significantly more dry matter when inoculated with strains USDA 122 and USDA 7, than when inoculated with strains USDA 71a and 61A65. It also produced significantly more dry matter when inoculated with strain USDA 122 than with USDA 135 inoculation. There were no significant differences in dry matter production by Hill when inoculated with strains USDA 7, USDA 110, USDA 122, USDA 123, 61A69, 5566 and the control.

Kent produced significantly more dry matter when inoculated with strains USDA 7 than with strain USDA 135 inoculation but there were no significant differences between the results of inoculation with USDA 7 and the other strains as well as the control. The strain means showed that the greatest dry matter was from inoculation with USDA 110 while the lowest was from

Table 3. Comparative effect of nine strains of Rhizobium japonicum on total dry matter production.

Average total dry weight* : Variety x Strain						
Rhizobial						
Strain	Amscy	Clark 63	Wayne	Hill	Kent	Strain Mean
USDA 7	8.73	7.70	8.10	7.80	8.53	7.97
USDA 71a	8.30	8.36	8.10	6.60	7.87	7.85
USDA 110	8.08	8.57	8.93	7.73	8.13	8.28
USDA 122	8.33	8.13	8.76	8.03	7.87	8.22
USDA 123	8.33	8.03	9.00	7.50	8.33	8.24
USDA 135	7.87	8.10	8.33	7.03	7.57	7.78
61A65	6.80	7.67	8.53	6.83	8.33	7.63
61A69	8.23	7.90	8.60	7.30	8.00	8.00
5566	7.53	7.87	8.27	7.23	7.67	7.71
Control	8.20	8.07	8.13	7.26	7.90	7.91
Variety Mean	8.04	8.04	8.48	7.23	8.02	7.96

L.S.D. (.05) Between two strains within the same variety = 0.91

L.S.D. (.05) Between two varieties within the same strain = 0.74

* grams per 5 plants.

inoculation with 61A65. Varietal means showed that the greatest dry matter production was in Wayne and the lowest in Hill.

After careful consideration of average number of nodules per plant of strain means and the average nodule fresh-weight produced with inoculation of different varieties with each of the nine strains, strain USDA 7 was selected for inoculation of seeds planted in the field study. This strain was selected because it produced the greatest number of nodules (33.9) per plant and because inoculation of Hill and Kent with this strain resulted in the greatest amount of nodule fresh-weight production. In addition, there were no significant differences between nodule weight of Wayne and Clark 63 with inoculation of USDA 7 and USDA 135 which resulted in the greatest amount

of nodule weight in Wayne and Clark 63. Amsoy produced the greatest amount of nodule weight with strain USDA 123 inoculation but there were no significant differences between the effects of USDA 123 and USDA 7 on nodule fresh-weight of Amsoy.

The greenhouse evaluation study showed that the strains of R. japonicum tested differ in their ability to infect and cause nodulation in soybean varieties. The study also showed that particular strains may be equally effective for nodule formation on a number of varieties as strains USDA 7, and USDA 71a proved equally effective on the five varieties of soybean tested as regards nodule number, and nodule fresh-weight. The study also showed variation within varieties in their response to nodule formation upon infection by strains of R. japonicum under the conditions of greenhouse where the experiment was conducted. Hill produced significantly more nodules per plant than other varieties. Amsoy produced significantly more nodules per plant than Wayne, Clark 63, and Kent, but there were no significant differences in the last three varieties as regards nodule number. The soil used for the experiment had been grown to inoculated soybean seeds in the past, and most probably had residual effective bacteria present and this could account for the relatively high number of nodules per plant on the non-inoculated plants of the control. This could also account for the non-significant differences between nodule fresh-weight of inoculated and non-inoculated plants. The non-inoculated plants even produced about two nodules per plant more than plants inoculated with strains USDA 110, 61A65 and 5566. So the relative competitiveness of strain USDA 7 was considered in its selection for inoculation for field study since strains in the inoculum must compete with strains in the soil.

Field Experiment

The field experiment, conducted at the Agronomy Research Farm at Manhattan, Kansas, was designed to study the response of inoculated seeds of four varieties of soybean (Wayne, Clark 63, Kent, and Hill) to 5 dates of planting (I = May 16, II = May 28, III = June 7, IV = June 20, and V = July 1), and three row widths (10, 20, and 30 inches), as expressed by nodulation, yield and yield components, and other agronomic characteristics of the varieties. Analysis of variance data are shown in Tables 36-49, Appendix II. The results obtained on each factor are discussed in the succeeding paragraphs.

Nodulation

From daily samplings made, starting on the ninth day after planting, it was found that first formed nodules became visible with the aid of hand lens when the unifoliate leaves became completely unfolded (11 to 12 days after planting), and this was taken to be the time of nodule initiation. The results of average nodules per plant from the first samplings, six weeks after nodule initiation is shown in Table 4, and graphically illustrated in Fig. 3.

Statistical analysis showed that variety Wayne produced significantly higher number of nodules per plant than Hill in date I, there were no significant differences between Wayne, Clark 63 and Kent. There were no significant differences between Hill, Clark 63 and Kent. In date II, Wayne and Clark 63 produced significantly more nodules per plant than Hill but there were no significant differences between Wayne, Clark 63 and Kent. There was no significant difference between Kent and Hill. In date III, Wayne produced significantly more nodules per plant than Clark 63, Kent and Hill, and Clark

63 produced significantly more nodules per plant than Hill but there was no significant difference between Hill and Kent.

In date IV, Wayne produced significantly more nodules per plant than Clark 63, Kent and Hill. Clark 63 produced significantly more nodules per plant than Kent and Hill but there was no significant difference between Kent and Hill. In Date V, Wayne and Clark 63 though not significantly different from each other, produced significantly more nodules than Kent and Hill. Kent also produced significantly more nodules per plant than Hill.

Comparisons between varieties within the same date of planting show a general trend of maturity effect on nodulation during the first samplings as shown in Table 4, and as illustrated in Fig. 3. The order of maturity is: Wayne (earliest), Clark 63, Kent and Hill (latest). The results show that Wayne produced the greatest number of nodules per plant and Hill produced lowest. However there were no significant differences between the varieties in order of maturity in every case as already noted in this discussion.

Comparisons between different dates of planting within a variety show that Hill produced the greatest nodules per plant (24.9) in date IV and the nodule number was significantly greater than the nodule numbers attained in dates I, II and V. Nodule number in date I was significantly lower than in dates II and III.

Wayne produced the greatest number of nodules per plant (34.1) in date IV and the nodule number (34.1) was significantly greater than those of dates I, II and V. Nodule number of Wayne in date III was not significantly different from that of date IV, but was significantly greater than that of dates I and II.

Kent produced significantly lower nodules per plant in dates I

than in the other four dates in which there were no significant differences, though the greatest number of nodules was obtained in date IV (21.8).

Table 4. Effect of date of planting on nodulation of Hill, Wayne, Kent and Clark 63 soybeans, six weeks after nodule initiation (first samplings).

Average number of nodules per plant, planting date x variety						
Variety	Planting date					Mean
	I	II	III	IV	V	
Hill	10.5	17.9	18.2	24.9	16.2	17.5
Wayne	16.2	22.6	30.7	34.1	26.5	26.0
Kent	12.7	21.2	21.1	21.8	20.4	19.4
Clark 63	13.9	22.2	22.7	30.1	26.7	23.1
Mean	13.3	20.9	22.7	27.7	22.5	21.5

L.S.D. (.05) Between two dates within the same variety = 6.9

L.S.D. (.05) Between two varieties within the same date = 3.9

Table 5. Effect of date of planting on nodulation of Hill, Wayne, Kent and Clark 63, nine weeks after nodule initiation (Second samplings).

Average number of nodules per plant, planting date x variety						
Variety	Planting date					Mean
	I	II	III	IV	V	
Hill	19.6	26.1	28.5	26.0	19.4	23.9
Wayne	31.4	37.6	32.7	32.0	23.1	31.3
Kent	27.6	31.9	30.4	26.9	23.4	28.1
Clark 63	27.4	33.6	35.1	27.2	22.7	29.2
Mean	26.5	32.3	31.7	28.0	22.1	28.1

L.S.D. (.05) Between planting date means = 4.3

L.S.D. (.05) Between variety means = 3.5

Clark 63 produced the greatest number of nodules per plant in date IV and the nodule number was significantly greater than nodule numbers obtained from dates I, II, and III. Nodule number in date I was significantly

less than in dates II, III and V. There was no significant difference between nodule number in date IV and V. For all the varieties there was a progressive increase in nodule number from dates I to IV and then there was a decrease in number in date V. The progressive increase might be due to increased precipitation as the growing season progressed, as adequate soil moisture content was available for development of soybean roots and formation of nodules from the time of nodule initiation.

The second nodule samplings were taken nine weeks after nodule initiation. Comparisons between date of planting means, as shown in Table 5, showed that the greatest nodule number was attained in date II (32.3). There was no significant difference between nodule numbers in dates II and III but these were significantly greater than nodule numbers in dates I and V. There was no significant difference between nodule numbers in dates I and IV but these were significantly greater than nodule number obtained in date V. There was a slight but progressive decrease in nodule number from dates III to V as shown in Table 5, and graphically illustrated in Fig. 5.

Comparisons between variety means show that there were no significant differences between nodules per plant in Wayne, Clark 63 and Kent but Wayne produced the greatest number of nodules per plant (31.3). Hill produced significantly lower number of nodules (23.9) per plant than the other varieties. The average number of nodules per plant were in the order of maturity as was found during the first samplings, with the greatest nodule number in Wayne and the lowest in Hill as shown in Fig. 5. Roots with nodules for the four varieties of soybean, from the second sampling in date II, are shown in Plate I.

The results of the third samplings taken 12 weeks after nodule initiation are shown in Table 6. Statistical analysis shows that there were

Further explanation of Figure 3.

Date of planting

I	=	May 16
II	=	May 28
III	=	June 7
IV	=	June 20
V	=	July 1

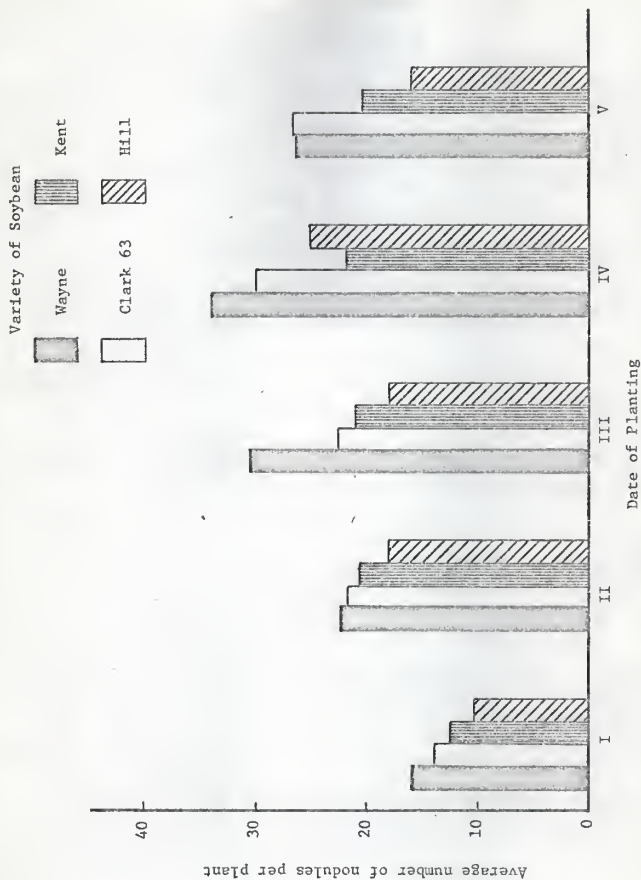


Fig. 3. Effect of date of planting on nodulation of Wayne, Clark 63, Kent and Hill soybeans for samples taken 6 weeks after nodule initiation. Varieties are arranged in order of maturity with Wayne=earliest and Hill=latest.

Explanation of Figures

Figure 4. Varietal differences in nodulation of soybeans for samples taken nine weeks after nodule initiation.

Figure 5. Effect of date of planting on nodulation of four varieties of soybeans for samples taken nine weeks after nodule initiation.

Dates of planting

I	=	May 16
II	=	May 28
III	=	June 7
IV	=	June 20
V	=	July 1

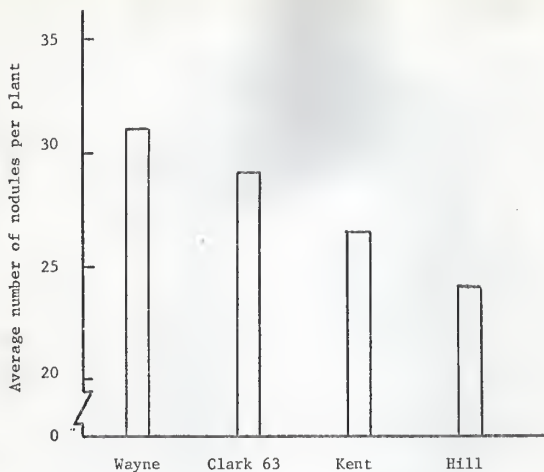


Fig. 4. Variety of soybean.

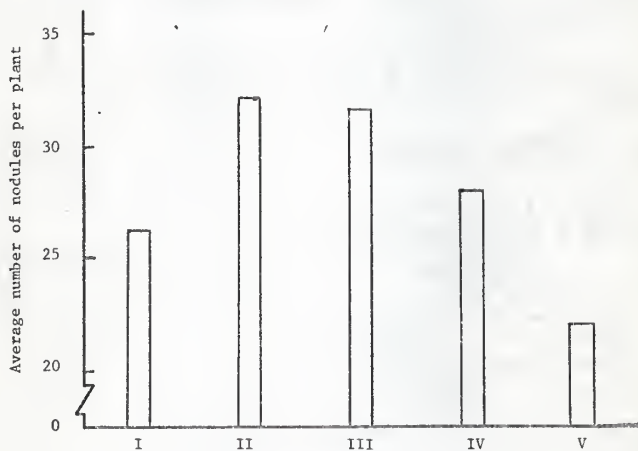


Fig. 5. Date of planting.

EXPLANATION OF PLATE I

Nodulated roots of Hill, Wayne, Kent and
Clark 63 (from left to right) soybeans
from date II at 9 weeks after nodule initi-
ation.

PLATE I



Hill

Wayne

Kent

Clark 63

no significant differences between varieties in date I. In dates II, IV and V, Hill had significantly more nodules per plant than Wayne and Clark 63 but there was no significant difference between Hill and Kent. There was no significant differences between the nodule numbers of Wayne and Clark 63.

In date III, Hill and Wayne had significantly more nodules than Clark 63 but there were no significant differences between Hill, Wayne and Kent. Kent was not significantly different from Clark 63. The order of nodules per plant followed a pattern of maturity but was opposite from the type of results obtained during the first and second samplings. That is, during third samplings it was found that the later the maturity, the more the nodules on the roots.

The order of average number of nodules per plant from dates II to V was Hill, Kent, Clark 63 and Wayne, with greatest nodule number in Hill and lowest in Wayne except in date III where Wayne had 0.8 more nodules per plant than Hill. The results are shown in Table 6 and also graphically illustrated in Fig. 6. The results in Table 6 also show a progressive and significant decrease in nodule number from dates III to V for all the varieties.

The greatest average number of nodules per plant for Wayne, Clark 63, and Kent was obtained from samples taken nine weeks after nodule initiation in all the five dates of planting. In dates I and II the greatest number of nodules per plant for Hill was obtained from samples taken twelve weeks after nodule initiation, and this necessitated further samplings to determine when there was a decrease in nodule formation; and this was found to be at the time the lower leaves were about to be turning yellow. However, in dates III, IV, and V, the greatest nodule number for Hill was obtained from samples taken nine weeks after nodule initiation. Fig. 7 shows the nodulation of the four varieties of soybean from the three row widths during the sampling periods for each of the five dates of planting.

Table 6. Effect of date of planting on nodulation of Hill, Wayne, Kent and Clark 63 soybeans, twelve weeks after nodule initiation (third samplings).

Average number of nodules per plant, planting date x variety						
Variety	Planting date					Mean
	I	II	III	IV	V	
Hill	22.7	28.6	22.2	18.0	12.9	20.9
Wayne	23.5	25.1	23.0	13.7	7.9	18.6
Kent	23.6	26.1	20.2	15.5	10.7	19.2
Clark 63	24.0	25.0	18.1	13.1	9.6	18.0
Mean	23.5	26.2	20.9	15.1	10.2	19.2

L.S.D. (.05) Between two dates within the same variety = 3.0

L.S.D. (.05) Between two varieties at the same level of date = 2.8

Table 7. Effect of date of planting on nodule fresh-weight of Hill, Wayne, Kent and Clark 63 soybeans, six weeks after nodule initiation (first samplings).

Average nodule fresh-weight*, planting date x variety						
Variety	Planting date					Mean
	I	II	III	IV	V	
Hill	0.60	1.09	1.45	2.40	1.65	1.44
Wayne	1.84	2.02	3.71	4.53	3.66	3.15
Kent	1.17	2.22	2.31	2.51	2.51	2.14
Clark 63	1.29	2.02	2.32	3.30	3.94	2.57
Mean	1.22	1.84	2.50	3.13	2.94	2.33

L.S.D. (.05) Between two dates within the same variety = 1.25

L.S.D. (.05) Between two varieties within the same date = 0.90

*grams per 10 plants

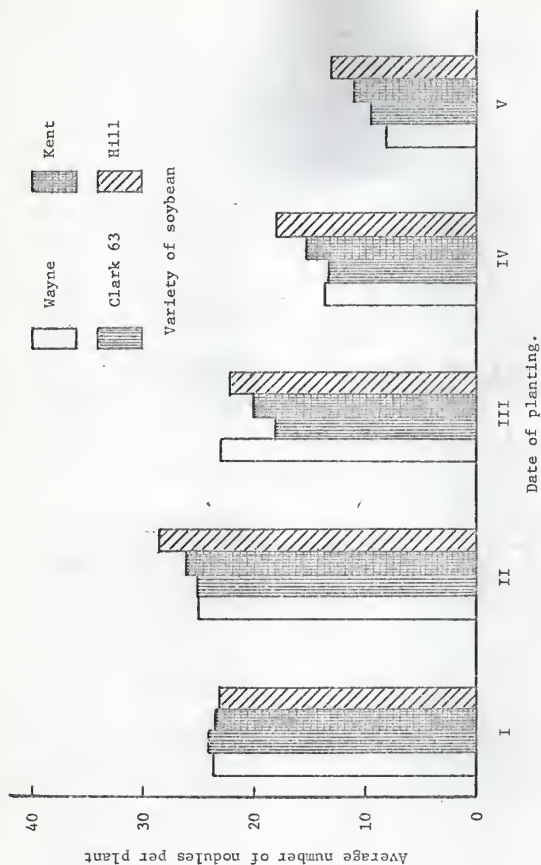


Fig. 6. Effect of date of planting on nodulation of Wayne, Clark 63, Kent and Hill soybeans for samples taken 12 weeks after nodule initiation. Varieties are arranged in order of maturity with Wayne=earliest, and Hill=latest.

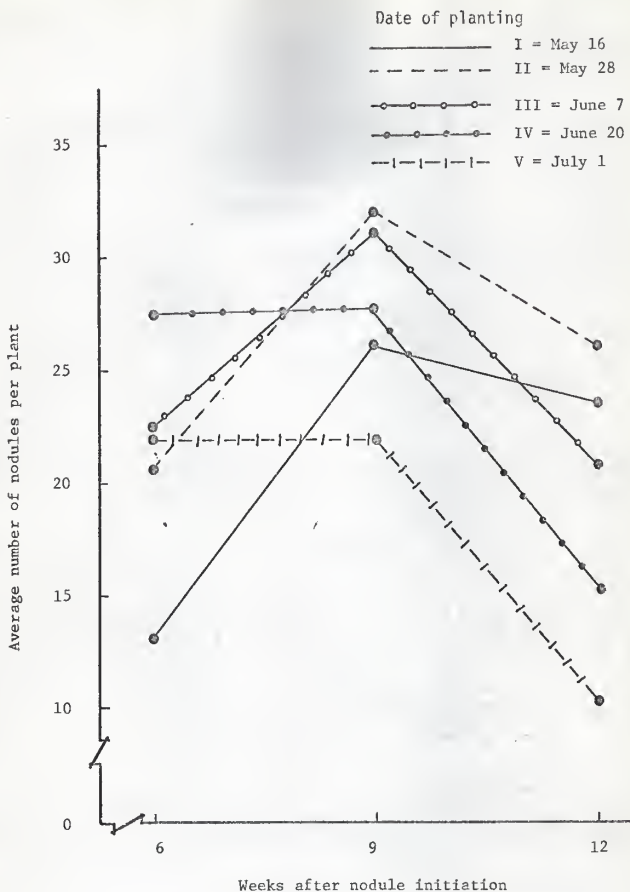


Fig. 7. Nodulation of Wayne, Clark 63, Kent and Hill soybeans in 10-, 20-, and 30-inch row widths during the sampling periods for each date of planting.

Results of nodule fresh-weight during the first samplings is shown in Table 7. Nodule fresh-weight for all varieties increased progressively (though not significantly in all cases) from dates I to IV and then there was a decrease in weight in date V. In date I, Wayne produced significantly greater nodule weight than Hill but there were no significant differences between Wayne, Kent and Clark 63. In date II, Hill produced significantly lower nodule weight than Wayne, Kent and Clark 63 but there were no significant differences between these last three varieties. In dates III and IV, Wayne produced significantly greater nodule weight than Hill, Kent and Clark 63 but no significant differences between Hill, Kent and Clark 63.

In date V, Wayne and Clark 63 produced significantly greater nodule weight than Kent and Hill, and there was no significant difference between Kent and Hill. The order of nodule weight for varieties was similar to the pattern of average nodule number per plant as shown by results in Table 4. Although differences between varieties were not significant in every case as already reported, the order of amount of nodule weight was Wayne (greatest), Clark 63, Kent and Hill (lowest).

Analysis of variance, Table 37, Appendix II, shows significant effects of row width on nodule fresh-weight and the results are shown in Table 8. There was significantly greater nodule fresh-weight from the 10-inch row width than from the 20-inch, and 30-inch row widths but there was no significant difference between nodule weight from the 20 and 30-inch row widths. This could be due to the earlier ground cover attained by the 10-inch row spacings than in the wider row widths, since covering of the soil by the shading of the leaves reduces the rate of moisture loss through evaporation and more moisture is available to plants in 10-inch row widths than in 20-inch and 30-inch row spacings for root and nodule formation.

Table 8. Effect of row width on average nodule fresh-weight* of four varieties of soybeans, row width x variety (first samplings).

Variety	Row width inches			Mean
	10	20	30	
Hill	1.71	1.32	1.29	1.44
Wayne	3.91	2.73	2.82	3.15
Kent	2.56	1.82	2.06	2.14
Clark 63	2.61	2.67	2.43	2.57
Mean	2.70	2.13	2.15	2.33

L.S.D. (.05) Between row width means = 0.41

L.S.D. (.05) Between variety means = 0.37

* grams per 10 plants

Table 9. Effect of date of planting on average nodule fresh-weight* of four varieties of soybeans, date x variety (second samplings).

Variety	Planting date					Mean
	I	II	III	IV	V	
Hill	3.19	3.31	3.64	3.64	4.00	3.55
Wayne	7.22	8.82	8.18	6.85	5.89	7.39
Kent	5.86	7.33	6.64	5.46	6.12	6.28
Clark 63	5.14	7.00	6.94	5.46	5.41	5.99
Mean	5.36	6.61	6.35	5.35	5.36	5.81

L.S.D. (.05) Between date of planting means = 2.32

L.S.D. (.05) Between variety means = 0.80

* grams per 10 plants

The analysis of variance for nodule fresh-weight for the second sampling shows significant differences between varieties as shown in Table 39, Appendix II. The results are shown in Table 9. Wayne produced significantly greater nodule weight than Clark 63, Kent and Hill. Clark 63 and Kent produced significantly greater nodule weight than Hill.

Statistical analysis shows that Wayne produced significantly greater nodule fresh-weight than Hill and Kent in date I of the third samplings. Results are shown in Table 10. Clark 63 and Kent produced significantly greater nodule weight than Hill but no significant difference between Wayne and Clark 63. In date II, Hill produced significantly lower nodule weight than Wayne, Kent, and Clark 63 but there were no significant differences between these three varieties. In date III, Wayne produced significantly more nodule weight than Kent, Clark 63 and Hill but there were no significant differences between these last three varieties.

In date IV, Hill and Kent had significantly greater nodule weight than Clark 63, but there were no significant differences between Hill, Kent and Wayne. In date V, there were no significant differences between the varieties. There was a general progressive decrease in nodule fresh-weight from dates III to V for all varieties. This shows that plants in dates I and II apparently had nodules for longer periods of time than plants in later dates.

However, despite the decrease in nodule weight from dates III to V, later maturing varieties had significantly greater nodule weight than the earlier maturing varieties in dates IV and V. The order of nodule weight was Hill (greatest), Kent, Clark 63 (with some inconsistency in date IV), and Wayne (lowest).

In dates I and II, nodule fresh-weight increased throughout the three sampling periods but the nodule fresh-weight decreased after second

Table 10. Average nodule fresh-weight* of four varieties of soybeans during third samplings; planting date x variety.

Variety	Planting date					Mean
	I	II	III	IV	V	
Hill	5.45	7.27	4.28	5.00	2.97	5.00
Wayne	9.86	9.55	7.44	4.04	2.03	6.58
Kent	8.10	8.89	5.23	4.70	2.83	5.95
Clark 63	8.88	8.44	4.45	3.29	2.36	5.48
Mean	8.08	8.54	5.34	4.26	2.55	5.75

L.S.D. (.05) Between two dates within the same variety = 1.46

L.S.D. (.05) Between two varieties within the same date = 1.16

* grams per 10 plants

Table 11. Effect of date of planting and row width on seed yield* of Hill, Wayne, Clark 63 and Kent soybeans, planting date x row width.

Row width (inches)	Planting date					Mean
	I	II	III	IV	V	
10	44.8	40.7	35.4	29.8	25.7	35.3
20	42.9	40.7	36.9	28.9	24.4	34.7
30	40.7	41.8	38.3	31.1	27.6	35.9
Mean	42.8	41.1	36.9	29.9	25.9	35.3

L.S.D. (.05) Between two dates within the same row width = 0.90

L.S.D. (.05) Between row widths within the same date = 0.84

* Bushels per acre

samplings in dates III to V. Wayne and Clark 63 produced their greatest nodule weights in date I while Kent and Hill produced greatest nodule weight in date II as shown in Table 10.

Seed Yield

Analysis of variance on seed yield data shows that the effects of date of planting, row width, and variety were not independent of one another. Comparisons of seed yields between dates of planting within the same row width show that the highest seed yields were obtained in date I from the 10-inch row width (44.8 Bu/A), and the 20-inch row width (42.9 Bu/A). The highest seed yield under 30-inch row width was obtained in date II (41.8 Bu/A) and thereafter there were significant and progressive decreases in seed yield with delay in planting. In 10-inch and 20-inch row widths, significant and progressive yield decrease started from date II through V. The results are shown in Table 11 and in Fig. 9.

Comparisons between row widths within the same date of planting show significant increases with decreasing row widths in date I. That is, the yield obtained from 10-inch row width was greater than that obtained from 20-inch row width and that of 20-inch greater than the yield obtained from 30-inch row width in date I. But from dates II to V, 30-inch row width resulted in significantly greater yield than the yields obtained from 10-inch and 20-inch row widths.

In date II there was no significant difference between the yields from 10-inch and 20-inch row widths but significantly greater yield was obtained in 30-inch row width than seed yield from 10-inch, and 20-inch row widths. In date III, yield obtained from 20-inch row width was significantly greater than that of 10-inch row width, but in dates IV and V, significantly

Table 12. Average seed yield (Bu/A); date of planting x variety.

Variety	Planting date					Mean
	I	II	III	IV	V	
Hill	41.7	40.4	30.7	22.7	18.0	30.7
Wayne	45.5	42.4	40.7	36.5	30.6	39.1
Kent	43.6	41.9	37.7	29.3	27.4	36.0
Clark 63	40.4	39.6	38.4	31.3	27.7	35.5
Mean	42.8	41.1	36.9	29.9	25.9	35.3

L.S.D. (.05) Between two dates within the same variety = 1.1

L.S.D. (.05) Between two varieties within the same date = 1.0

Table 13. Average seed yield (Bu/A); row width x variety.

Variety	Row width (inches)			Mean
	10	20	30	
Hill	28.3	31.4	32.4	30.7
Wayne	40.6	38.5	38.2	39.1
Kent	35.7	35.1	37.2	36.0
Clark 63	36.5	34.1	35.8	35.5
Mean	35.3	34.7	35.9	35.3

L.S.D. (.05) Between two row widths within the same variety = 0.76

L.S.D. (.05) Between two varieties within the same row width = 0.80

greater yield was obtained from 10-inch row width than from 20-inch row width.

The decrease in yield with closer spacings for later plantings could be due partly to reduced number of nodes per plant as this would consequently result in less number of pods per plant. Also greater lodging in closer spacings might adversely affect the development of the plant as well as the seed production.

Comparisons between varieties within the same date of planting show that Wayne produced significantly higher seed yield than Kent, Hill and Clark 63 in date I. Kent produced significantly greater seed yield than Hill and Clark 63, and Hill also produced significantly higher seed yield than Clark 63. The results are shown in Table 12, and in Fig. 8.

In date II, there was no significant difference between seed yield of Wayne and Kent but the two of them produced significantly greater seed yield than Hill and Clark 63. There was no significant difference between Hill and Clark 63.

In date III, Wayne produced significantly greater seed yield than Kent, Hill and Clark 63. Hill produced significantly lower yield than Kent and Clark 63, but there was no significant difference between Kent and Clark 63. In dates IV, all varieties were significantly different from one another in seed yield production. The order was: Wayne (highest), Clark 63, Kent and Hill (lowest).

In date V, Wayne produced significantly more seed yield than other varieties. There was no significant difference between seed yields of Kent and Clark 63, both of which produced significantly more seed yield than Hill. The results are shown in Table 12, and graphically illustrated in Fig. 8. These results show that later maturing varieties were affected more than the early maturing varieties by delay in planting as regards seed yields.

Comparisons between dates of planting within the same variety show that the highest seed yields were obtained in date I for all varieties and significantly lower seed yields with subsequent dates of planting except for Clark 63. There was no significant difference between yield production in dates I and II but thereafter there was progressive and significant decreases in seed yield with delay in planting of Clark 63.

Table 13 shows the results of effects of row width on seed yield of the soybean varieties. Comparisons between row widths within the same variety shows that with Hill, the seed yield increased significantly with increase in row width. The seed yield of Wayne decreased significantly with increase in row width. Kent produced significantly more seed yield from the 30-inch row width than from the 10-inch and 20-inch row widths but no significant differences were obtained from 10-inch and 20-inch row widths.

There was no significant difference between seed yields obtained from 10-inch and 30-inch row widths for Clark 63, but seed yield obtained from 20-inch row width was significantly lower than the other two row widths. The results are shown in Table 13 and in Fig. 10. Comparisons between varieties within the same row width show that Wayne produced significantly greater seed yield than the other varieties in 10-inch row width. There was no significant difference in seed yield of Kent and Clark 63 but both produced significantly greater seed yield than Hill.

In 20-inch and 30-inch row widths, Wayne produced significantly greater seed yield than the other varieties. Kent and Clark 63 produced significantly more seed yield than Hill, and Kent produced significantly greater seed yield than Clark 63. The results as shown in Table 13 seem to indicate that Wayne and Clark 63 could probably stand high plant population better than the other varieties since they produced greatest seed yield from

Explanation of Figures

Figure 8. Effect of date of planting and row width on seed yield of four varieties of soybeans.

Figure 9. Effect of date of planting on seed yield of Hill, Wayne, Kent and Clark 63 soybeans.

Date of planting

I	=	May 16
II	=	May 28
III	=	June 7
IV	=	June 20
V	=	July 1

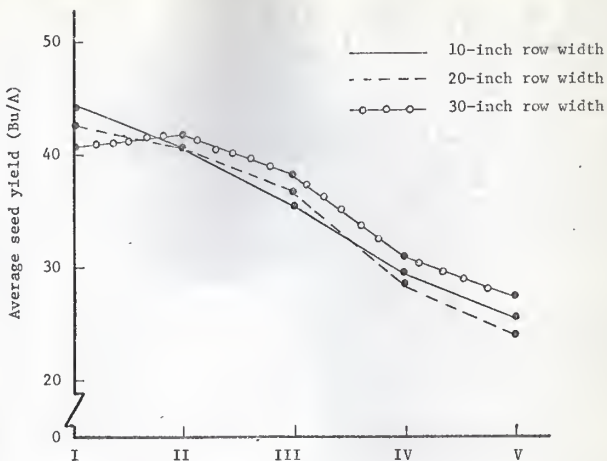


Fig. 8. Date of planting.

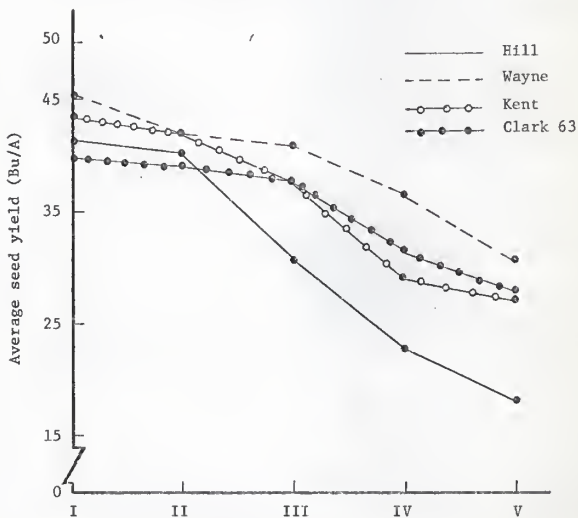


Fig. 9. Date of planting.

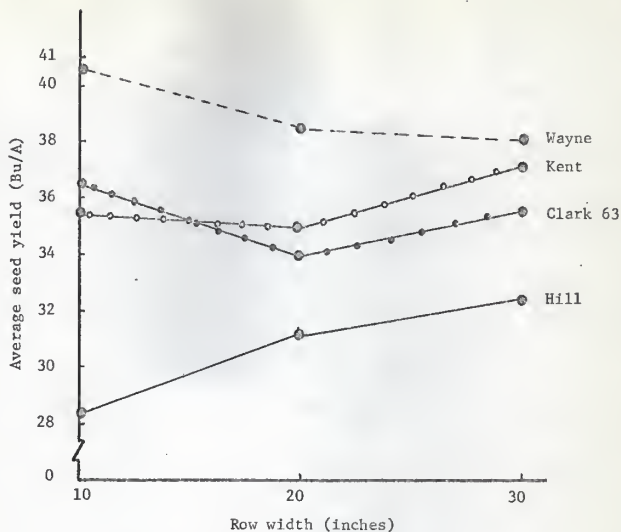


Fig. 10. Effect of row width on seed yield of Wayne, Clark 63, Kent and Hill soybeans.

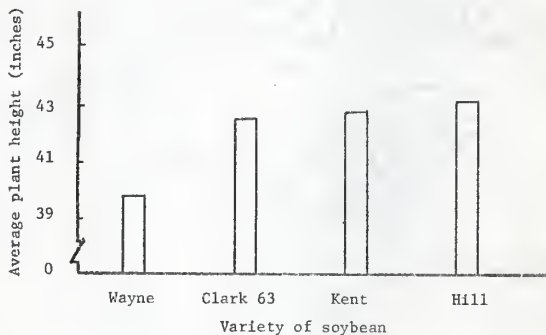


Fig. 11. Varietal differences in average height of Wayne, Clark 63, Kent and Hill soybean plants.

10-inch row width. The comparatively lower seed yield of Hill than other varieties, most especially in 10-inch row width may be attributed to greater lodging during the vegetative growth than other varieties as shown in Table 21.

Plant Height

The analysis of variance on data collected for plant height, Table 43, in Appendix II, shows independent effects of date of planting, row width and variety on plant height. Statistical analysis shows that plants in date II were significantly taller than plants in dates I, IV and V. Plants in date II were 1.7 inches taller than plants in date I, 2.2 inches taller than plants in date IV, and 4.5 inches taller than plants in date V. There was no significant difference between plant height in date II and III but plants in date III were significantly taller than plants in date V by 3.5 inches.

There were no significant differences between the height of plants in dates I, III and IV but plants in date V were significantly shorter than plants in dates I, III, and IV by 2.8, 3.2, and 2.5 inches respectively. There was a progressive decrease in plant height from dates III to V. The results are shown in Table 14, and graphically illustrated in Fig. 12.

Comparisons between variety means show that Hill plants were significantly taller than Wayne by 3.5 inches and Clark 63 by 2.7 inches. There was no significant difference between Hill and Kent in plant height, and there was no significant difference between Kent and Clark 63. Kent was significantly taller than Wayne by 3.0 inches and Clark 63 by 2.8 inches. The varietal differences in plant height are graphically shown in Fig. 11.

Plant height increased slightly but progressively with narrow spacings. There was no significant difference of plant height in 10-inch and 20-inch row widths though plants in 10-inch row width were slightly

Table 14. Average plant height (inches); planting date x variety.

Variety	Planting date					Mean
	I	II	III	IV	V	
Hill	43.3	44.3	44.0	42.7	41.6	43.2
Wayne	39.8	41.2	40.8	39.2	35.3	39.7
Kent	43.3	44.8	43.7	42.3	39.2	42.7
Clark 63	42.3	44.7	43.4	42.5	39.5	42.5
Mean	42.2	43.9	42.9	41.7	39.4	42.0

L.S.D. (.05) Between date of planting means = 1.5

L.S.D. (.05) Between variety means = 0.6

Table 15. Effect of row width on average height (inches) of four varieties of soybean; row width x variety.

Variety	Row width (inches)			Mean
	10	20	30	
Hill	43.7	43.1	42.6	43.2
Wayne	40.0	40.5	38.8	39.7
Kent	43.5	42.5	41.9	42.7
Clark 63	43.0	42.6	41.7	42.5
Mean	42.6	42.2	41.3	42.0

L.S.D. (.05) Between row width means = 0.5

L.S.D. (.05) Between variety means = 0.6

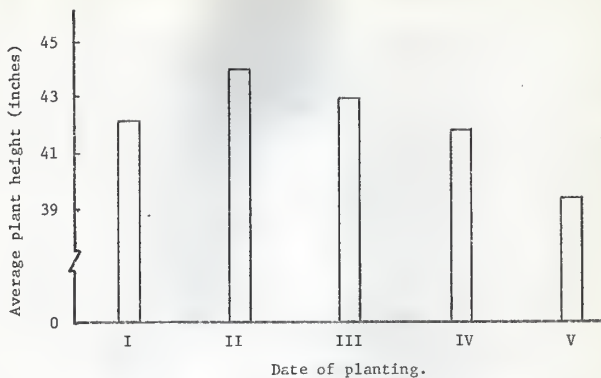


Fig. 12. Effect of date of planting on plant height of Wayne, Clark 63, Kent and Hill soybeans.

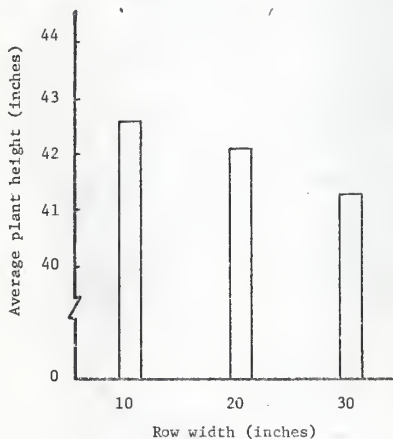


Fig. 13. Effect of row width on plant height of Wayne, Clark 63, Kent and Hill soybeans.

taller than plants in 20-inch row width, as shown in Table 15. Plants in 30-inch row width were significantly shorter than plants in 10 and 20-inch row widths. The increase in height of plants in narrow row widths could be due to greater competition for light by the plants, especially in the 10-inch row width. The effect of row width on plant height is illustrated in Fig. 13.

Nodes Per Plant

Statistical analysis of variance, Table 44, in Appendix II, shows that the effects of date of planting, row width and variety on average number of nodes per plant were not independent of one another. Comparisons between dates of planting within the 10-inch, 20-inch and 30-inch row width, show that there were no significant differences between nodes per plant in dates I and II, but node numbers in dates I and II were significantly greater than node numbers in dates III to V. Node number per plant in dates III to V were significantly different from one another with a progressive decrease with delay in planting. Plants in dates I and II produced approximately two more nodes per plant than plants in date III and plants in date III produced two more nodes per plant than plants in date IV. Plants in date IV produced one more node per plant than plants in date V. Results are shown in Table 16.

Comparisons of average nodes per plant between row widths within the same date show that in dates III, IV, and V, every 10 inches increase in widening of row width resulted in an increase of approximately one node per plant. In dates I and II, there was an increase of one node per plant by increasing row width from 10-inches to 20-inches, and an increase of about 1.5 nodes per plant by increasing row width to 30-inches from 20-inches. The results are shown in Table 16 and graphically illustrated in Fig. 14.

Comparisons between varieties within the same date of planting

Table 16. Average number of nodes per plant; planting date x row width.

Row width (inches)	Planting date					Mean
	I	II	III	IV	V	
10	20.6	20.7	18.4	16.4	15.4	18.3
20	21.6	21.8	19.4	17.6	16.3	19.3
30	23.0	23.3	20.2	18.5	17.3	20.5
Mean	21.7	21.9	19.2	17.5	16.4	19.4

L.S.D. (.05) Between two dates within the same row width = 0.31

L.S.D. (.05) Between two row widths within the same date = 0.26

Table 17. Average number of nodes per plant; planting date x variety.

Variety	Planting date					Mean
	I	II	III	IV	V	
Hill	18.1	18.2	15.1	14.6	13.7	16.0
Wayne	22.2	22.9	19.7	18.4	16.6	19.9
Kent	23.2	23.7	21.8	19.2	18.2	21.2
Clark 63	23.1	22.9	20.8	17.7	16.9	20.3
Mean	21.7	21.9	19.2	17.5	16.4	19.4

L.S.D. (.05) Between two dates with the same variety = 0.35

L.S.D. (.05) Between two varieties within the same date = 0.36.

Explanation of Figures

Figure 14.

Effect of date of planting and row width on average number of nodes per plant for four varieties of soybeans.

Figure 15.

Effect of date of planting on average number of nodes per plant in Hill, Wayne, Kent and Clark 63 soybeans.

Date of Planting

I	=	May 16
II	=	May 28
III	=	June 7
IV	=	June 20
V	=	July 1

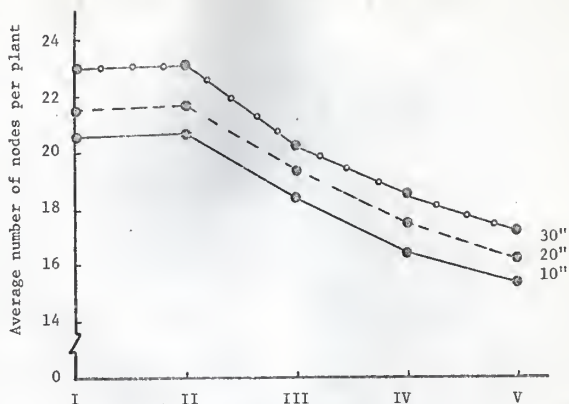


Fig. 14. Date of planting.

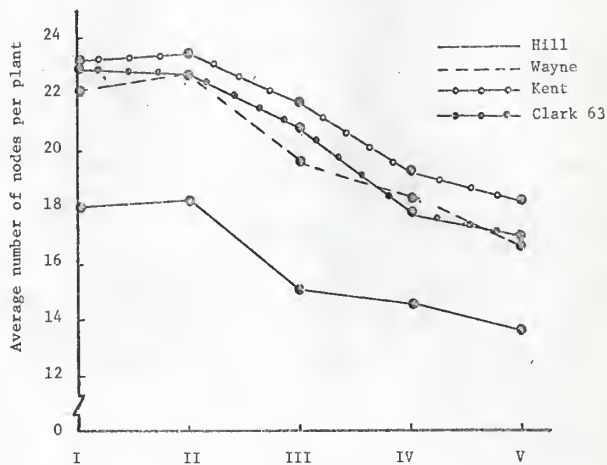


Fig. 15. Date of planting.

show that there were no significant differences in nodes per plant for Kent and Clark 63 in date I but both produced significantly more nodes per plant than Wayne by 1, and Hill by 5 nodes. Wayne produced 4 more nodes per plant than Hill. In date II Kent produced more nodes than Wayne and Clark 63 by approximately 1 node per plant. Kent produced 5.5 more nodes per plant than Hill, while Clark 63 and Wayne produced about 4.7 more nodes per plant than Hill. The results are shown in Table 17, and in Fig. 15.

From dates III to V there were significant differences between all varieties with a progressive decrease with delay in planting. The varietal means shows that Kent produced about 1 more node per plant than Clark 63, and Wayne. Kent produced 4 more nodes per plant than Hill.

Comparisons between the row widths within the same variety show 1 more node per plant for Hill by changing row width from 10 inches to 20 inches, and 2 more nodes per plant by changing row width from 20 to 30 inches. For Kent, Wayne and Clark 63, every 10-inch increase in row width resulted in 1 more node per plant within the limits of row widths used in this study. The results are shown in Table 18.

Lodging

Lodging was rated from 1 to 5, where 1 = almost all plants are erect, 5 = 80% or more plants down, and 2 to 4 = intermediates as shown in Table 19. Analysis of variance, Table 47, shows that the effects of date of planting, row width and variety on lodging were not independent of one another. Comparisons between dates of planting within 10-inch, 20-inch, and 30-inch row widths show that there were no significant differences in lodging between plants in dates I, and II. Plants lodged significantly more in dates III to V than plants in dates I and II for all the three row widths.

Table 18. Average number of nodes per plant; row width x variety.

Variety	Row width (inches)			Mean
	10	20	30	
Hill	15.0	15.9	17.1	16.0
Wayne	18.7	19.9	21.3	19.9
Kent	20.3	21.2	22.1	21.2
Clark 63	19.1	20.4	21.5	20.3
Mean	18.3	19.3	20.5	19.4

L.S.D. (.05) Between two row widths within the same variety = 0.26

L.S.D. (.05) Between two varieties within the same row width = 0.28

Table 19. Effect of date of planting and row width on lodging* of four varieties of soybeans; date x row width means.

Row width (inches)	Planting date					Mean
	I	II	III	IV	V	
10	2.8	3.1	3.6	4.0	4.2	3.5
20	2.2	2.4	3.0	3.6	3.8	3.0
30	2.2	2.6	3.2	3.0	3.3	2.8
Mean	2.4	2.7	3.3	3.5	3.7	3.1

L.S.D. (.05) Between two dates within the same row width = 0.40

L.S.D. (.05) Between two row width within the same date = 0.33

* Lodging is rated from 1-5, where 1 = almost all plants are erect, 2 = almost all plants leaning slightly, 3 = almost all plants leaning moderately or 25 to 50% of plants down, 4 = almost all plants leaning considerably, or 50 to 80% of plants down, 5 = 80% or more plants down.

In the 10-inch row width there was no significant difference in lodging of plants in date III and IV, and there was no significant difference in lodging of plants in date IV and V but plants in date V lodged significantly more than plants in date III.

In the 20-inch row width plants in date IV and V lodged significantly more than plants in date III but there was no significant difference in lodging of plants in date IV and V. In the 30-inch row width there were no significant differences between the lodging of plants in dates III to V. The date of planting means show a progressive increase in lodging with delay in planting. This might be due to rapid development toward maturity with delay in planting. The rapid growth might also result in long and thin internodes that may not be able to resist strong wind to a great extent.

Comparisons between row widths within the same date of planting show that in dates I, II, and III, there were no significant differences in lodging of plants in 20-inch and 30-inch row widths but plants in 10-inch row width lodged significantly more than plants in 20 and 30-inch row widths. In dates IV and V there were significant differences between the lodging of plants for the three row widths, with the greatest amount of lodging in the 10-inch row width and the least in 30-inch row widths as shown in Table 19.

Comparisons between varieties within the same date of planting show that there were no significant differences between the lodging of Wayne and Kent in dates I to IV but Kent lodged significantly more than Wayne in date V. For all dates of planting Hill lodged significantly more than all other varieties. Clark 63 lodged significantly more than Kent and Wayne in date I. In date II, Clark 63 lodged significantly more than Wayne but there was no significant difference between Clark 63 and Kent. In dates III and IV Clark 63 lodged significantly more than Kent and Wayne. In date V, Wayne

Table 20. Effect of date of planting and variety on lodging*; planting date x variety means.

Variety	Planting date					Mean
	I	II	III	IV	V	
Hill	3.8	4.1	4.5	4.5	4.7	4.3
Wayne	1.8	2.0	2.8	3.0	3.5	2.6
Kent	1.6	2.2	2.7	3.0	3.0	2.5
Clark 63	2.2	2.5	3.3	3.6	3.8	3.1
Mean	2.4	2.7	3.3	3.5	3.7	3.1

L.S.D. (.05) Between two dates within the same variety = 0.42

L.S.D. (.05) Between two varieties within the same date = 0.34

* Lodging rating, as shown in Table 19.

Table 21. Effect of row width and variety on lodging*; row width x variety means.

Variety.	Row width (inches)			Mean
	10	20	30	
Hill	4.3	4.4	4.4	4.3
Wayne	3.1	2.5	2.2	2.6
Kent	3.1	2.3	2.2	2.5
Clark 63	3.8	2.9	2.6	3.1
Mean	3.5	3.0	2.8	3.1

L.S.D. (.05) Between two row widths within the same variety = 0.22

L.S.D. (.05) Between two varieties within the same row width = 0.26

* Lodging rating, as shown in Table 19.

and Clark 63 lodged significantly more than Kent but there was no significant difference in lodging of Wayne and Clark 63. The variety means showed that Hill lodged greatest, followed by Clark 63, Wayne and Kent (least). The results are shown in Table 20.

The data on lodging of varieties from different row widths is shown in Table 21. There were no significant differences between the lodging of Kent and Wayne within the same row width for all the three row widths and both lodged significantly less than Clark 63 and Hill while Hill lodged significantly more than Clark 63.

Comparisons between the row widths within variety Hill show that there were no significant differences between all the three row widths. There were significant differences between lodging of Wayne and Clark 63 for all the three row widths, with the greatest lodging in the 10-inch row width and the least in the 30-inch row width. There was no significant difference between the lodging of Kent in the 20 and 30-inch row widths but plants in 10-inch row width lodged significantly more than plants in the other two row widths. There was a general progressive increase in lodging as the row width narrowed for all the varieties.

Seed Weight

The seed weight is the weight in grams per 100 seeds and it is considered as a yield component. Analysis of variance on data collected is shown in Table 45, Appendix II. The effects of date of planting, row width and variety were not independent of one another. Comparisons between dates of planting within 10-inch row width show significant differences between all dates. The decrease in seed weight was progressive with delay in planting from dates II to IV and then a slight but significant increase in date V

above seed weight in date IV. The results are shown in Table 22.

Within the 20-inch row width, seed weight in date I was significantly greater than seed weight in date II but no significant difference between seed weight in date II and III both of which were significantly greater than seed weight in dates IV and V. Seed weight in date V was significantly greater than seed weight in date IV.

Within the 30-inch row width, seed weight in date II was significantly greater than seed weight in other dates. There were no significant differences between seed weight in dates I and III but both were significantly greater than seed weight in dates IV and V. There was no significant difference between seed weight in dates IV and V.

Comparison of seed weight from different row widths within the same date show that in date I, there was no significant difference between seed weight from 10 and 20-inch row widths but seed weight from the 30-inch row width was significantly lower. In date II, there was no significant difference between seed weight from 10 and 20-inch row widths but both were significantly lower than seed weight from 30-inch row width. This seems to follow the pattern of seed yield as shown in Table 11, in which seed yield from the 30-inch row width was significantly greater than seed yield from 10 or 20-inch row width.

In date III there were significant differences between the seed weight from different row widths. The greatest seed weight from the 30-inch and the lowest from the 10-inch row width. In date IV there was no significant difference between seed weight in 10 and 20-inch row widths but seed weight from the 30-inch row width was significantly greater than seed weight from 10-inch and 20-inch row widths. In date V there were no significant differences between seed weight from the three row widths, as shown in

Table 22. Effect of planting date and row width on average seed weight*; planting date x row width.

Row width (inches)	Planting date					Mean
	I	II	III	IV	V	
10	14.7	13.9	13.5	12.6	13.1	13.6
20	14.5	13.9	13.8	12.8	13.2	13.6
30	14.2	14.6	14.2	13.3	13.3	13.9
Mean	14.4	14.1	13.8	12.9	13.1	13.7

L.S.D. (.05) Between two dates within the same row width = 0.27

L.S.D. (.05) Between two row widths within the same date = 0.20

* Grams per 100 seeds

Table 23. Average seed weight*; date of planting x variety.

Variety	Planting date					Mean
	I	II	III	IV	V	
Hill	11.9	11.8	11.3	9.9	9.6	10.9
Wayne	16.4	15.9	15.9	14.2	14.7	15.4
Kent	14.9	14.6	14.6	14.3	14.3	14.5
Clark 63	14.5	14.3	13.7	13.3	14.0	14.0
Mean	14.4	14.1	13.8	12.9	13.1	13.7

L.S.D. (.05) Between two dates within the same variety = 0.30

L.S.D. (.05) Between two varieties within the same date = 0.20

* Grams per 100 seeds

Table 22.

Comparisons between varieties within the same date, as shown in Table 23, show that the seed weight of varieties were significantly different from one another, and followed this order: Wayne (greatest), Kent, Clark 63, and Hill (lowest) in dates I, II, III and V. In date IV, there was no significant difference in seed weight between Wayne and Kent but both were significantly greater than seed weight of Hill and Clark 63. Clark 63 was also significantly greater in seed weight than Hill. All varieties had the greatest seed weight in date I, and decreased with later planting from dates II to IV and a slight but significant increase of seed weight in date V above seed weight in date IV, except for Kent.

Comparisons between dates of planting within the same variety show that there was no significant difference in seed weight of Hill in dates I and II but seed weight from these two dates were significantly greater than seed weight in dates III to V. There was no significant difference between seed weight in dates IV and V but both were significantly lower than seed weight in date III.

Wayne had significantly greater seed weight in date I than in dates II to V. There was no significant difference between seed weight in dates II and III but both were significantly greater than seed weight in dates IV and V, while seed weight in date V was significantly greater than that of date IV.

Kent had significantly more seed weight in date I than in dates IV and V. There were no significant differences between seed weight in dates II to V. There was no significant difference between seed weight of Clark 63 in dates I and II but seed weight in dates I and II were significantly greater than seed weight in dates III to V. There was no significant

Table 24. Average seed weight*; variety x row width.

Variety	Row width (inches)			Mean
	10	20	30	
Hill	10.5	10.9	11.2	10.9
Wayne	15.3	15.4	15.6	15.4
Kent	14.5	14.4	14.7	14.5
Clark 63	13.9	13.9	14.1	14.0
Mean	13.6	13.6	13.9	13.7

L.S.D. (.05) Between two row widths within the same variety = 0.17

L.S.D. (.05) Between two varieties within the same row width = 0.16

* Grams per 100 seeds

Table 25. Effect of date of planting and row width on seed quality* of four varieties of soybean, date x row width means.

Row width (inches)	Planting date					Mean
	I	II	III	IV	V	
10	1.5	1.6	1.5	1.7	2.0	1.6
20	1.5	1.6	1.5	1.8	2.3	1.7
30	1.6	1.6	1.5	1.9	2.4	1.8
Mean	1.5	1.6	1.5	1.7	2.2	1.7

L.S.D. (.05) Between two dates within the same row width = 0.20

L.S.D. (.05) Between two row widths within the same date = 0.17

* Seed quality is rated according to the following scale considering seed development, purple seed stain, mottling, damage, wrinkling of seed coat and objectionable color for all varieties: 1 = very good, 2 = good, 3 = fair, 4 = poor, 5 = very poor.

difference between seed weight in dates III and V but both were significantly greater than seed weight in date IV as shown in Table 23.

Comparisons between varieties within the same row width, show significant differences between varieties for seed weight in all the three row widths. The order of seed weight was Wayne (greatest), Kent, Clark 63, and Hill (lowest). This follows the same trend of seed yield of varieties.

Comparisons between row widths within the same variety show that there were no significant differences between seed weight in 10 and 20-inch row widths for Wayne, Kent, and Clark 63, but seed weight for these varieties in 30-inch row width was greater than seed weight in 10 and 20-inch row widths. For Hill there were significant differences between the row widths, with the greatest seed weight in 30-inch row width and the lowest in 10-inch row width as shown in Table 24.

Seed Quality

Seed quality was rated and numbers assigned considering development, damage, purple seed stain, mottling, wrinkled seedcoat, and objectionable color for all the varieties. The scale is arbitrarily set from 1 to 5 where 1 = very good, 5 = very poor, 2 to 4 = intermediates as shown in Table 25. The analysis of variance, Table 46, Appendix II, showed that the effects of date of planting, row width, and variety on seed quality were not independent of one another.

Comparisons between dates of planting within the 10-inch row width show that there were no significant differences between seed quality in dates I to IV but seed quality in date V was significantly lower than the other dates. Within the 20-inch and 30-inch row widths there were no significant differences in seed quality from dates I to III but seed quality in

Table 26. Effect of date of planting on seed quality* of four varieties of soybean; planting date x variety means.

Variety	Planting date					Mean
	I	II	III	IV	V	
Hill	1.4	1.4	1.4	1.6	1.7	1.5
Wayne	1.5	1.5	1.5	1.7	2.2	1.7
Kent	1.6	1.6	1.5	2.0	2.4	1.8
Clark 63	1.7	1.6	1.6	2.0	2.7	1.9
Mean	1.5	1.6	1.5	1.7	2.2	1.7

L.S.D. (.05) Between two dates within the same variety = 0.15

L.S.D. (.05) Between two varieties within the same date = 0.14

* Seed quality rating, as shown in Table 25.

Table 27. Effect of row width on seed quality* of four varieties of soybean, variety x row width means.

Variety	Row width (inches)			Mean
	10	20	30	
Hill	1.5	1.5	1.5	1.5
Wayne	1.6	1.7	1.8	1.7
Kent	1.7	1.9	1.9	1.8
Clark 63	1.8	1.9	2.0	1.9
Mean	1.6	1.7	1.8	1.7

L.S.D. (.05) Between two row widths within the same variety = 0.12

L.S.D. (.05) Between two varieties within the same row width = 0.11

* Seed quality rating, as shown in Table 25.

dates IV and V were significantly lower than those of dates I to III. Seed quality in date V was lower than seed quality in date IV. The lower seed quality in dates IV and V might be due to the damp weather that set in just before the pods were dry enough for threshing. The results are shown in Table 25.

Comparisons between row widths within the same date show that there were no significant differences between seed quality in dates I to III for the three row widths. In date IV, there was no significant difference between seed quality in 10 and 20-inch row widths, while 30-inch row width resulted in significantly lower seed quality. In date V, there was no significant difference between seed quality in 20 and 30-inch row width but seed quality in 10-inch was significantly better.

As shown in Table 26, Hill shows a consistently better seed quality than other varieties in all dates of planting while Clark 63 had the lowest seed quality rating. In dates I to III there were no significant differences in seed quality of Hill and Wayne; similarly there was no significant difference in seed quality of Wayne and Kent but seed quality of Hill was significantly better than that of Kent and Clark 63. There was no significant difference in seed quality of Kent and Clark 63 and Wayne was significantly better in seed quality than Clark 63 in date I.

In date IV there was no significant difference between seed quality of Hill and Wayne and there was no significant difference between seed quality of Kent and Clark 63, but both were significantly lower in seed quality than Hill and Wayne. In date V, all the varieties were significantly different from one another in seed quality in this order: Hill (highest), Wayne, Kent, and Clark 63 (lowest). For each variety, there were no significant differences in seed quality in dates I to III but subsequent and significant lower

seed quality was evident in dates IV and V.

Table 27 shows the combined effects of row width and variety on seed quality. Comparisons between row widths within the same variety show that row width has no effect on seed quality of Will. Wayne and Clark 63 had significantly better seed quality in 10-inch than in 30-inch row width but no significant difference between seed quality in 10 and 20-inch row widths. There was no significant difference in seed quality in 20 and 30-inch row widths. Kent had significantly better seed quality from 10-inch than 20-inch and 30-inch row widths, but no significant difference between seed quality from 20 and 30-inch row widths. The better seed quality in 10-inch row width as compared to the 30-inch row width seems to show that plants in 30-inch row widths were exposed more to the environmental conditions that may affect seed development adversely than plants in 10-inch row widths.

Maturity

Maturity was recorded as days from emergence when approximately 95% of the pods were ripe and most of the leaves had dropped. Analysis of variance, Table 48, Appendix II, shows that the effect of date of planting, row width and variety on maturity were not independent of one another. Comparisons between dates of planting within the row widths, Table 28, showed significant decrease in number of days to maturity with delay in planting. The decrease in number of days to maturity became considerable in dates III, IV and V. This might be due to rapid growth toward maturity as day length shortens during later part of the growing season. Favorable high temperatures as growing season progressed can also contribute to rapid growth.

The date of planting means show that plants in date I matured two days earlier than plants in date II. Plants in date III matured 7 days earlier

Table 28. Effect of date of planting and row width on maturity* of four varieties of soybean; row width x date of planting means.

Row Width (inches)	Planting date					Mean
	I	II	III	IV	V	
10	125	123	116	107	101	114
20	122	121	114	105	100	112
30	121	120	113	105	99	111
Mean	123	121	114	106	100	113

L.S.D. (.05) Between two dates within the same row width = 0.41

L.S.D. (.05) Between two row widths within the same date = 0.40

* Maturity was recorded as days from emergence when approximately 95 percent of the pods were ripe and most of the leaves had dropped.

Table 29. Effect of date of planting and variety on maturity*; planting date x variety means.

Variety	Planting date					Mean
	I	II	III	IV	V	
Hill	132	129	122	112	107	120
Wayne	116	114	107	100	93	106
Kent	124	123	116	107	102	115
Clark 63	120	118	111	102	97	110
Mean	123	121	114	106	100	113

L.S.D. (.05) Between two dates within the same variety = 0.42

L.S.D. (.05) Between two varieties within the same date = 0.41

* Maturity = as reported in Table 28.

than plants in date II and plants in date IV matured 8 days earlier than plants in date III. Plants in date V matured 6 days earlier than plants in date IV, and 23 days earlier than plants in date I.

Comparisons between the row widths within the same date showed that plants in 30-inch row width matured 1 day earlier than plants in 20-inch row widths in dates I, II, III, and V. There was no significant difference in maturity of plants in 20- and 30-inch row widths in date IV. In date I, plants in 30-inch row width matured 4 days earlier than plants in 10-inch row width, and plants in 20-inch row width matured 3 days earlier than plants in 10-inch row width.

In dates II and III plants in 30-inch row width matured 3 days earlier, and plants in 20-inch row width matured 2 days earlier than plants in 10-inch row width. In date IV plants in 20 and 30-inch row width matured 2 days earlier than plants in 10-inch row width. In date V, plants in 30-inch row width matured 2 days earlier than plants in 10-inch row width and plants in 20-inch row width matured 1 day earlier than plants in 10-inch row width. The row width means show delay in maturity with close spacing. Decreasing row width from 30 inches to 20 inches increased maturity by 1 day and decreasing row width to 10 inches from 20 inches increased maturity by 2 days. The results are shown in Table 28, and graphically illustrated in Fig. 17.

Comparisons between varieties within the same date show significant differences in their maturity for all dates of planting. There was a significant and progressive decrease in number of days to maturity with delay in planting especially from dates III to V as shown in Table 29. There was no consistent decrease in days to maturity between varieties from one date of planting to the next. The variety means showed that Wayne matured about 6

Table 30. Effect of row width and variety on maturity*; row width x variety means.

Variety	Row width (inches)			Mean
	10	20	30	
Hill	122	120	119	120
Wayne	108	106	105	106
Kent	116	115	114	115
Clark 63	111	109	109	110
Mean	114	112	111	113

L.S.D. (.05) Between two row widths within the same variety = 0.32

L.S.D. (.05) Between two varieties within the same row width = 0.31

* Maturity = as reported in Table 28.

Table 31. Effect of date of planting and row width on ground cover* by four varieties of soybean; date x row width means.

Row width (inches)	Planting date					Mean
	I	II	III	IV	V	
10	41	36	35	32	28	34
20	60	54	53	45	41	51
30	70	66	64	54	50	61
Mean	57	52	51	44	40	49

L.S.D. (.05) Between two dates within the same row width = 0.90

L.S.D. (.05) Between two row widths within same date = 0.87

*Ground cover = expressed as days after planting when the in-between row soil was almost or completely shaded.

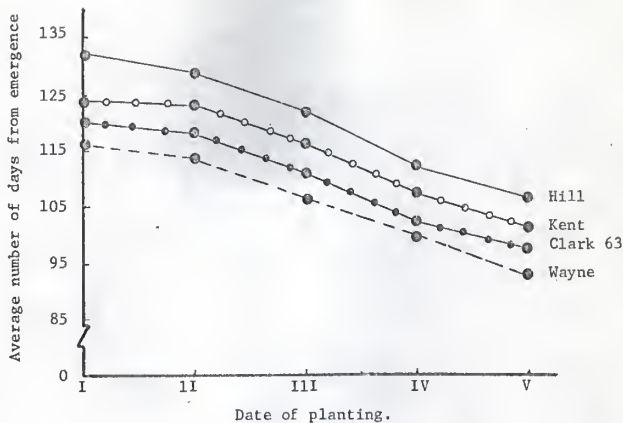


Fig. 16. Effect of date of planting on maturity of Wayne, Clark 63, Kent and Hill soybeans.

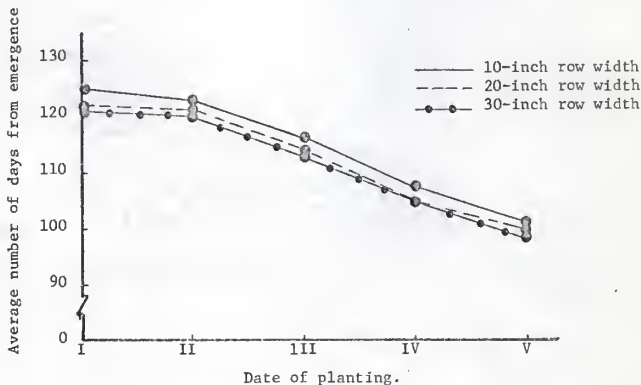


Fig. 17. Effect of date of planting and row width on maturity.

days before Clark 63, Clark 63 matured 5 days before Kent, and Kent matured 5 days before Hill. The results of the combined effect of variety and date of planting on maturity is illustrated graphically in Fig. 16.

Comparisons between varieties within the same row width, Table 30, show significant differences between them in maturity for all the row widths in about the same way as discussed for varietal differences in the preceding paragraph. Comparisons between row widths within the same variety showed that Wayne, and Hill matured 3 days earlier in 30-inch row width than in 10-inch row width, and one day earlier than in 20-inch row width. Kent matured 2 days earlier in 30-inch row width than 10-inch row width and 1 day earlier than in 20-inch row width. Clark 63 matured 1 day earlier in 30-inch and 20-inch row widths than in 10-inch row width.

Ground Cover

Data on ground cover was taken as the average number of days after planting when the soil between rows was completely or almost completely shaded by the plants. Analysis of variance data is shown in Table 49, in Appendix II. Comparisons between dates of planting within the same row width and comparisons between the row widths within the same date all show significant differences. The later the date of planting the earlier the ground cover. This could be attributed partly to rapid plant growth toward maturity under shorter photoperiod in later planting coupled with favorable high temperatures as the growing season progressed.

The wider the row width, the longer the number of days it took to attain ground cover. The differences between the row widths were not consistent from one date of planting to another as can be seen in Table 31. The date of planting means show that plants in date 11 attained ground cover

Table 32. Effect of row width and variety on ground cover*; row width x variety means.

Variety	Row width (inches)			Mean
	10	20	30	
Hill	34	51	61	49
Wayne	34	50	60	48
Kent	34	51	61	49
Clark 63	34	51	60	48
Mean	34	51	61	49

L.S.D. (.05) Between two row widths within the same variety = 0.74

L.S.D. (.05) Between two varieties within same row width = 0.56

* Ground cover = as reported in Table 31.

five days earlier than plants in date I, and plants in date III attained ground cover one day earlier than plants in date II. Ground cover was attained seven days earlier in date IV than in date III, and in date V, four days earlier than in date IV.

Comparisons between row widths within the same date show that for all dates of planting, the plants in the 20-inch row width attained ground cover about ten days before the 30-inch row width. In dates I, II, and III, ground cover was attained in the 10-inch row width about 18 days earlier than in 20-inch row width but in dates IV and V it was 13 days.

Table 32 shows the results of combined effects of row width and varieties on ground cover. Comparisons between varieties within the same row width showed no difference between varieties in attaining ground cover in the 10-inch row width. In 20-inch row width, Wayne attained ground cover one day earlier than other varieties, and in the 30-inch row width, Wayne and Kent attained ground cover a day earlier than Clark 63 and Hill.

SUMMARY

The greenhouse experiment was designed to evaluate the relative effectiveness of nine strains of Rhizobium japonicum to cause nodule formation on the roots of Amsoy, Wayne, Clark 63, Kent and Hill soybeans (glycine max). Statistical analysis of results shows that two strains—USDA 7 and USDA 7a—produced significantly more nodules per plant than the control (non-inoculated plants), as well as the other seven strains used in the study. There were no significant differences between the other seven strains and the control. The control even produced two more nodules per plant than strains USDA 110, 61A65 and 5566. The nodule formation on the non-inoculated plants may be attributed to residual bacteria in the soil, since the soil had been grown to inoculated soybeans in prior years.

The average nodule number of all treatments for each variety shows that Hill produced significantly more nodules per plant than Amsoy, Wayne, Clark 63 and Kent. Amsoy produced significantly more nodules per plant than Wayne, Clark 63, and Kent but there were no significant differences between the last three varieties.

Kent and Hill produced the greatest nodule fresh-weight when inoculated with strain USDA 7 while Wayne and Clark 63 produced greatest nodule weight with strain 135 and Amsoy with USDA 123. However, there were no significant differences between the effects of strains USDA 135 and USDA 7 on nodule weight of Clark 63, and Wayne or between USDA 123 and USDA 7 on nodule weight of Amsoy. There were no significant differences between inoculated and non-inoculated control plants as regards nodule weight. Amsoy, Clark 63, Wayne and Hill produced the lowest nodule weight when inoculated with strain 61A65 while Kent produced lowest nodule weight with strain 5566. Strain USDA 7

was selected for the field planting because it produced the greatest number of nodules per plant, and contributed greatest to nodule weight of Hill and Kent and there was no significant difference between its effect on nodule weight and the strains that contributed greatest to nodule weight of Amsoy, Wayne and Clark 63.

The field experiment was conducted to study the response of inoculated plants of Wayne, Clark 63, Kent and Hill soybeans to five dates of planting (I = May 16, II = May 28, III = June 7, IV = June 20, and V = July 1) and 3 row widths (10, 20, and 30 inches) as expressed by nodulation, seed yield and other agronomic characteristics of the varieties, at Manhattan, Kansas.

Statistical analysis of results obtained on nodulation from samples taken six weeks after nodule initiation showed that all varieties produced the greatest number of nodules per plant when planted June 20. There was a progressive increase in nodules per plant from dates I to IV and then a decrease in number of nodules per plant in date V.

Results obtained from samplings taken nine weeks after nodule initiation showed that nodules per plant in date II, and III were significantly greater than nodules per plant obtained in dates I, IV, and V. There was no significant difference between nodule number in dates I and IV but nodule number in date V was significantly lower than nodule number in date I.

Wayne, Clark 63 and Kent produced significantly more nodules per plant than Hill. Average number of nodules per plant was in the order of maturity as found during the first samplings with Wayne (earliest in maturity) producing 31.3 nodules per plant, Clark 63, 29.2, Kent, 28.1, and Hill (latest in maturity) 23.9 nodules per plant for second samplings.

Third nodule samplings were taken twelve weeks after nodule

initiation. All the varieties had the highest number of nodules per plant in date II, and thereafter a progressive decrease was noted with delayed planting. The order of nodules per plant obtained during third samplings was opposite the type of results obtained during first and second samplings from dates II to V and it was in this order—Hill (producing greatest nodule number per plant), Kent, Clark 63, and Wayne (lowest).

In all the three samplings, results of nodule number for Wayne, Clark 63, and Kent for each date of planting was greatest during second samplings. Hill had highest nodule numbers in dates I and II during third samplings and in dates III to V during second samplings.

Wayne, Kent and Hill produced the greatest nodule fresh-weight in date IV and Clark 63 in date V from samplings made six weeks after nodule initiation. The order of varietal nodule weight was Wayne (greatest), Clark 63, Kent and Hill (lowest). Nodule weight obtained from 10-inch row width was significantly greater than nodule weight from 20 or 30-inch row width.

Wayne produced significantly greater nodule fresh-weight from samplings made nine weeks after nodule initiation than Clark 63, Kent, and Hill. Clark 63 and Kent produced significantly greater nodule weight than Hill at nine weeks after nodule initiation.

The results of nodule fresh-weight from samplings made 12 weeks after nodule initiation show that Wayne and Clark 63 produced the greatest nodule weight in date I, Hill and Kent produced greatest nodule weight in date II. There was a progressive decrease in nodule weight from dates III to V for all varieties.

All the varieties produced the greatest seed yield from plantings made on May 16, followed by a progressive decrease in subsequent planting dates. The decrease became very sharp in plantings made after June 7,

most especially with later maturing varieties. The order of seed yield from May 16 planting was Wayne (45.5 Bu/A), Kent (43.6), Hill (41.7) and Clark 63 (40.4). Wayne and Clark 63 produced greater average seed yield from 10-inch than from 20 or 30-inch row width. Kent and Hill produced greater average seed yield from 30-inch than from 10-or 20-inch row width.

Plants in date II were significantly taller than plants in dates I, IV and V. Plants in date V were significantly shorter than plants in dates I, III, and IV. Hill was significantly taller than other varieties. Clark 63 and Kent were significantly taller than Wayne. Plants in 30-inch row width were significantly shorter than plants in 10-inch and 20-inch row widths.

Hill, Wayne, and Kent produced the greatest number of nodes per plant in date II with Kent producing (23.7), Wayne (22.9), Hill (18.2) and Clark 63 producing greatest number of nodes per plant in date I (23.1). Node number decreased progressively from dates III to V. All varieties produced the greatest number of nodes per plant in the 30-inch row width and lowest in 10-inch row width.

All varieties had greatest seed weight in date I in this order: Wayne (16.4 gms/100 seeds), Kent (14.9), Clark 63 (14.5) and Hill (11.9). All varieties had greater seed weight from 30-inch row width than from the other row widths.

For all varieties there were no significant differences in seed quality from dates I to III. The lower seed quality in dates IV and V might be due to the prolonged damp weather before the pods were dry enough for threshing.

All varieties lodged greatest in date V and least in date I. Generally the order of lodging of varieties in all dates was Hill (greatest),

Clark 63, Wayne and Kent (least). Wayne, Clark 63, and Kent lodged greatest in 10-inch row width and least in 30-inch row width. Hill lodged equally badly in all the three row widths.

The shortest number of days to maturity for all varieties was in date V. The decrease in number of days to maturity with delay in planting was not consistent from date to date for any of the varieties. Plants in 30-inch row width matured earliest while plants in 10-inch row width matured latest.

For all the varieties, the closer the row width, the quicker the attainment of ground cover. In all the three row widths, the number of days to achieve ground cover was highest in May 16 planting and lowest in July 1 planting. This might be due to shorter photoperiod coupled with favorable high temperatures as the growing season progressed, which seemed to speed up plant growth toward maturity in later plantings.

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APPENDIX I

Greenhouse Nodulation Study (1968)

Experimental Design and Analysis of Data

Nine strains of Rhizobium japonicum were evaluated in the greenhouse study for their relative ability to cause nodule formation on roots of five varieties of soybeans. A split-plot design was used. Varieties were randomized within the strains. Each variety with ten treatments, including the control (noninoculated seeds) was replicated three times. The soil used was taken from the site selected for field planting on the Agronomy Farm.

Soil PH	= 6.6
Available phosphorus	= 92 lbs/A
Available potassium	= 900 ⁺ lbs/A
Organic matter content	= 2.3%

There are 50 treatments altogether. The data for each measurement were subjected to the following analysis of variance.

<u>Source of variation</u>	<u>D.F.</u>
Replicates	2
Strains A	9
Error (A)	18
Varieties B	4
A x B	36
Error (B)	80
Total	<u>149</u>

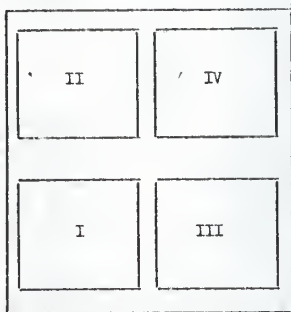
Least significant differences (L.S.D., $P = .05$) also were calculated if a significant F-value was found.

Field Experimental Design and Analysis of Data.

The response of inoculated soybean varieties to date of planting, and row width as expressed by nodulation and yield was conducted at Kansas State University's Agronomy Research Farm in 1968.

A split-split-plot design with 4 replications of each treatment was used. There were 5 dates of planting, 3 row widths and 4 varieties of soybeans. The design of experiment and layout of treatments and plots receiving them is outlined in the appendix. The setup and outline of replicates is given below.

The setup and outline of replicates



Design of experiment and layout with treatments
and plots receiving them

	DATE I	DATE II	DATE IV	DATE V	DATE III
R	H W K	K W C	K K H	W K H	C K H
E	C H C	W K H	W C K	H C W	K W W
P.	K C H	H C K	C H C	K H K	W H C
II	W K W	C H W	H W W	C W C	H C K
	30 20 10	10 20 30	10 20 30	30 20 10	20 30 10

	DATE III	DATE V	DATE I	DATE II	DATE IV
R	H H W	H K W	W H C	C H K	W C W
E	W K C	K H K	C C W	K C W	H W K
P.	C C K	W C C	K W H	W K C	C K C
I	K W H	C W H	H K K	H W H	K H H
	20 10 30	20 30 10	30 10 20	30 20 10	10 30 20

10-inch Row Width
20-inch Row Width
30-inch Row Width

H = Hill Variety
C = Clark 63 Variety
W = Wayne Variety
K = Kent Variety

R E P. IV	DATE V	DATE II	DATE III	DATE I	DATE IV
	H H C	C W W	H H K	W K C	H K W
	C C H	W H K	K K H	C H W	K W H
	K W K	K C H	C W W	H W K	W C K
	W K W	H K C	W C C	K C H	C H C
	30 20 10	30 20 10	20 30 10	10 30 20	20 30 10

R E P. III	DATE V	DATE III	DATE I	DATE IV	DATE II
	C K C	C H W	C K K	W H H	W C H
	H C W	H C K	W W H	H K W	H W W
	K H H	K W H	H C W	K C K	C K C
	W W K	W K C	K H C	C W C	K H K
	30 10 20	10 30 20	20 30 10	30 10 20	20 10 30

There are 60 treatments altogether. Data for each measurement were subjected to the following analysis of variance.

<u>Source of Variation</u>		<u>D.F.</u>
Replicates		3
Dates of planting	A	4
Error (A)		12
Row widths	B	2
A x B		8
Error (B)		30
Varieties	C	3
A x C		12
B x C		6
A x B x C		24
Error (C)		<u>135</u>
Total		<u><u>239</u></u>

APPENDIX II

Table 33. Analysis of variance on nodulation: Greenhouse Study

Average number of nodules per plant			
Sources of variance	D.F.	Mean Square	F
Replicates	2	789.993	16.06**
Factor A	9	241.157	4.90**
Error (A)	18	49.183	
Factor B	4	1759.059	62.53**
A x B	36	27.070	0.96
Error (B)	80	28.132	

Table 34. Analysis of variance on nodule fresh-weight: Greenhouse Study

Sources of variance	D.F.	Mean Square	F
Replicates	2	0.528	5.39**
Factor A	9	0.729	7.38**
Error (A)	18	0.098	
Factor B	4	0.423	9.20**
A x B	36	0.095	2.07**
Error (B)	80	0.046	

Table 35. Analysis of variance on total dry weight: Greenhouse Study

Sources of variance	D.F.	Mean Square	F
Replicates	2	4.346	7.14**
Factor A	9	0.789	1.29
Error (A)	18	0.609	
Factor B	4	6.085	31.79**
A x B	36	0.384	2.01**
Error (B)	80	0.191	

* = Significant at = .05

** = Highly significant at = .01

A = Strains

B = Varieties

Field Study

Table 36. Analysis of variance on nodulation: First Samplings

Average number of nodules per plant			
Sources of variance	D.F.	Mean Square	F
Replicates	3	267.174	2.33
Factor A	4	1323.335	6.61*
Error (A)	12	200.215	
Factor B	2	26.952	0.31
A x B	8	47.390	0.55
Error (B)	30	85.887	
Factor C	3	859.042	43.98**
A x C	12	69.117	3.54*
B x C	6	12.921	0.66
A x B x C	24	15.894	0.81
Error (C)	135	19.531	

Table 37. Analysis of variance on nodule fresh-weight: First Samplings

Sources of variance	D.F.	Mean Square	F
Replicates	3	3.290	0.62
Factor A	4	30.082	5.67*
Error (A)	12	5.304	
Factor B	2	8.169	4.94*
A x B	8	1.927	1.17
Error (B)	30	1.653	
Factor C	3	31.282	29.15**
A x C	12	2.885	2.69*
B x C	6	1.581	1.47
A x B x C	24	0.517	0.48
Error (C)	135	1.073	

* = Significant at = .05

** = Highly significant at = .01

A = Dates

B = Row widths

C = Varieties

Table 38. Analysis of variance on nodulation: Second Samplings

Average number of nodules per plant			
Sources of variance	D.F.	Mean Square	F
Replicates	3	595.813	6.24**
Factor A	4	830.710	8.70**
Error (A)	12	95.505	
Factor B	2	19.398	0.72
A x B	8	28.061	1.04
Error (B)	30	27.081	
Factor C	3	581.265	19.97**
A x C	12	50.934	1.75
B x C	6	13.183	0.45
A x B x C	24	29.682	1.02
Error (C)	135	29.103	

Table 39. Analysis of variance on nodule fresh-weight: Second Samplings

Sources of variance	D.F.	Mean Square	F
Replicates	3	15.058	0.55
Factor A	4	18.687	0.68
Error (A)	12	27.399	
Factor B	2	12.565	2.75
A x B	8	3.912	0.86
Error (B)	30	4.562	
Factor C	3	157.055	33.84**
A x C	12	4.726	1.02
B x C	6	6.073	1.31
A x B x C	24	3.379	0.73
Error (C)	135	4.641	

Table 40. Analysis of variance on nodulation: Third Samplings

Average number of nodules per plant			
Sources of variance	D.F.	Mean Square	F
Replicates	3	99.060	5.51*
Factor A	4	2009.238	111.78**
Error (A)	12	17.974	
Factor B	2	5.837	0.33
A x B	8	13.789	0.78
Error (B)	30	17.648	
Factor C	3	94.805	8.91**
A x C	12	28.174	2.65**
B x C	6	18.441	1.73
A x B x C	24	11.205	1.05
Error (C)	135	10.635	

Table 41. Analysis of variance on nodule fresh-weight: Third Samplings

Sources of variance	D.F.	Mean Square	F
Replicates	3	3.254	0.25
Factor A	4	309.932	23.94**
Error (A)	12	12.944	
Factor B	2	3.797	0.43
A x B	8	3.918	0.45
Error (B)	30	8.774	
Factor C	3	27.516	7.13**
A x C	12	15.263	3.96**
B x C	6	3.408	0.88
A x B x C	24	4.704	1.22
Error (C)	135	3.857	

Table 42. Analysis of variance on seed yield

Sources of variance	D.F.	Mean Square	F
Replicates	3	9.966	7.43**
Factor A	4	2505.390	1868.73**
Error (A)	12	1.341	
Factor B	2	25.106	18.57**
A x B	8	34.976	25.87**
Error (B)	30	1.352	
Factor C	3	726.352	478.86**
A x C	12	82.056	54.10**
B x C	6	51.622	34.03**
A x B x C	24	17.271	11.39**
Error (C)	135	1.517	

Table 43. Analysis of variance on average plant height

Sources of variance	D.F.	Mean Square	F
Replicates	3	80.383	7.56**
Factor A	4	137.785	12.96**
Error (A)	12	10.629	
Factor B	2	35.637	12.74**
A x B	8	5.413	1.94
Error (B)	30	2.797	
Factor C	3	141.272	57.73**
A x C	12	3.227	1.32
B x C	6	2.593	1.06
A x B x C	24	1.043	0.43
Error (C)	135	2.447	

Table 44. Analysis of variance on average number of nodes per plant

Sources of variance	D.F.	Mean Square	F
Replicates	3	0.700	3.76*
Factor A	4	296.766	1594.57**
Error (A)	12	0.186	
Factor B	2	95.754	811.09**
A x B	8	0.598	5.06**
Error (B)	30	0.118	
Factor C	3	328.411	1730.17**
A x C	12	3.953	20.82**
B x C	6	0.848	4.47**
A x B x C	24	0.629	3.32**
Error (C)	135	0.189	

Table 45. Analysis of variance on seed weight

Sources of variance	D.F.	Mean Square	F
Replicates	3	0.513	2.09
Factor A	4	19.583	79.83**
Error (A)	12	0.245	
Factor B	2	2.535	34.33**
A x B	8	1.257	17.02**
Error (B)	30	0.074	
Factor C	3	232.901	3442.13**
A x C	12	2.774	41.01**
B x C	6	0.362	5.35**
A x B x C	24	0.356	5.27**
Error (C)	135	0.067	

Table 46. Analysis of variance on seed quality

Sources of variance	D.F.	Mean Square	F
Replicates	3	0.124	2.43
Factor A	4	4.656	92.07**
Error (A)	12	0.051	
Factor B	2	0.544	12.07**
A x B	8	0.171	3.79**
Error (B)	30	0.045	
Factor C	3	2.167	75.00**
A x C	12	0.248	8.58**
B x C	6	0.073	2.53*
A x B x C	24	0.049	1.56
Error (C)	135	0.029	

Table 47. Analysis of variance on lodging

Sources of variance	D.F.	Mean Square	F
Replicates	3	4.520	9.61**
Factor A	4	16.490	34.44**
Error (A)	12	0.479	
Factor B	2	11.009	56.92**
A x B	8	0.548	2.84*
Error (B)	30	0.193	
Factor C	3	41.554	254.09**
A x C	12	0.432	2.64**
B x C	6	1.949	11.92**
A x B x C	24	0.154	0.94
Error (C)	135	0.163	

Table 48. Analysis of variance on maturity

Sources of variance	D.F.	Mean Square	F
Replicates	3	0.815	2.92
Factor A	4	4632.317	17371.19**
Error (A)	12	0.267	
Factor B	2	150.954	487.39**
A x B	8	3.142	10.14**
Error (B)	30	0.309	
Factor C	3	2389.859	9832.57**
A x C	12	5.006	20.59**
B x C	6	1.259	5.18**
A x B x C	24	1.135	4.67**
Error (C)	135	0.243	

Table 49. Analysis of variance on ground cover

Sources of variance	D.F.	Mean Square	F
Replicates	3	14.283	10.92**
Factor A	4	2303.225	1738.28**
Error (A)	12	1.325	
Factor B	2	14350.817	9897.11**
A x B	8	72.650	50.10*
Error (B)	30	1.450	
Factor C	3	5.394	9.25**
A x C	12	0.825	1.41
B x C	6	2.061	3.53**
A x B x C	24	0.700	1.20
Error (C)	135	0.583	

Table 50. Average Seed Yield (Bu/A): date of planting x row width x variety

Variety	Row width (inches)	Date of Planting					Mean
		I	II	III	IV	V	
Hill	10	42.5	39.0	22.3	21.2	16.7	28.3
Hill	20	43.9	40.3	32.9	21.8	18.0	31.4
Hill	30	38.8	42.1	36.8	25.3	19.3	32.5
Mean		41.7	40.5	30.7	22.7	18.0	30.7
Wayne	10	49.6	42.6	41.4	37.6	32.2	40.7
Wayne	20	46.3	41.2	40.2	37.1	28.0	36.5
Wayne	30	40.7	43.4	40.6	34.7	31.8	38.2
Mean		45.5	42.4	40.7	36.5	30.7	39.1
Kent	10	44.8	41.0	38.8	27.8	26.4	35.8
Kent	20	43.9	41.7	36.2	28.0	25.6	35.1
Kent	30	42.5	42.9	38.1	32.0	30.2	37.1
Mean		43.7	41.9	37.7	29.3	27.4	36.0
Clark 63	10	42.4	40.6	39.0	32.9	27.8	36.5
Clark 63	20	37.7	39.5	38.3	28.9	26.2	34.1
Clark 63	30	41.0	38.8	37.8	32.2	29.2	35.8
Mean		40.4	39.6	38.4	31.3	27.7	35.5

Table 51. Average Seed Yield (BU/A): date of planting x row width x variety

Variety	Row width (inches)	Date of Planting					Mean
		I	II	III	IV	V	
Hill	10	42.5	39.0	22.3	21.2	16.7	28.3
Wayne	10	49.6	42.6	41.4	37.6	32.2	40.7
Kent	10	44.8	41.0	36.2	28.0	25.6	35.8
Clark 63	10	42.4	40.6	39.0	32.9	27.8	36.5
Mean		44.8	40.8	34.7	29.9	25.6	35.2
Hill	20	43.9	40.3	32.9	21.8	18.0	31.4
Wayne	20	46.3	41.2	40.2	37.1	28.0	38.5
Kent	20	43.9	41.7	36.2	28.0	25.6	35.1
Clark 63	20	37.7	39.5	38.3	28.9	26.2	34.1
Mean		42.9	40.7	36.9	28.9	24.5	34.8
Hill	30	38.8	42.1	36.8	25.3	19.3	32.5
Wayne	30	40.7	43.4	40.6	34.7	31.8	38.2
Kent	30	42.5	42.9	38.1	32.0	30.2	37.1
Clark 63	30	41.0	38.8	37.8	32.2	29.2	35.8
Mean		40.8	41.8	38.3	31.1	27.6	36.4

VARIETAL RESPONSE OF SOYBEANS TO RHIZOBIUM JAPONICUM,
ROW WIDTH, AND DATE OF PLANTING AS EXPRESSED BY
NODULATION AND SEED YIELD

by

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AN ABSTRACT OF A MASTER'S THESIS

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It is a well-established concept that a particular strain of *Rhizobium* may be highly effective in nodulation on one host and ineffective on closely related species or even varieties of the same species as regards *Rhizobium*-Legume symbiotic relationship. This concept has prompted the evaluation of nine strains of *Rhizobium japonicum* on five varieties of soybean in the greenhouse in Spring, 1968.

The soil used for the experiment was taken from the site selected for the field experiment, and tested for pH (6.6), available phosphorus (92 lbs/A), available potassium (900⁺ lb/A) and organic matter content (2.3%) by the Soil Testing Laboratory, Agronomy Department, Kansas State University. Seeds of each variety were inoculated with each of the nine strains of *R. japonicum*. There was a control (non-inoculated seeds) for each variety. Inoculated and non-inoculated seeds were planted in plastic pots and replicated three times. The roots were removed 39 days after emergence and nodules counted and weighed.

Two strains—USDA 7 and USDA 71a produced significantly more nodules per plant than the control as well as the other seven strains. There were no significant differences between the other seven strains and the control. The control produced 2 more nodules per plant than strains USDA 110, 61A65 and 5566. The nodule formation on the non-inoculated plants may be attributed to residual bacteria in the soil, since the soil had been grown to inoculated soybeans in prior years.

The average nodule number of all treatments for each variety shows that Hill produced significantly more nodules per plant than Amsoy, Wayne, Clark 63 and Kent. Amsoy produced significantly more nodules per plant than Wayne, Clark 63 and Kent but there were no significant differences in nodules per plant among the last three varieties.

Kent and Hill produced the greatest nodule fresh-weight with strain

USDA 7, Wayne and Clark 63 produced greatest nodule weight with strain USDA 135 and Amsoy with USDA 123, but there were no significant differences between the effects of strains USDA 135, and USDA 7 on nodule weight of Clark 63, and Wayne or between USDA 123 and USDA 7 on nodule weight of Amsoy. There were no significant differences between inoculated and non-inoculated control plants as regards nodule weight. Amsoy, Clark 63, Wayne and Hill produced the lowest nodule weight with strain 61A65 while Kent produced lowest nodule weight with 5566. Strain USDA 7 was selected for the field planting.

This thesis also describes the field experiment conducted at Manhattan during 1968 growing season. The experiment was designed to study the response of inoculated plants of Hill, Wayne, Clark 63, and Kent to 5 dates of planting (I = May 16, II = May 28, III = June 7, IV = June 20, and V = July 1) and 3 row widths (10, 20, & 30-inches) as expressed by nodulation and seed yield.

Data on nodulation for samples taken 6 weeks after nodule initiation showed greatest number of nodules per plant for all varieties when planted June 20. The number of nodules per plant followed the order of variety maturity with greatest nodulation on Wayne (earliest maturing variety), followed by Clark 63, Kent, and Hill (latest maturing variety). Wayne, Kent, and Hill produced greatest nodule fresh-weight in date IV, while Clark 63 produced greatest nodule fresh weight when planted July 1. Nodule fresh-weight from 10-inch row width was significantly greater than nodule fresh-weight from the 20, or 30-inch row width.

Second nodule samplings were made 9 weeks after nodule initiation. Plants in dates II and III produced significantly more nodules per plant than plants in dates I, IV and V. There was no significant difference between nodule number in dates I and IV but nodule number in date V was significantly lower than that of date I.

Wayne, Clark 63, and Kent produced significantly more nodules per

plant than Hill. Wayne produced significantly greater nodule weight than Kent, Clark 63 and Hill. Clark 63 and Kent produced significantly greater nodule weight than Hill.

Third nodule samplings were made 12 weeks after nodule initiation. All varieties had highest number of nodules per plant in date II. The order of nodules per plant was opposite the type of results obtained during first and second samplings, with Hill producing highest nodule number followed by Kent, Clark 63, and Wayne (lowest) in dates II, IV, and V. There was a progressive decrease in nodule number from dates III to V. Wayne and Clark 63 produced greatest nodule weight in date II.

The greatest average number of nodules per plant for Wayne, Clark 63 and Kent was obtained from samples taken 9 weeks after nodule initiation in all the 5 dates of planting. The greatest nodule number for Hill was obtained 12 weeks after nodule initiation in dates I and II, and this necessitated further samplings to determine when there was a decrease in nodule formation. In dates III, IV and V, the greatest nodule number for Hill was obtained 9 weeks after nodule initiation.

All varieties produced the greatest seed yield in date I and there was a progressive decrease in yield in each subsequent planting date. The order of seed yield in date I was Wayne (45.5 bu/A), Kent(43.6), Hill(41.7), and Clark 63 (40.4). Wayne and Clark 63 produced greater seed yield from 10-inch than from 20, or 30-inch row width. Kent and Hill produced greater seed yield from 30-inch than from 10, or 20-inch row width.

Plants in date II were significantly taller than plants in dates I, IV and V. Plants in date V were significantly shorter than plants in dates I, III and IV. Hill was significantly taller than other varieties. Clark 63 and Kent were significantly taller than Wayne. Plants in 30-inch row width were significantly shorter than plants in 10-inch and 20-inch row widths.

Hill, Wayne and Kent produced the highest number of nodes per plant in date II with Kent producing (23.7), Wayne (22.9), Hill (18.2) and Clark 63 produced highest nodes per plant in date I (23.1). Node number decreased progressively in plantings made after May 28. All varieties produced highest number of nodes per plant in 30-inch row width and lowest in 10-inch row width.

All varieties had greatest seed weight in date I in this order: Wayne (greatest), Kent, Clark 63 and Hill (lowest). Row width comparisons showed greatest seed weight for all varieties from 30-inch row width.

For all varieties there were no significant differences in seed quality from May 16, May 28 and June 7 plantings. The lower seed quality from June 20 and July 1 plantings might be due to prolonged damp weather before the pods were dry enough for threshing.

All varieties lodged greatest in date V (July 1 planting) and least in date I (May 16 planting). Generally the order of lodging of varieties in all dates was Hill (greatest), Clark 63, Wayne, and Kent (least). Wayne, Clark 63 and Kent lodged greatest in 10-inch row width and least in 30-inch row width. Hill lodged equally badly in all the three row widths.

The shortest number of days to maturity for all varieties was in date V. The decrease in number of days to maturity with delay in planting was not consistent from date to date for any of the varieties. Plants in 30-inch row width matured earliest while plants in 10-inch row width matured latest.

For all varieties, the closer the row width, the quicker the attainment of ground cover. In all the 3 row widths the number of days to achieve ground cover was highest in date I and lowest in date V. This might be due to shorter photoperiod coupled with favorable temperatures as the growing season progressed, which seemed to speed up plant growth toward maturity in later plantings.