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EFFECTS OF ROW SPACING, PLANT POPULATION,
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(GLYCINE MAX (L.) MERRILL)
PRODUCTION

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# EFFECTS OF ROW SPACING, PLANT POPULATION, AND VARIETIES ON BOTH IRRIGATED AND NON IRRIGATED SOYBEAN [GLYCINE MAX (L.) MERRILL] PRODUCTION

By

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ABSTRACT

EFFECTS OF ROW SPACING, PLANT POPULATION,
AND VARIETIES ON BOTH IRRIGATED
AND NON IRRIGATED SOYBEAN
[GLYCINE MAX (L.) MERRILL]
PRODUCTION

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In the sandy soils of southwestern Michigan, supplemented irrigation is required to produce optimum corn yields. However, little research is available to chronicle ideal soybean production practices for irrigation. The objective of this study was to determine the effects of irrigation, row spacing (25, 51, and 76 cm), plant population, and varieties of maturity Groups I and II on soybean production.

The irrigation study was conducted in southwestern Michigan during the 1980 and 1981 growing seasons on an Elston series sandy loam soil. The experiment was designed as a split-split plot and analyzed as a factorial arrangement.

Irrigation significantly increased lodging both years, but caused increased yields and delayed maturity only in 1981. Plants in narrow rows produced an average of 18% greater yields than those in 76 cm rows both years. Different plant populations produced few effects. Later maturing varieties were highly correlated with higher yields.

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# INTRODUCTION

Michigan is faced with a unique situation. It is surrounded by water, yet it has the least precipitation during the growing season of any state east of the Mississippi River. Lack of rainfall plus sandy soils necessitate crop land irrigation in many areas of the state.

However, unlike western states which are rapidly depleting their deep underground water reserves, Michigan has vast renewable ground water supplies and a shallow water table. The long term water supply outlook for Michigan looks bright.

Until recently, corn has been the main crop to receive irrigation in southwestern Michigan. However, growers are interested in including soybeans in their rotation to improve both pest management and marketing flexibility.

While research on irrigated soybean production practices have been conducted in the southern and western United States, little research has been done in Michigan's unique climate. This study attempts to uncover the effects of row spacing, plant population, and varieties of different maturities and plant types on irrigated and non irrigated soybean production in Michigan.

# LITERATURE REVIEW

The effects of water stress on plant growth and development have been widely reviewed (15,27,34,39,40). A general review of water relations in soybeans is also available (25).

The following review looks at the effects of water stress on soybeans from both the physiological and morphological standpoints.

## Effects of Water Stress on Soybean Physiology

In general agronomic texts, the wilting point from which plants do not recover is -15 bars. However, this varies among plant species. Boyer (16) found that soybeans can recover from leaf water potentials as low as -41 bars. According to Gardner and Neiman, physiological processes within plants have different sensitivities to water stress (14). Boyer (5) showed that leaf enlargement is the most sensitive physiological process in soybeans. The rate of leaf enlargement at -4 bars was only 25 percent of the rate in well watered plants (5). The lowest water potential associated with leaf enlargement was -12 bars (5).

The next process to be affected by decreasing water potentials is photosynthesis (6). In soybeans, photosynthesis was relatively unaffected until leaf water potentials dropped below -11 bars. At -16 bars, photosynthesis was 60 percent of that of well watered plants (6). Shaw and Laing (34) reported that net photosynthesis declined sharply below a relative leaf water content of 90 percent. Boyer (6) concluded diffusive resistance of the stomates to carbon dioxide entry resulting from water stress appeared to be the primary factor limiting photosynthesis.

In soybeans, as in most C3 plants, respiration is divided into dark respiration and photorespiration. Boyer (5) found that dark respiration decreased 50 percent when leaf water potential dropped from -8 to -16 bars. Below -16 bars, dark respiration was constant.

The effect on photorespiration is unknown. However, it may be related to stomatal closure. Research has shown that drought stressed plants have higher leaf temperatures than nonstressed plants (30). Furthermore, increasing leaf temperatures have been correlated with decreasing water potentials (20,33) and greater stomatal resistance (20). Since respiration increases with higher temperatures, perhaps photorespiration increases as the stomates begin closing at -11 bars.

## Effects of Water Stress on Soybean Morphology

The physiological effects just discussed are reflected in the morphological changes in water stressed plants. The height of water stressed plants is less than that of well watered plants (2,12,13,26). On the other hand, irrigated soybeans attain greater height which results in increased lodging (2,13). The leaf area index of stressed plants is reduced (32) and plant dry weight is reduced at various rates depending on the stage of phenological development in which water stress occurred (1,32).

The most important economic effect of water stress is the effect on yield. Many field research studies have shown water stress, due to lack of irrigation in dry years, reduces soybean seed yields (1,9,12,13,20,23,24,26,34).

The phenological timing of drought stress is important. Shaw and Laing (34), and Sionit and Kramer (38), showed that yields suffer the greatest reduction when water stress occurs during the late pod initiation and pod filling periods. Momen, et al (26) indicated that the pod filling period was most critical. Both studies showed the components of yield varied due to drought stress during various phenological periods.

Shaw and Laing showed that stress during flowering and early pod development resulted in decreasing numbers of pods per plant, while stress during pod filling resulted in fewer seeds per pod and a reduction in seed size (34). Their study further pointed out the amazing adaptability of indeterminate soybean varieties. When moisture stress occurred during early flowering, plants set fewer pods on the lower nodes. Stressed in late flowering, plants set fewer pods on the upper nodes. In both cases, with fewer pods per plant, the number of seeds per pod and the seed size increased.

Soybean Irrigation

Several studies on soybeans have been conducted to ascertain the optimum timing of irrigation. Doss, et al (12) found that adequate moisture during the pod filling period was critical in obtaining optimum yields. Several researchers have shown that yields did not significantly differ between full season irrigation and irrigations starting at the full bloom period (1,12,23). Long-term correlations of precipitation and soybean yields have shown similar results. After analyzing 48 years of data for Urbana, Illinois, Runge and Odell (31) found above normal precipitation during July and from mid-August through September to be optimum for high soybean yields. Summarizing 38 years of data for Illinois, Indiana, Iowa, Missouri, and Ohio, Thompson (42) found that above normal precipitation coupled with below normal temperatures during July and August produced optimum soybean yields.

The rate of irrigation water applied also affects soybean yields. Doss and Thurlow (13) found an average yield increase of only 2 percent between irrigating when 40 percent of the available soil moisture was depleted versus irrigating when 80 percent of the available soil moisture was depleted. Cassel, et al (9) concluded that under-irrigation reduces yield and over-irrigation may result in the depletion of mobile plant nutrients from the solum. Their inference was that optimum irrigation rates would provide the amount of water equal to the amount of crop evapotranspiration depletion.

## Cultural Practices

Cultural practices in field grown soybeans include spacial arrangement (row spacing and plant population) and variety selection. These cultural practices can affect not only the final soybean yields, but also the water use of soybeans. Row spacing, population, and varieties are discussed in separate sections which follow.

## Row Spacing

One theory for altering the distance between rows is that light interception is maximized when the space between rows is minimized, resulting in optimum yields.

Much research on the effects of row spacing on yields has been conducted over the years. In the 1930s, Whiggans (47) in New York reported a 36 percent yield increase from narrowing the rows from 81.3 cm to 20.3 cm. In more recent years, researchers in the northern states have shown that yields increased as soybeans were planted in narrower rows (3,11,17,21,45). The effects of row spacing on lodging are unclear. Narrowing the row width has been shown to both increase (17) and decrease (3) lodging.

Hicks, et al (17) and Weber, et al (45) have shown the photosynthetic area, or leaf area index (LAI), increases as the space between rows decreases. While soybeans do not have an optimum LAI for seed yield (36), LAI is somewhat related to the narrow row advantage. Shibles and Weber (37) reported that "for maximum yields to be attained, complete (maximum light) interception must be reached prior to the period of production of economic yield (flowering)." Furthermore, they found that soybeans in narrower rows achieved full light interception sooner than those in wider rows.

The length of the vegetative period prior to flowering is also important. In the southern U.S., the growing season and the vegetative periods are longer. Therefore, even in wide rows, soybeans can form a closed canopy before flowering. In the northern U.S., where the growing season is shorter, narrow rows enable plant canopies to close before flowering (19).

Costa, et al (11) found that earlier maturing Group 0 varieties showed a greater yield response to narrow rows than later Group I and II varieties. They speculated that the taller stature of the Group I and II varieties enabled them to fill the rows sooner.

Row width also affects water use patterns. Peters and Johnson (28) found that between 25 to 50 percent of the total water loss in a dry year and greater than 50 percent of the water loss in a wet year is due to evaporation from the soil surface. They also found 50.8 cm rows had a greater water use efficiency (kg seed produced/kg water used) than 101 cm rows. They suggested this may be due to earlier shading of the ground between the rows by the narrower rows. Similarly, Doss, et al (13) found that during the vegetative period, soybeans in 90 cm rows used more water than those in 60 cm rows. Again, soil shading by the narrow rows was credited.

However, there are dissenting viewpoints. Taylor (41) hypothesized that without irrigation in a dry year, the rapid canopy development in narrow rows would cause an increase in transpiration and deplete the existing soil moisture. As a result, less water would be available during the critical seed filling period and yields would be reduced. Furthermore, he expected wide rows (100 cm) to yield more than narrow rows under those conditions. The results from his experiment showed a greater seasonal soil moisture depletion in 25 cm rows. However, the 25 cm rows yielded slightly, though not significantly, more than the 100 cm rows.

Timmons, et al (43) found no difference in evapotranspiration between soybeans in 20.3, 61.0, and 101.6 cm rows in dry years in west central Minnesota.

## Plant Population

Plant population refers to the number of plants in a given unit area. Given a constant row width, changes in population affect the within-the-row spacial arrangement of individual plants. In the 1930s, Whiggans (48) found the optimum population for soybeans was six plants per square foot (645,820 plants/ha). He concluded yields were optimized as row spacings narrowed and populations decreased to allow an equidistant spacing between plants. In 1945, Probst (29) found the optimum population in 76.2 cm rows between 172,218 and 258,224 plants per hectare.

Bassnet, et al (2) and Costa, et al (11) found that populations within reasonable rates had no significant effect on yield. Costa, et al (11) concluded wide variations in intra row spacing have little effect on soybean yields. Still other researchers have found that the effect of population on yield varied from year to year (13,17,21,22). Doss and Thurlow (13, and Lueschen and Hicks (22) found higher populations had a significant effect on yields in only one year of a three-year study.

Populations higher than the optimum rate result in delayed maturity (29), increased plant height (13,17,45) and increased lodging (2,17,23,29,45). Cooper (10) reported that lodging can decrease yields as much as 23 percent.

Soybean plants can compensate for a wide range of plant densities by varying the number of branches per plant and the number of pods per plant (22). High levels of population increase the dry matter production on a per plant basis (45), and the LAI of individual plants (17,45). But, high levels of population cause a decrease in the number of the following components of yield: branches per plant

(2,11,21,45), pods per plant (2,17,22), seeds per pod (21), and seeds per plant (2,21,22). It appears as populations are increased, the harvest index decreases.

The effect of population on seed yields due to irrigation has also been studied. Doss and Thurlow (13) found no irrigation x population interaction. Bassnet, et al (2) found no significant yield increase due to population in their irrigation study. Timons, et al (43) found no significant different in evapotranspiration rates with 226,378, 452,732, and 905,464 plants per hectare.

## Soybean Varieties

There is great diversity among soybean varieties in maturity, height, lodging, and yield potential. Some of these factors are reflected in the differences of yield components among varieties (21,22,26). It is not surprising that varieties respond differently to changes in the macro and micro environments.

Water and water availability constitute a part of the macro environment. Several researchers have found that yield response to different irrigation regimes varies among varieties (1,13,23,24). Timmons, et al (43) found no difference in evapotranspiration between the varieties Chippewa and Merit under water stressed conditions. Mederski and Jeffers (24) found a difference among varieties within the same maturity group for their yield response between high and low moisture stress conditions.

Boyer and Johnson (7) discovered a difference in the mid afternoon leaf water potentials between newer and older varieties. They suggested that plant breeders, while selecting for high yields over the years, had also produced varieties with superior shoot water balances. They found that the root density of Wayne, a newer variety in their experiment, was greater than Richmond, a older variety. Boyer and Johnson concluded that the difference in the water status between varieties was due to increased root densities of newer varieties.

Researchers have also found that varieties have different responses to spacial arrangements in the field (micro environment). Variety x row space interactions have been reported (21,48) as well as variety x population interactions (22,29,47,48). Beaver and Johnson (3) found determinate and indeterminate varieties respond similarly to both row spacing and population.

In recent years, the difference among plant types (determinate, semi-determinate, and indeterminate) adapted to the north central United States has received much attention. In 1968, Weber (44) suggested that determinate varieties may result in increased yields in the north due to less competition between vegetative growth and seed filling as photosynthetic sinks.

Several studies using near isolines, varying only in morphological traits, have been conducted to determine the important traits in soybean plants. Hicks, et al (17) found that crosses with tall determinate traits produced the best yields. Hartung, et al (16) found that crosses with semi-determinate and short internode traits gave best yields. However, Wilcox (49) found no yield difference between semi-determinate and indeterminate crosses. But, he found that semi-determinate plants had increased resistance to lodging.

Beavers and Johnson (4) studied genotype x environment interactions of pre-existing determinate, semi-determinate, and indeterminate varieties. Their study considered varieties in maturity Groups II, III, and IV at several locations in Illinois. They found that the yields of determinate varieties were not as stable as yields of indeterminate varieties among locations and years. This may be due to the compactness of the flowering period of the determinate varieties. Ashley (1) in Alabama, found that determinate varieties responded to irrigation at flowering.

## MATERIALS AND METHODS

A soybean irrigation study was conducted on the Marantette farm near Mendon, Michigan, during the 1980 and 1981 growing seasons. The soil was an Elston sandy loam (coarse loamy, mixed mesic, Typic Argiudoll). In 1980, the study followed a maize crop, and no additional fertilizer was needed. In 1981, the study followed a wheat crop, after which 336.3 kg/ha of 7-28-28 fertilizer was applied.

In both years, the fields were fall plowed. A preplant incorporated herbicide mixture containing 0.841 kg/ha profluralin and 2.94 kg/ha vernolate was applied. The field was disced twice before planting. The planting dates were 24 May 1980 and 22 May 1981.

The study was designed as a 2 x 3 x 10 x 2 factorial and arranged in a split-split plot design. The main plot was split into irrigated and nonirrigated halves. Due to irrigation equipment limitations, the succeeding replications were not randomized. Each of the four replications of the water treatments was further split into three row spacings. In each row spacing, the smaller plots consisted of ten varieties at two plant populations.

The three row spacings used were 25, 51, and 76 cm. In each row spacing, varieties were seeded at either recommended populations or 75 percent of recommended populations. The plant populations are shown in Table 1.

Table 1. Plant populations at each row width.

| ROW WIDTH (CM) | RECOMMENDED POPULATION (PLANTS/HA) | 75% OF RECOMMENDED POPULATION (PLANTS/HA) |
|---|---|---|
| 76 | 344,438 | 258,328 |
| 51 | 385,698 | 289,328 |
| 25 | 466,426 | 349,819 |

All plots were 5.5 meters long. The plots with the 51 and 76 cm. row spacings were four rows wide and the plots with the 25 cm. row spacings were eight rows wide.

The ten varieties used are shown in Table 2.

Table 2. Varieties used in the soybean irrigation study.

| VARIETY | MATURITY GROUP | COMMENT |
|---|---|---|
| Hodgson 78 | I | |
| Hardin | I | |
| SRF 150P | I | Narrow leaf |
| Nebsoy | Early II | |
| Wells II | Early II | |
| Corsoy 79 | II | |
| Harcor | II | |
| SRF 200 | II | Narrow leaf |
| Beeson 80 | Late II | |
| Gnome | Late II | Determinate |

These varieties reflect a range in both maturities and plant types. Beeson 80 was not included in the study in 1981 due to errors made when the seed was prepared for planting.

Tensiometers and Irrigation

Soil tensiometers were placed at 30 cm depths in the varieties Harcor and Hardin and at 46 cm depths in Nebsoy and Gnome at the recommended population levels at each row spacing for the four varieties. In 1980, tensiometers were placed in reps I and II of the irrigated half and rep II of the nonirrigated half on 17 July. In 1981, tensiometers were placed in reps I and IV in both the irrigated and non-irrigated halves on 17 July. Readings were made twice a week both years and daily from 31 July through 18 August in 1980 and 21 July through 26 August in 1981.

Irrigations were scheduled when the average soil moisture tension exceeded -50 centibars, which corresponded to a 40 percent depletion of the available soil moisture as calculated from a soil moisture characteristic curve. The irrigation water was pumped from the St. Joseph River and applied with a traveler irrigation system. The traveler system used applies 2270 liters per minute. The amount of irrigation water was determined by the speed of the winch pulling the traveler. In 1980, the only irrigation required was 3.8 cm of water, applied on 26 July. In 1981, three applications were made on the following dates at the following rates: 11 July, 3.8 cm; 24 July, 2.4 cm; and 15 August, 5.1 cm. A fourth irrigation was scheduled on 24 August, but tensiometer readings indicate it was not applied.

Plant Samples

In order to determine how the production practices affected plant morphology, plant samples were taken and analyzed. One third meter of row was harvested at stage R5.0 in 1980 from one rep of each row spacing, population rate, and water treatment for the varieties Hardin, Harcor, Nebsoy, and Gnome. The leaf area was measured for each sample on a Li-cor LI-3000 area meter and the leaf area index was calculated.

Another one third meter of row was harvested from one rep of each of the 120 possible treatment combinations at stage R8.0. The number of nodes, branches, and pods on a per plant basis was determined, as was the average number of seeds per pod.

Light Penetration

In 1980, at growth stage R6.5, light penetration through the canopy was calculated for one rep in both water treatments for the following varieties: Harcor, Hardin, Nebsoy and Gnome. A meter long Li-cor light sensor attached to a Li-cor LI-185 photometer was used for the measurements. The sensor was placed perpendicular to the rows at the base of the canopy. The irradiance below the canopy was divided by the irradiance above the canopy and multiplied by 100 to arrive at the percent light penetration. Two readings were made per plot in one rep of both the irrigated and nonirrigated treatments.

## Leaf Water Potential

Random measurements of the leaf water potential were made in 1981 using a portable pressure bomb (PMS Instrument Company, Corvallis, Oregon) within one hour of solar noon. A nitrogen gas source was used. The uppermost fully expanded leaf of the plant to be sampled was excised and secured in the pressure chamber. Gas pressure was increased at a rate of one bar per minute and readings were taken when gas bubbles were seen coming from the xylem vessels. Each reading took six to twelve minutes.

## Harvest

At the end of each season, the maturity date, lodging score, and plant height for each plot was recorded. Plants were considered mature when 95 percent of the pods had turned to the mature color and the pods would crack under finger pressure. Lodging scores were recorded on a scale of one to five. A lodging score of one indicates all plants are erect and five indicates all plants are prostrate. Plant heights (cm) were measured from the ground surface to the uppermost node of a representative plant in each plot. The plots were trimmed to a uniform length. The plots were harvested with a Hege B125 self-propelled combine. With the exception of Gnome, all treatments were harvested on 30 September, in 1980. Due to excessive seed moisture, the Gnome plots were hand harvested on 10 October 1980, dried, and threshed with the same Hege combine. In 1981, all non-irrigated plots of the study were harvested on 3 October and the irrigated plots were harvested on 7 October. The seeds were dried and cleaned. Seed size (g/100 seeds) was measured and yields were reported in kg/ha at 13 percent moisture.

## RESULTS AND DISCUSSION

### Climate

The growing season precipitation was above normal both years of the study. During 1980 and 1981, total precipitation from June through August was 63 percent and 43 percent above the 30 year mean at Three Rivers, Michigan, the closest reporting weather station, some 16 km southeast of the study location. Between the two years of the study, 1981 was drier.

Table 3. Monthly precipitation and irrigation means (mm)

| | 1980 | | 1981 | | 30 YEAR PPT. MEAN |
|---|---|---|---|---|---|
| MONTH | PPT | IRR | PPT | IRR | THREE RIVERS, MI |
| JUNE | 147 | --- | 129 | --- | 107 |
| JULY | 107 | 38 | 147 | 64 | 93 |
| AUGUST | 194 | --- | 113 | 51 | 74 |
| TOTAL | 448 | 38 | 389 | 115 | 274 |

As Table 3 shows, precipitation during June and August, 1980 was higher than in 1981.

More important than the total amount of precipitation is the timing and the rate of rainfall on a given day.

Figures 1 and 2 show the daily rainfall totals as well as the cumulative crop evapotranspiration, cumulative precipitation, cumulative precipitation + irrigation, and tensiometer readings for both the irrigated and nonirrigated treatments. The cumulative precipitation line does not take into consideration the amount of water lost due to gravitational flow through the sandy loam soil. If this loss were considered, the cumulative precipitation line and the cumulative precipitation + irrigation lines would be lower.

The tensiometer readings are of particular interest. They chart the difference in soil moisture tension between the irrigated and nonirrigated treatments.

In Figure 1, the difference in the tensiometer readings between the water treatments following the 26 July irrigation is very obvious. This three week difference in soil moisture status occurred during the pod filling period. The resulting yield increase, probably due to irrigation, is discussed in later sections.

In 1981, three irrigations were applied (Figure 2). Tensiometers were not in place when the first irrigation was made on 11 July. However, differences between the water treatments following irrigations on 24 July and 15 August are marked. Heavy rains (89mm) on 28 July saturated the soil and equalized the soil moisture between the treatments. The three irrigations correspond to the early pod initiation period (11 July) and the pod filling period (24 July

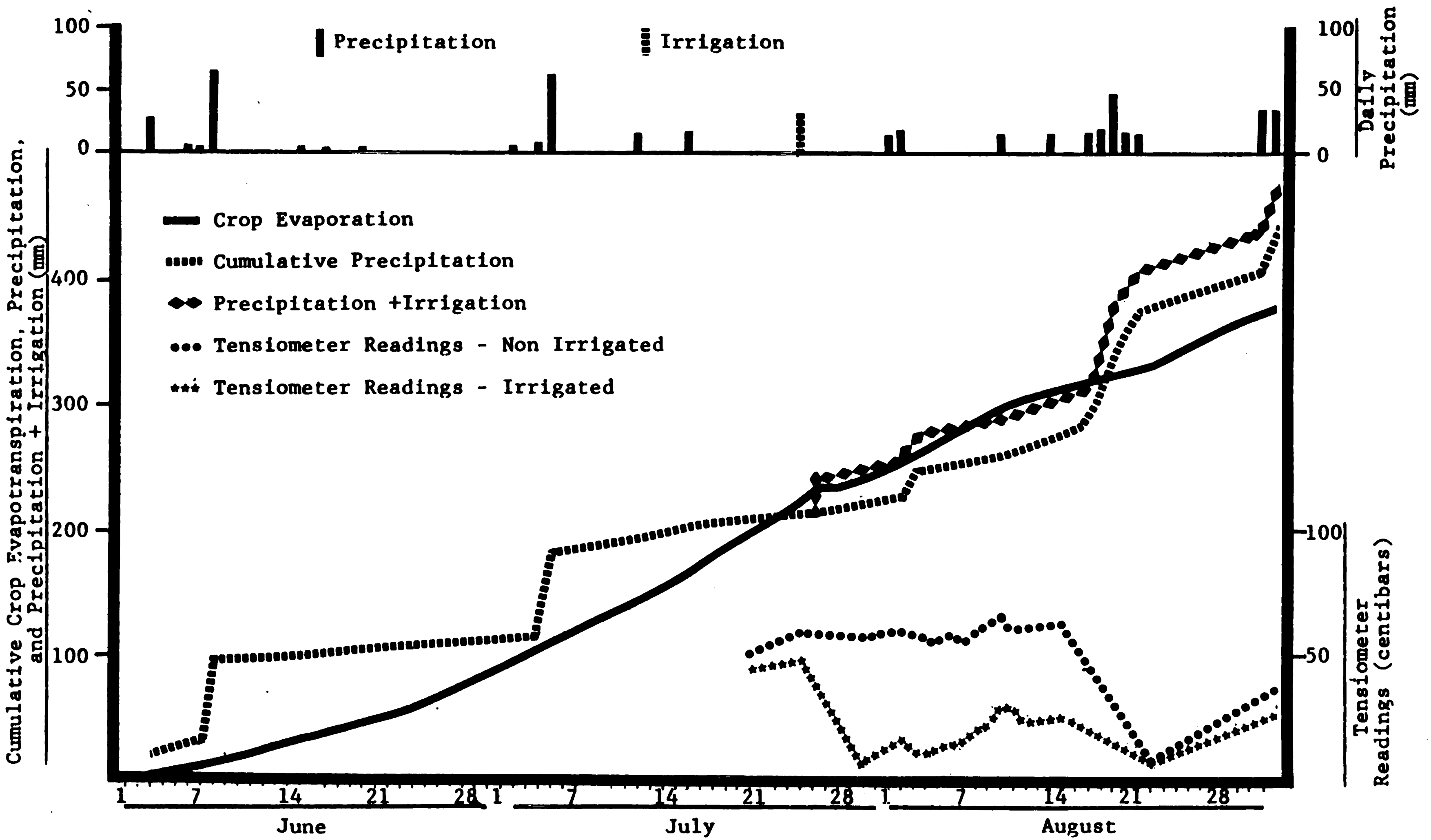


Figure 1 Climatic Data for 1980.

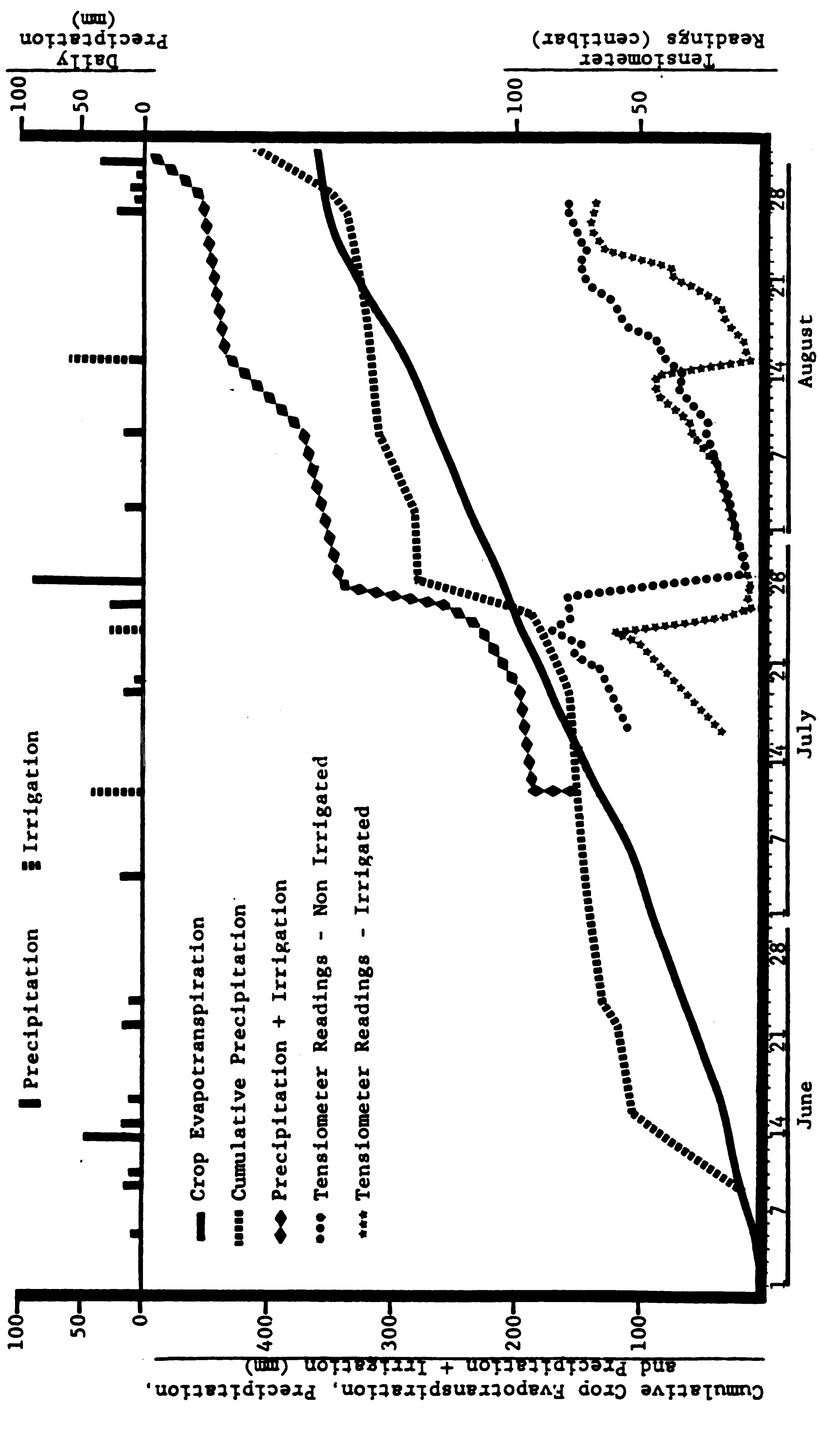


Figure 2 Climatic Data for 1981.

and 15 August). The effects on yield and other factors are discussed in later sections.

The climatic information presented in Figures 1 and 2 does not depict all the meteorological events. On 12 July 1980 a hail storm caused some damage to the plants. An insurance investigator estimated a 15 percent yield reduction in the cooperator's adjacent field. The main stems of some plants were broken, but the plants responded by increasing the number of branches.

## Herbicide Damage

Herbicide damage was encountered both years of the study due to different causes each year. In 1980, areas of the study were damaged by atrazine carry-over. Prior to planting the 1979 corn crop, atrazine applications were accidentally overlapped in the headlands. Although the cooperator noticed no damage in the corn crop, enough atrazine remained to damage soybeans in 1980. Two of the four reps of the nonirrigated treatments were severely damaged. The data from these reps were not used in the final analysis. Fortunately, the irrigated treatments were undamaged. The harvest data from 1980 were analyzed in the following three groupings: the remaining two reps of the nonirrigated treatment, all four reps of the irrigated treatment, and a combined analysis containing the two reps of the nonirrigated treatment and two adjacent reps of the irrigated treatment.

In 1981, herbicide damage resulted from excessive rates of preplant incorporated herbicides coupled with cool wet weather and soil crusting. The recommended rates of vernolate and profluralin for sandy loam soils are 2.26 and 0.56 kg/ha of active ingredient, respectively (8). They were applied by the cooperator at rates of 2.94 and 0.84 kg/ha.

Research at Iowa State University has shown that excessive application rates of profluralin to soybean plants result in thickened hypocotyls and inhibition of lateral roots. Furthermore, high rates of vernolate result in slowed emergence and leaf malformations (18).

Soybean plants in our study exhibited delayed emergence, thickened, brittle hypocotyls, and malformed leaves. Soil crusting compounded the situation. The reduced vigor of the seedlings coupled with soil crusting resulted in missing plants within rows. This was especially evident in 25 cm rows. In 51 and 76 cm rows a fissure in the soil crust formed between emerging seedlings which aided their survival. In 25 cm rows, the space between seedlings was greater and no cracks in the crust developed between seedlings. Consequently, the seedlings were slower to emerge and many were killed, resulting in skips in the rows.

A subjective rating of the herbicide-induced stunting and resulting skips within rows for each plot was made on 20 July 1981. Stunting increased in lower plant populations, narrower row spacings, and varied among soybean varieties. The Appendix contains the rating system used and the resulting analyses of variance.

Because of the herbicide damage, the skip and stunt scores were used separately and in conjunction as potential covariates. It was found that the stunting score, when used as an adjustment to remove the effects of the herbicide damage, resulted in a significant and substantial reduction of the error mean square term in the analysis of variance. While the analysis of covariance reduced the error term, the herbicide damage partially masked the effects of plant populations and varieties. Overall yields did not seem greatly reduced as soybeans are versatile in responding to catastrophe by altering their morphology.

## Irrigation

Irrigation increased yields in both 1980 and 1981. However, since the precipitation patterns and amounts varied each year, the response to irrigation also varied between years. Consequently, the results from each year will be discussed separately.

1980. The irrigated treatments yielded 7 percent more than the nonirrigated treatments. However, this difference was not significant at the 5 percent level. Perhaps this was due to the relatively short period of water stress, or to the experimental design. The use of a split split plot design results in a lack of precision between the main plots.

Table 4. Effects of irrigation on the 1980 harvest data (averaged over row spacing, population, and variety).

| WATER TREATMENT | YIELD (KG/HA) | MATURITY (MONTH-DAY) | HEIGHT (CM) | LODGING SCORE |
|---|---|---|---|---|
| Irrigated | 3191 | 9-20 | 78.7 | 1.90 |
| Non-irrigated | 2970 | 9-21 | 70.7 | 1.57 |
| LSD (.05) | N.S. | N.S. | N.S. | 0.11 |

It appears that irrigation had little effect on maturity in 1980. Lodging is the only factor which proved to be significantly increased by irrigation. Table 4 shows that irrigated plots tended to be taller. This increased height coupled with the increased yields is perhaps the cause of the greater lodging seen in irrigated plots.

Table 5. Effects of irrigation on the components of yield, 1980 (averaged over row spacing, population, and varieties).

| | SEEDS PER POD | PODS PER PLANT | SEEDS PER PLANT | SEED WT. (G/100) | NODES PER PLANT | BRANCHES PER PLANT |
|---|---|---|---|---|---|---|
| Irrigated | 2.20 | 37.5 | 82.4 | 16.1 | 15.6 | 1.63 |
| Non-irr. | 2.27 | 33.7 | 76.5 | 16.9 | 15.1 | 1.34 |

Table 5 gives the yield components for the irrigated and nonirrigated treatments. Since the yield components were measured on only one rep of each water treatment, a statistical analysis was impossible.

Several interesting trends which help explain the contribution of irrigation to yield can be seen in Table 5. Irrigated plants tended to have more pods per plant and smaller seed while nonirrigated plants had fewer pods but larger seed. Soybeans are known to respond to water stress by aborting some pods and devoting their diminished photosynthetic supply to the development of the remaining seed. Once the period of water stress passes, photosynthesis resumes to normal rates. Each seed of the previously stressed plant gets a proportionately larger amount of photosynthate compared to nonstressed plants which have more seed.

1981. Irrigation significantly increased yields by 11 percent in 1981. Irrigation also caused delayed maturity, increased plant height, and increased lodging.

Table 6. Effects of irrigation on the 1981 harvest data (averaged over row spacing, population, and variety).

| WATER TREATMENT | YIELD (KG/HA) | MATURITY (MONTH-DAY) | HEIGHT (CM) | LODGING SCORE | SEED WT |
|---|---|---|---|---|---|
| Irrigated | 3569 | 9-22 | 92.0 | 2.96 | 16.1 |
| Nonirrigated | 3207 | 9-17 | 77.6 | 2.20 | 16.2 |
| LSD (.05) | 359 | 0- 1 | 4.0 | 0.25 | N.S. |

Table 6 shows that averages for yield, maturity, height, and lodging were all significantly changed by irrigation, but that seed size based on weight was not.

One of the most striking differences illustrated by the data was the delay in maturity induced by irrigation. Maturity was five days later in irrigated treatments than in nonirrigated treatments. This was probably due to the increased plant height and perhaps due to increased leaf area index and branching. Similar results were not obtained in 1980 due to the shorter water stress period and the more abundant rainfall in August.

Components of yield were not measured in 1981. As mentioned earlier, one of the effects of the herbicide damage in 1981 was skips within rows. Soybeans can readily compensate for population densities by altering their morphological development. This made selecting representative plant samples all but impossible. Due to the herbicide damage, a representative sample of a plot would not have necessarily represented the cultural factors for which the plot was designed. With skips within plots and a general stunting of plants, the results would probably have shown both the effects of the cultural practices and the herbicide damage, with no indication of which effect was being measured.

The data in Table 6 show an increase in both yield and plant height. Perhaps the herbicide damage is also reflected in these results in that irrigation helped plants overcome the deleterious effects of herbicide injury. However, these results are consistent with the results of previous soybean irrigation experiments (2,12,13,26).

Of considerable importance is the fact that lodging scores increased in response to irrigation in both years of the study. Lodging continues to be a serious problem with irrigated soybeans.

Row Spacing

Yields increased as the space between rows decreased in both years of the study. Yields increased 18.1 and 18.3 percent in 1980 and 1981 respectively, when row spacing was decreased from 76 to 25 cm. As shown in Figure 3, most of the yield increase occurred between 76 and 51 cm rows. Yields were not significantly increased by narrowing the rows from 51 to 25 cm in either year although there was an increase.

The increases in yield are graphically presented in Figure 4. In 1981, results of an orthgonal polynomial analysis indicated that the yield response due to narrowing row widths was both linear and quadratic. Yields seemed to increase linearly between 76 and 51 cm, but the response was quadratic between 51 and 25 cm. In 1980, the trend was strictly linear. The results from both years suggest that optimum soybean yields are obtained in southwestern Michigan when soybeans are planted in rows narrower than 51 cm.

While both irrigation and narrow rows increased yields separately, there was no interaction between the factors

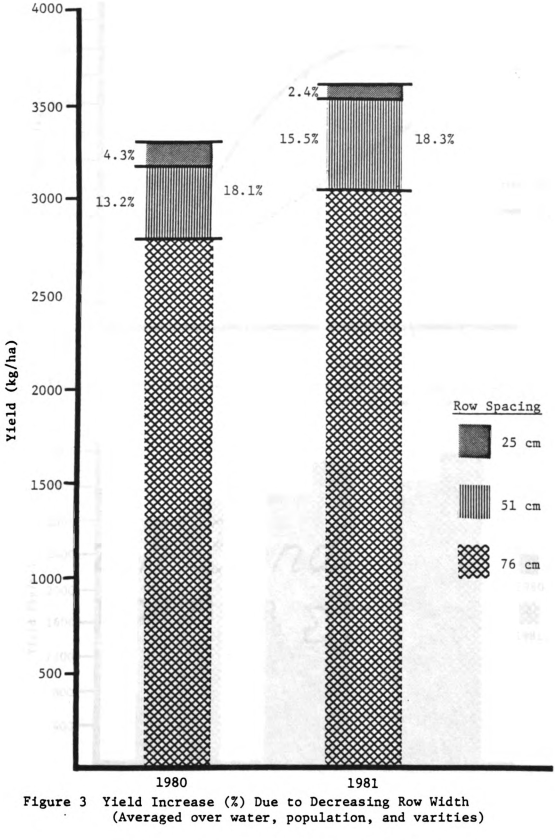


Figure 3 Yield Increase (%) Due to Decreasing Row Width (Averaged over water, population, and varities)

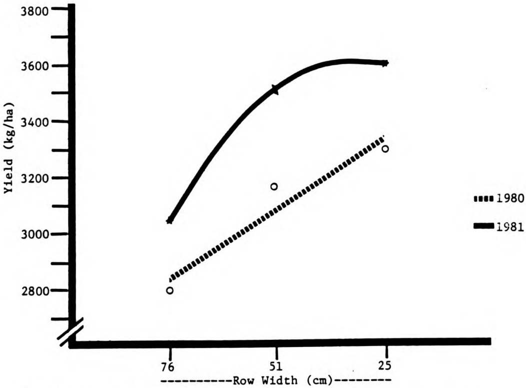


Figure 4 Yield Response Curves for Row Spacing in 1980 and 1981
(Averaged over water, population, and varieties)

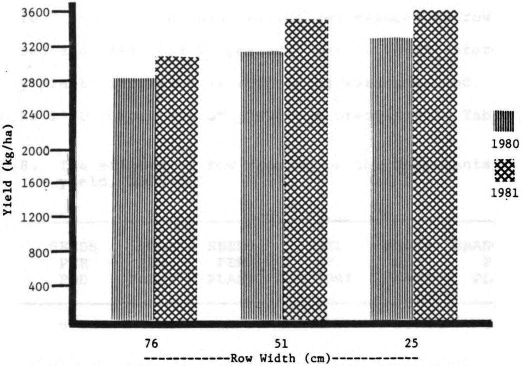


Figure 5 The effect of Row Spacing On Yields in 1980 and 1981
(Averaged over water, population and varieties)

either year. We cannot predict whether this independence would hold with greater drought stress.

Table 7 presents data from leaf area and light penetration measurements made in 1980.

Table 7. The effect of row spacing on leaf area index (at stage R5.0) and light penetration (at stage R6.5), averaged over measurements made on Hardin, Harcor, Nebsoy, and Gnome, 1980

| ROW WIDTH (CM) | LIGHT PENETRATION (%) | LEAF AREA INDEX (LEAF AREA/SOIL AREA) |
|---|---|---|
| 25 | 5.47 | 4.9 |
| 51 | 6.34 | 3.3 |
| 76 | 10.38 | 2.9 |

As Table 7 shows, light penetration was reduced as row width decreased and leaf area increased. Hence, light interception by plants increased as row widths were narrowed.

The 1980 components of yield are presented in Table 8.

Table 8. The effects of row spacing on the components of yield, 1980

| ROW WIDTH (CM) | SEEDS PER POD | PODS PER PLANT | SEEDS PER PLANT | SEED WT. (G/100) | NODES PER PLANT | BRANCHES PER PLANT |
|---|---|---|---|---|---|---|
| 25 | 2.24 | 32.8 | 74.4 | 16.7 | 14.7 | 1.46 |
| 51 | 2.23 | 36.0 | 80.2 | 16.6 | 15.8 | 1.57 |
| 76 | 2.25 | 38.1 | 85.7 | 16.3 | 15.4 | 1.43 |

As Table 8 shows, the number of pods per plant and seeds per plant tended to increase as the space between rows increased. This reflects the decrease in plant population associated with wider rows. The average of normal and 75 percent of normal plant populations for each row width was as follows: 408,123 plts/ha in 25 cm rows, 337,513 plts/ha in 51 cm rows, and 301,384 plts/ha in 76 cm rows. Since plant populations were lowest in 76 cm rows, plants responded by increasing the number of seeds and pods per plant. Consequently, the changes in seeds per plant reflect the difference in plant population, not row spacing.

The harvest data changes due to row spacing are shown in Tables 9 and 10.

Table 9. Effects of row spacing on the 1980 harvest data (averaged over water, population, and variety).

| ROW WIDTH (CM) | YIELD (KG/HA) | MATURITY (MONTH-DAY) | HEIGHT (CM) | LODGING SCORE |
|---|---|---|---|---|
| 25 | 3294 | 9-22 | 75.1 | 1.67 |
| 51 | 3157 | 9-21 | 74.8 | 1.67 |
| 76 | 2790 | 9-20 | 74.2 | 1.88 |
| LSD (.05) | 327 | 0- 1 | N.S. | 0.11 |

Similar increases in yields due to row spacing were found both years.

Table 10. Effects of row spacing on the 1981 harvest data (averaged over water, population, and variety).

| ROW WIDTH (CM) | YIELD (KG/HA) | MATURITY (MONTH-DAY) | HEIGHT (CM) | LODGING SCORE | SEED WT. |
|---|---|---|---|---|---|
| 25 | 3602 | 9-20 | 83.2 | 2.51 | 16.3 |
| 51 | 3518 | 9-20 | 85.4 | 2.51 | 16.1 |
| 76 | 3046 | 9-20 | 85.4 | 2.71 | 15.9 |
| LSD (.05) | 142 | N.S. | 1.4 | 0.15 | N.S. |

Differences existed in other factors, however. In 1980, a slight delay in maturity in narrower row spacings was recorded. This is believed to be due to the restriction of air movement within the plant canopy in narrower rows. A similar, but not significant trend was noticed in 1981.

In 1980, plant heights increased as row widths decreased. This can be explained by the basic physiological principle that as light becomes limiting within a dense plant canopy, the auxin produced in the stems is not degraded. The result is taller plants.

In 1981, plant height decreased as row width decreased. This is attributed to two factors. The herbicide damage produced skips in the rows, resulting in open areas in the plant canopy and allowing more light penetration and more auxin degradation. This resulted in shorter plants. One of the herbicides, vernolate, inhibits cell division and elongation and may alter gibberellic acid distribution in plants

(18). Soybeans in 25 cm rows were slower to emerge and may have absorbed more chemical. As a result, long term stunting would occur. However, the decrease in height between row spacings was slight.

In both years lodging increased slightly as row width increased. This may have been caused by the weight of the extra seeds per plant.

## Plant Population

The effects of plant population on yield are unclear. In 1980, low plant populations resulted in a small but not significant yield increase. In 1981 however, it was the normal populations which produced a significant increase in yield. This may have been due to the different precipitation patterns for the two years.

Table 11. Effects of population on the 1980 components of yield (averaged over water, row spacing, and variety).

| POPULATION LEVEL | SEEDS PER POD | PODS PER PLANT | SEED WT. (G/100) | GRAMS PER PLANT* | NODES PER PLANT | BRANCHES PER PLANT |
|---|---|---|---|---|---|---|
| Normal | 2.24 | 32.9 | 16.6 | 12.2 | 14.7 | 1.09 |
| Low | 2.25 | 37.8 | 16.4 | 13.9 | 16.2 | 1.80 |

* As a function seeds/pod x pods/plant x (seed wt./100).

Table 11 shows that at low populations, each plant tended to have more pods per plant, nodes per plant, and branches per plant, while seed weight was slightly lower. Since the low population was 75 percent of the rate of normal population, the product of the yield components (grams per plant) would have to increase 133 percent before the yields of the two populations would be equal.

While plant population by itself did not have a significant effect on yield in 1980, the population x row spacing interaction proved significant (Figure 6). Plants in normal populations produced higher yields in 51 and 76 cm rows in 1980. However, plants in low populations produced higher yields in 25 cm rows in 1980 than did normal populations. In 1981, yields were higher for normal populations in all row spacings.

Table 12. Effects of the population x row spacing interaction on the 1980 components of yield (averaged over water and variety).

| ROW SPACING (CM) | POPULATION LEVEL | SEEDS PER POD | PODS PER PLANT | NODES PER PLANT | BRANCHES PER PLANT |
|---|---|---|---|---|---|
| 25 | Normal | 2.23 | 29.8 | 14.1 | 1.09 |
| | Low | 2.16 | 35.3 | 15.9 | 1.83 |
| 51 | Normal | 2.19 | 30.8 | 15.4 | 1.28 |
| | Low | 2.22 | 41.2 | 16.3 | 1.86 |
| 76 | Normal | 2.22 | 33.3 | 14.6 | 1.15 |
| | Low | 2.27 | 43.0 | 16.3 | 1.71 |

Data from Table 12 show that the yield components for plants in low populations were higher than those for plants

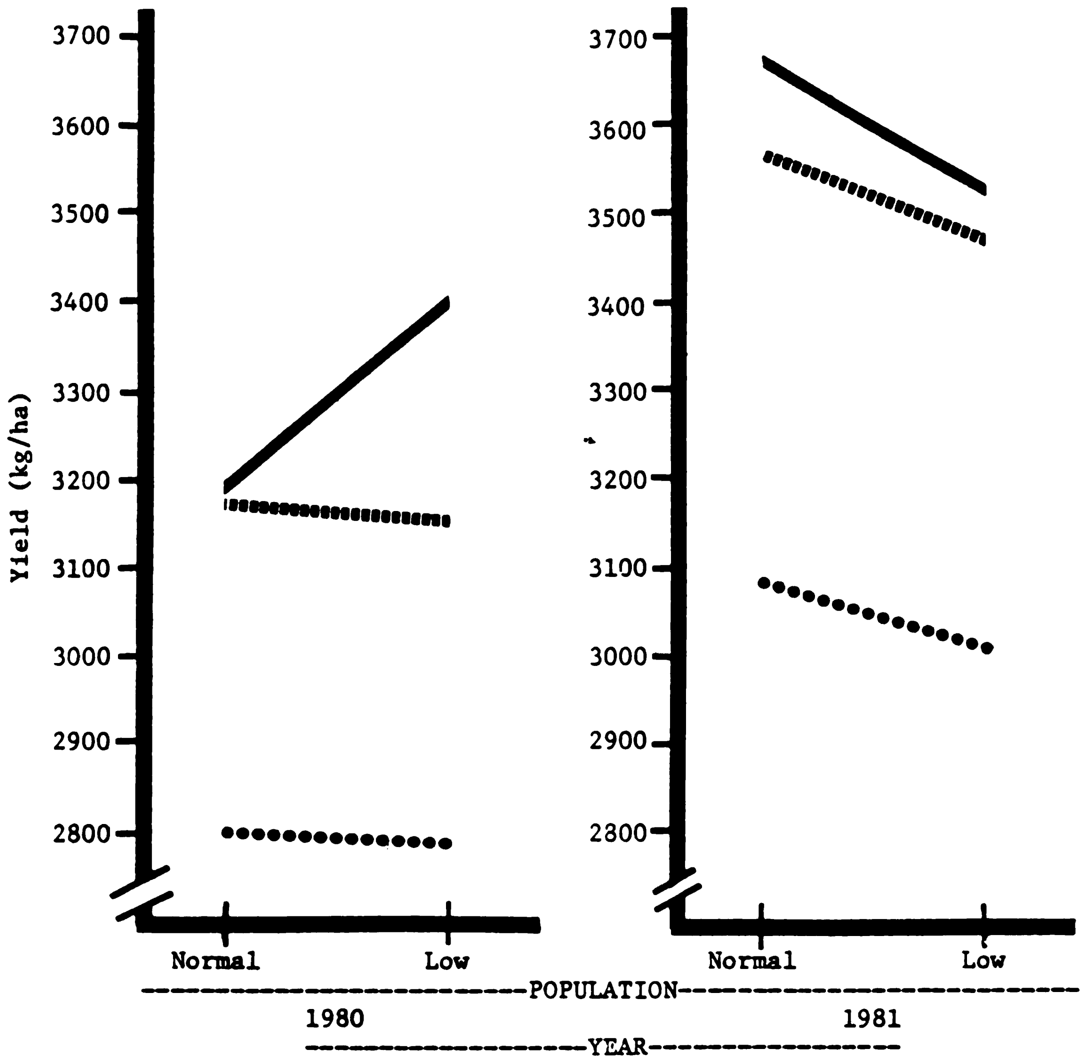


Figure 6 Population x Row Width Interaction Effects on Yield (Averaged over water and varieties)

in normal populations in all row spacings. The difference in yield components between population levels is no greater in 25 cm rows than in other row spacings. Hence, there is no evidence to explain the yield increase in 25 cm rows caused by low populations shown in Figure 6.

Table 13. Effect of population on the 1980 harvest data (averaged over water, row spacing, and variety).

| POPULATION LEVEL | YIELD (KG/HA) | MATURITY (MONTH-DAY) | HEIGHT (CM) | LODGING SCORE |
|---|---|---|---|---|
| Normal | 3048 | 9-20.4 | 74.5 | 1.77 |
| Low | 3112 | 9-21.4 | 74.9 | 1.70 |
| LSD (.05) | N.S. | 0.2 | N.S. | N.S. |

Table 14. Effects of population on the 1981 harvest data (averaged over water, row spacing, and variety).

| POPULATION LEVEL | YIELD (KG/HA) | MATURITY (MONTH-DAY) | HEIGHT (CM) | LODGING SCORE | SEED WT. |
|---|---|---|---|---|---|
| Normal | 3442 | 9-20 | 85.0 | 2.65 | 16.2 |
| Low | 3335 | 9-20 | 84.6 | 2.50 | 16.1 |
| LSD (.05) | 63 | N.S. | N.S. | 0.07 | 0.1 |

The effects of population were not limited to yield (Tables 13 and 14). In 1980, low populations resulted in a slight but significant delay in maturity. No maturity delay was noticed in 1981. Population had no significant effect on plant height in either year.

However, there was a population x water interaction on plant height in both years. In 1980, irrigated plants were taller in low populations compared to normal populations. Nonirrigated plants were taller at normal populations. In 1981, the trends were reversed.

Seed weights were higher at normal populations in 1981 (Table 14). Lodging decreased at low populations both years. In 1981, lodging was significantly less at low populations.

Variety

Yields were affected more by varieties than by any other factor, including water and row spacing.

Varieties responded differently in each year of the study. As mentioned in the climate section, 1981 was a relatively dry year. However, the results of the 1981 season were obscured by herbicide damage. Hopefully, most of the error and the effects of the herbicide damage were removed with the analysis of covariance.

The two herbicides used in 1981 were vernolate and profluralin. While both were used at excessive rates for the particular soil texture, it is interesting to note their longevity and possible differential effects on varieties. Vernolate has a half life of 1.5 weeks in a loam soil at 21-27 c. While it is absorbed by, and translocated through soybean plants, it is quickly metabolized (46). Profluralin, on the other hand, is longer lived with a half life between 80-128 days (46). According to the herbicide handbook of the Weed Science Society of America, there is evidence that profluralin may interfere with both photosynthesis and respiration in plants and that the degree of selectivity may be at least partly related to the lipid content of the plant or its seeds (46).

The subjective rating of the herbicide damage, conducted on 15 July 1981, was itself statistically analyzed. It showed a differential varietal damage (skips and stunts) due to herbicide injury. The degree of skips, due to seedling mortality, may have reflected seed quality. However, the stunting was undoubtedly a result of altered plant physiology from herbicide injury. The harvest data were analyzed with the stunt and skip scores as possible covariates. Using the stunt score as a covariate, the mean square error of the resulting analysis was found to be significantly and substantually reduced. However, some inconsistencies were seen, especially regarding the row spacing x variety response. In light of this, the major emphasis of the variety section will be on the 1980 results.

Varieties were subplots of both water and row spacing treatments and were coupled with populations. Therefore, many interactions occurred. The variety section is divided into two parts. The main effects subsection discusses the yield, maturity, height, lodging and seed weight response of varieties when averaged over the other factors (water, row spacing and population). The interaction subsection discusses varietal response as affected by the other factors. Each of the subsections is further subdivided into years.

## Main Effects

1980. When results were averaged over water, row spacing, and population treatments, the yields of individual varieties in 1980 varied by as much as 1026 kg/ha (Table 15). As expected, linear regression analysis indicated a strong relationship between yield and the maturity date of the varieties (Figure 7). Later maturing varieties yielded more than earlier maturing varieties. Since all varieties were planted on the same date, the later maturing varieties had more time for photosynthetic accumulation and perhaps longer reproductive periods as well.

Table 15. Effects of varieties on the 1980 harvest data (averaged over water, row spacing and population).

| VARIETY | YIELD (KG/HA) | MATURITY (MONTH-DAY) | HEIGHT (CM) | LODGING SCORE |
|---|---|---|---|---|
| Gnome | 3498 | 9-28 | 52.4 | 1.00 |
| Harcor | 3404 | 9-23 | 81.2 | 2.53 |
| Corsoy 79 | 3262 | 9-22 | 80.5 | 2.18 |
| Beeson 80 | 3253 | 9-23 | 79.1 | 1.86 |
| SRF 200 | 3142 | 9-23 | 85.8 | 2.24 |
| SRF 150P | 3024 | 9-19 | 74.6 | 1.51 |
| Hardin | 3011 | 9-19 | 75.8 | 1.99 |
| Wells II | 2936 | 9-19 | 74.8 | 1.21 |
| Nebsoy | 2802 | 9-19 | 72.2 | 1.43 |
| Hodgson 78 | 2472 | 9-12 | 70.6 | 1.40 |
| x | 3080 | 9-21 | 74.7 | 1.74 |
| LSD (.05) | 132 | 0- 1 | 2.3 | 0.14 |

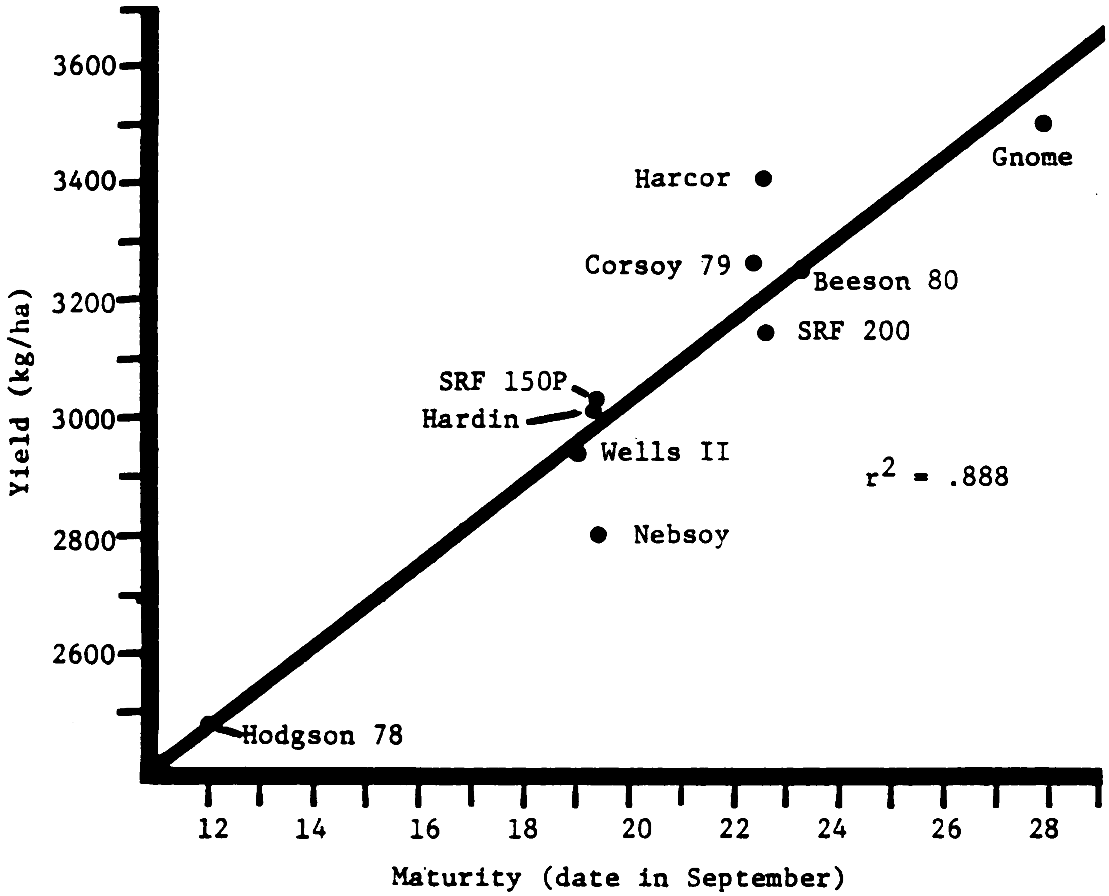


Figure 7 Linear Regression Analysis Comparing Variety Yields to Maturities in 1980 (Averaged over water, row spacings and populations)

The regression line in Figure 7 shows two main clusters of varieties and two outlying varieties. Gnome, a late maturity Group II variety, was the latest maturing variety and had the highest yield. Farther down the regression line is a cluster of varieties containing Harcor, Corsoy 79, Beeson 80, and SRF 200, all Group II varieties. The second cluster contains SRF 150P and Hardin, both Group I varieties, and Wells II and Nebsoy, both early Group II varieties. At the bottom of the line is Hodgson 78, the earliest maturing and lowest yielding variety.

Table 16. Effects of variety on the 1980 components of yield (averaged over water, row spacing, and population).

| VARIETY | SEEDS PER POD | PODS PER PLANT | SEED WT. (G/100) | GRAMS PER PLANT* | NODES PER PLANT | BRANCHES PER PLANT** |
|---|---|---|---|---|---|---|
| Gnome | 2.26 | 41.7 | 15.8 | 14.9 | 14.2 | 3.10 |
| Harcor | 2.05 | 41.8 | 16.2 | 13.9 | 15.4 | 2.10 |
| Corsoy 79 | 1.98 | 43.3 | 16.3 | 14.0 | 15.5 | 1.55 |
| Beeson 80 | 2.09 | 33.8 | 19.3 | 13.6 | 16.0 | 1.49 |
| SRF 200 | 2.80 | 29.2 | 16.3 | 13.3 | 16.7 | 1.54 |
| SRF 150P | 2.48 | 32.4 | 15.6 | 12.6 | 16.6 | 1.29 |
| Hardin | 2.02 | 39.4 | 14.9 | 11.9 | 15.6 | 1.16 |
| Wells II | 2.27 | 32.1 | 17.2 | 12.5 | 15.1 | 0.98 |
| Nebsoy | 2.26 | 32.8 | 17.4 | 12.9 | 15.4 | 0.53 |
| Hodgson 78 | 2.08 | 32.4 | 16.6 | 11.2 | 15.2 | 1.18 |

* Calculated weight of seeds per plant.
** Average from plants without hail damage.

The components of yield for each variety (Table 16) help explain some of the differences within and among the clusters. Orthogonal comparisons showed that varieties with above mean numbers of pods per plant and branches per plant had higher yields. However, these factors seemed to be linked in the varieties tested. Linear regression analysis showed seed weight and the number of seeds per pod were not correlated with yield in the varieties tested.

Plant height varied among varieties. With the exception of Gnome, plant height increased with increasing maturity. A linear regression analysis comparing height and maturity resulted in a correlation of 0.839 between the factors. The yield components showed a somewhat constant number of nodes per plant among varieties, so the difference in height must be due to differences in internode length.

Lodging also differed among varieties. Interestingly, linear regression analyses excluding Gnome, indicated that increased lodging is associated with increased yield (correlation of 0.773) and increased plant height (correlation of 0.447). A multiple linear regression analysis with yield and height as independent variables and lodging as the dependent variable, resulted in a correlation of 0.888. Obviously, tall indeterminate varieties laden with seed are prone to lodging.

Gnome, the only determinate variety in the study, was the exception to generalizations on both height and lodging. While Gnome was the latest maturing and highest yielding variety, it was also the shortest and lodged the least. Gnome's short stature is a unique part of its genetic makeup and contributes to its resistance to lodging.

1981. In 1981, yields, heights, and lodging scores were generally greater than in 1980. These differences may have been due to more clear days in 1981 than in 1980. The maturity was, on the average, one day earlier, but the field was planted two days earlier.

When results were averaged over water, row spacing, and population treatments, the yields in 1981 varied by 499 kg/ha among varieties (Table 17). As in 1980, much of the difference was related to differences in maturity among varieties. Linear regression analysis of mean variety yields and maturities resulted in a correlation of only 0.729. However, when Gnome was deleted from the analysis, the correlation rose to 0.885 (Figure 8). Gnome matured later than any other variety, but did not yield proportionately higher as it did in 1980. Perhaps this is due to a genotype x environment interaction. On the other hand, the yields of Gnome may have been artificially inflated in 1980, since, unlike the other varieties, it was hand harvested.

In 1981, varieties were not clustered on the regression line (Figure 8) as they were in 1980. Maturities were more spread out in 1981 due to either the difference in the growing season environment or to the herbicide damage. This would help explain the uncharacteristically low yield of SRF 150P.

As in 1980, the 1981 plant heights differed among varieties and were strongly correlated (.735) with maturity. Likewise, lodging reacted as it did the previous year, being

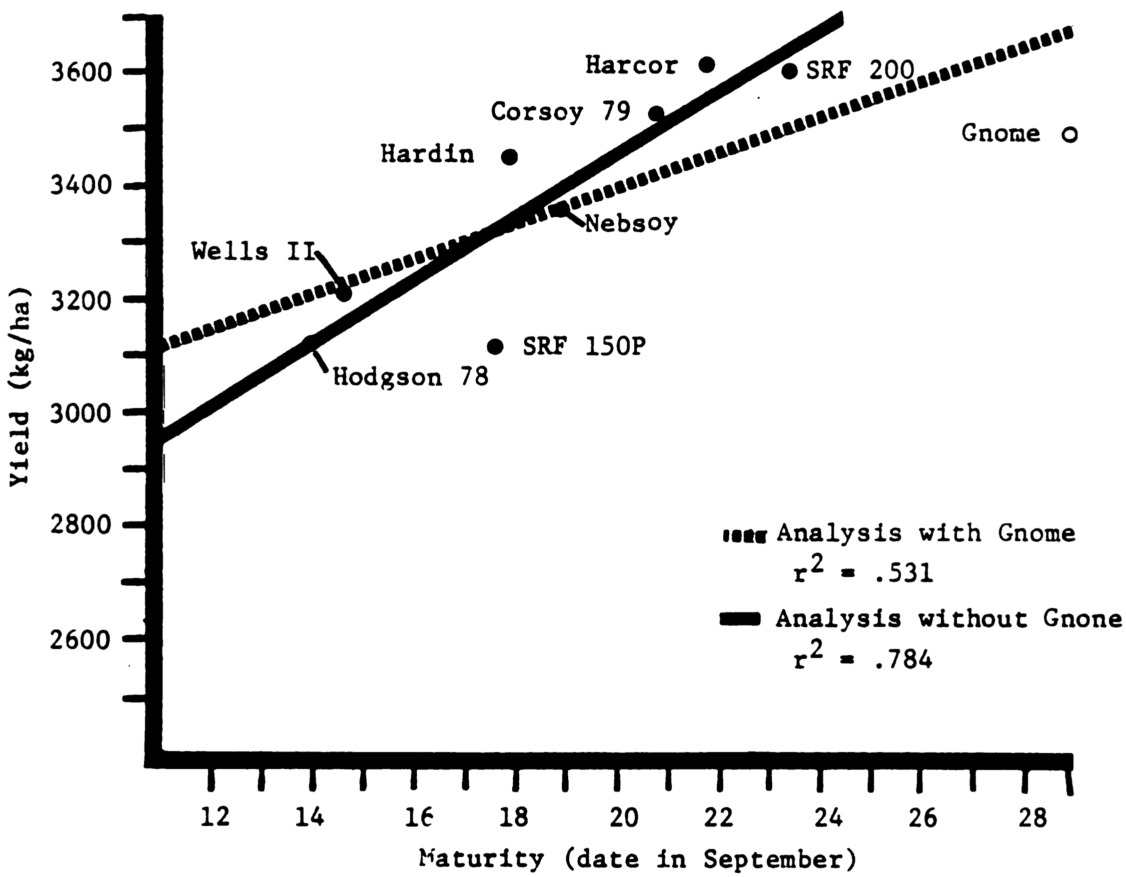


Figure 8 Linear Regression Analysis Comparing Variety Yields to Maturity Dates in 1981 (Averaged over water, row spacing, and population)

correlated to plant height (.814 and yield (.735). Again, Gnome did not fit the generalizations. It was the latest maturing variety, but was the shortest as well.

Table 17. Effects of variety on the 1981 harvest data (averaged over water, row spacing, and population)

| VARIETY | YIELD (KG/HA) | MATURITY (MONTH-DAY) | HEIGHT (CM) | LODGING SCORE | SEED WT. |
|---|---|---|---|---|---|
| Harcor | 3615 | 9-22 | 97.6 | 3.34 | 16.0 |
| SRF 200 | 3604 | 9-23 | 94.9 | 3.15 | 15.8 |
| Corsoy 79 | 3528 | 9-21 | 96.4 | 3.11 | 16.2 |
| Gnome | 3492 | 9-29 | 56.1 | 1.58 | 17.2 |
| Hardin | 3451 | 9-18 | 88.6 | 2.85 | 15.6 |
| Nebsoy | 3360 | 9-19 | 81.1 | 1.90 | 17.2 |
| Wells II | 3207 | 9-15 | 85.8 | 2.11 | 15.2 |
| Hodgson 78 | 3122 | 9-14 | 82.7 | 2.43 | 17.4 |
| SRF 150P | 3116 | 9-18 | 80.1 | 2.72 | 14.2 |
| $\bar{x}$ | 3288 | 9-20 | 84.8 | 2.58 | 16.1 |
| LSD (.05) | 130 | 0- 1 | 1.8 | 0.15 | 0.3 |

Seed weights were measured on all plots in 1981 and were included in the analysis of variance. While seed weights differed by variety, there seemed to be no direct correlation to yield. The differences in seed weight mostly reflected the different genetic makeup of the varieties.

Two-year summary on the main effects of varieties. Yields were influenced by maturity in that late maturing varieties out-yielded earlier varieties. Furthermore, maturity also influenced plant height of the indeterminate varieties. Plant height and yield both had effects on lodging. In 1981, yield was associated with lodging more than height. The reverse was true in 1980. Seed weights varied among varieties, but were not directly correlated to yield.

Interaction Effects--1980

Nineteen eighty was a relatively wet year. Consequently, few interactions involving water occurred. Only one significant interaction occurred in each of the measured effects (yield, maturity, height, and lodging). These interactions are covered in the effects sections listed below.

Yield. While no interactions involving yield were found in the 1980 combined analysis, a row spacing x variety interaction was found in the analysis of variance conducted on the four reps of the irrigated treatment. Under irrigated conditions, the varieties showed different yield responses to changes in row width (Table 18). Hardin and Corsoy 79 both showed a significant yield advantage for both 25 and 51 cm rows over 76 cm rows, but no significant difference between 25 and 51 cm rows. Hodgson 78 showed a significant advantage for 25 cm rows over both 51 and 76 cm rows, but no difference between 51 and 76 cm rows. SRF 150P, SRF 200, Harcor, and Wells II all showed significant yield advantages of 25 cm rows over 76 cm rows, but no differences between either 25 and 51 or 51 and 76 cm rows widths. Beeson 80 produced highest yields in 51 cm rows, which were significantly higher than yields in 76 cm but not 25 cm rows. Surprisingly, neither Gnome nor Nebsoy showed any significant yield differences among row spacings.

Table 18. Effects of row spacing x variety interaction on 1980 yields (kg/ha). (Averaged over water and population.)

| | ROW WIDTH (CM) | | |
|---|---|---|---|
| VARIETY | 25 | 51 | 76 |
| Gnome | 3885 | 3750 | 3371 |
| Harcor | 3874 | 3556 | 3201 |
| Corsoy 79 | 3672 | 3631 | 3065 |
| Beeson 80 | 3152 | 3577 | 2938 |
| SRF 200 | 3745 | 3304 | 2829 |
| SRF 150P | 3472 | 3212 | 2860 |
| Hardin | 3555 | 3177 | 2464 |
| Wells II | 3299 | 3124 | 2670 |
| Nebsoy | 2010 | 2808 | 2643 |
| Hodgson 78 | 3046 | 2528 | 2088 |

LSD (.05) = 475 for comparisons within columns.
LSD (.05) = 515 for comparisons within rows.

The differential varietal yield response can be seen in Figure 9, where the varieties are ranked by maturity. The maturity Group I varieties Hodgson 78 and Hardin showed the greatest yield increase of all varieties between 25 and 76 cm rows. With the exception of SRF 200, a trend of increasing response to narrow rows exists as the maturity dates decrease. This reflects the plant stature differences between the shorter Group I and taller Group II varieties. As pointed out in the literature review, optimum yield of a particular variety is obtained when it is planted in a row width which allows it to attain full canopy before

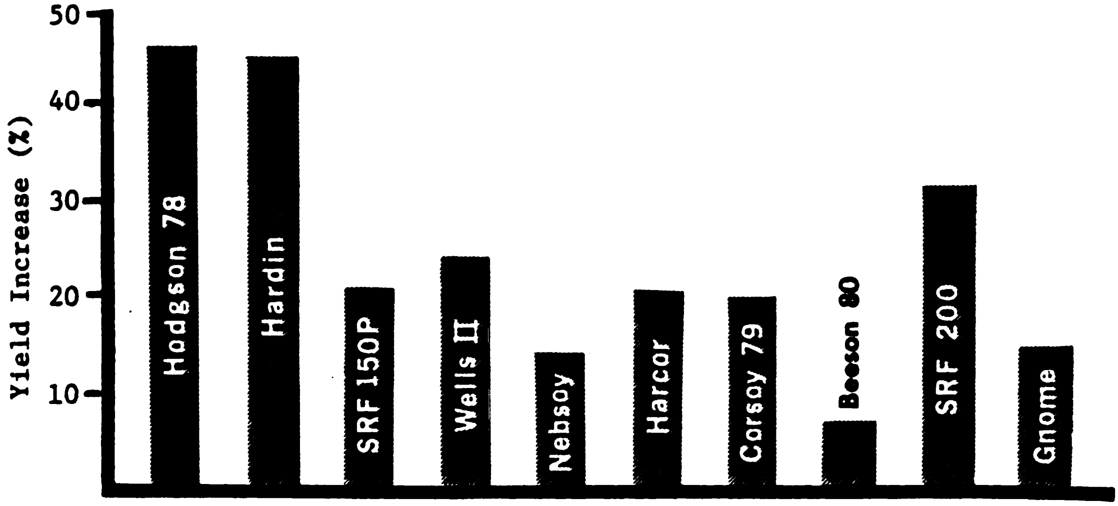


Figure 9 Yield Increase (%) Due to Decreasing Row Spacing from 76 cm to 25 cm in Irrigated Treatments in 1980 (Averaged over population)

the full flowering period (37). In the northern United States, earlier maturing varieties respond more to narrower rows than later varieties.

Maturity. Maturity was affected by a row spacing x variety interaction in the combined analysis in 1980. The maturities of Hardin and Hodgson 78 were significantly delayed in 25 cm rows as compared to 76 cm rows. None of the other varieties, including SRF 150P, also a Group I variety, showed any significant maturity differences among the three row spacings.

Height. A combined interaction effect between water and varieties on height was found to be significant at the 5 percent level in the analysis of variance. However, the individual differences between water treatments within any one variety were not significant (Table 19). Many differences among varieties within the same water treatment were significant.

Lodging. A water x variety interaction affected lodging in 1980. The lodging scores of only three varieties, SRF 150P, SRF 200, and Beeson 80, increased significantly due to irrigation. No significant lodging changes occurred in the other varieties.

Interaction Effects--1981

The growing season in 1981 was drier than in 1980. Consequently, water x variety interactions occurred in all the harvest data. Population x variety interactions were also found in all the harvest data except lodging. However, these interactions may reflect the effect of herbicide damage on the lower population, rather than a true population x variety interaction. A row spacing x variety interaction proved to have significant effects on yields, and a water x row spacing x variety interaction was found to affect both yields and seed weights.

Table 19. Effects of the water x variety interaction on 1980 plant heights (averaged over row spacing and population).

| | WATER TREATMENT | | |
|---|---|---|---|
| VARIETY | IRRIGATED | NON-IRRIGATED | Δ X |
| Gnome | 53.8 | 51.1 | 2.7 |
| Harcor | 85.3 | 77.0 | 8.3 |
| Corsoy 79 | 87.2 | 73.9 | 13.3 |
| Beeson 80 | 83.1 | 75.1 | 8.0 |
| SRF 200 | 90.9 | 80.7 | 10.2 |
| SRF 150P | 79.1 | 70.2 | 8.9 |
| Hardin | 78.1 | 73.4 | 4.7 |
| Wells II | 81.3 | 68.3 | 13.0 |
| Nebsoy | 75.8 | 68.7 | 7.1 |
| Hodgson 78 | 72.9 | 68.3 | 4.6 |

LSD (.05) = 6.5 for comparisons within colums
LSD (.05) = 16.4 for comparisons within rows

<u>Yield</u>. Irrigation resulted in significant yield increases in all varieties. However, the degree of response differed among varieties, resulting in a water x variety interaction (Figure 10).

As shown in Table 20, the two narrow-leafed varieties, SRF 150P and SRF 200, showed the greatest yield response to irrigation. However, these two varieties were also shown

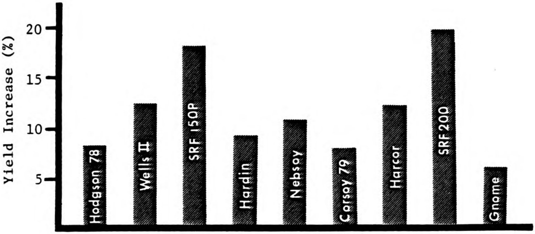


Figure 10 Yield Increase (%) of Varieties in Irrigated Treatments Over Non Irrigated Treatments in 1981 (Averaged over row spacing and population)

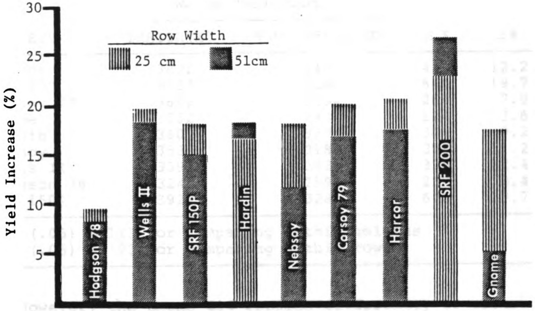


Figure 11 Yield Increase (%) Due to Decreasing Row Widths in 1981 (Averaged over water and population)

to have the greatest amount of herbicide damage. So the irrigation water may have helped them overcome the root pruning effects of profluralin. Harcor, Nebsoy, and Wells II showed a medium to high response to irrigation. Hardin, Corsoy 79, and Hodgson 78 showed a low to medium response. Surprisingly, Gnome, the only determinate variety in the study, showed only a 3.6 percent yield increase between irrigated and nonirrigated treatments. Rainfall must have been adequate during the flowering period, since water stress during the flowering period will usually reduce the yields of determinate varieties (13).

Table 20. Effects of water x variety interactions on 1981 yields (kg/ha) (averaged over row spacing and population).

| | WATER TREATMENT | | | |
|---|---|---|---|---|
| VARIETY | IRRIGATED | NON-IRRIGATED | Δ X | Δ % |
| Harcor | 3822 | 3407 | 414 | 12.2 |
| SRF 200 | 3927 | 3281 | 646 | 19.7 |
| Corsoy 79 | 3662 | 3394 | 268 | 7.9 |
| Gnome | 3552 | 3430 | 124 | 3.6 |
| Hardin | 3603 | 3299 | 304 | 9.2 |
| Nebsoy | 3538 | 3182 | 356 | 11.2 |
| Wells II | 3395 | 3020 | 375 | 12.4 |
| Hodgson 78 | 3248 | 2996 | 252 | 8.4 |
| SRF 150P | 3927 | 3281 | 646 | 19.7 |

LSD (.05) = 121 for comparing within columns
LSD (.05) = 93 for comparing within rows

However, the Gnome did respond differently to water stress than did Nebsoy. Leaf water potentials of both Gnome and Nebsoy were measured in 51 cm row widths at normal populations in both irrigated and nonirrigated treatments on 24 August 1981. Averaging over water treatments, Gnome had a leaf water potential of -4.4 bars compared to -12.3 bars for Nebsoy. It is unlikely that a difference of this magnitude could be explained by different osmotic or pressure potentials between the varieties. The higher leaf water potential of Gnome may have been due to root distribution or greater rooting depth as compared to Nebsoy. Undoubtedly this difference was reflected in the yield difference between the two varieties and the difference in yield response to irrigation.

Table 21. Effects of row spacing x variety interactions on the 1981 yields (kg/ha) (averaged over water and population).

| | ROW WIDTH (CM) | | |
|---|---|---|---|
| VARIETY | 25 | 51 | 76 |
| Harcor | 3869 | 3773 | 3202 |
| SRF 200 | 3805 | 3914 | 3093 |
| Corsoy 79 | 3769 | 3671 | 3144 |
| Gnome | 3812 | 3426 | 3237 |
| Hardin | 3596 | 3666 | 3093 |
| Nebsoy | 3612 | 3411 | 3057 |
| Wells II | 3407 | 3372 | 2843 |
| Hodgson 78 | 3230 | 3194 | 2942 |
| SRF 150P | 3317 | 3231 | 2798 |

LSD (.05) = 121 for comparing within columns.
LSD (.05) = 117 for comparing within rows.

A row spacing x variety interaction also had an effect on yields (Table 21). All varieties except Nebsoy and Gnome had significantly greater yields in both 25 and 51 cm rows than in 76 cm rows, but no significant difference occurred between 25 and 51 cm rows. Gnome and Nebsoy had significant yield differences among all three row spacings.

As in 1980, the degree of response to narrow row spacing differed among varieties (Figure 11). Unlike the 1980 results, the Group I varieties did not exhibit the greatest responses. Furthermore, both Harcor and SRF 200 had greatest yields in 51 cm rows, a totally unexpected result. Again, these unusual results may be a reflection of the herbicide injury.

A population x variety interaction had an effect on yields in 1981. The yields of Hodgson 78, SRF 200, Gnome, Hardin, and Wells II were significantly higher at normal populations. Corsoy 79, Harcor, and Nebsoy showed no significant yield differences between population levels but, SRF 150P had higher yields at lower populations.

A three-way interaction of water x row spacing x variety also affected yields. Basically, the response of varieties among row spacings varied due to water treatments (Table A3, Appendix).

<u>Maturity</u>. Irrigation dramatically delayed the maturity of all varieties. On the average, irrigation delayed maturity five days. However, each variety reacted somewhat differently, resulting in a water x variety interaction on maturity (Table 22). Also, the maturity ranking of varieties changed between water treatments.

Table 22. Effects of water x variety interaction on maturity (date in September) in 1981 (averaged over row spacing and population).

| VARIETY | WATER TREATMENT IRRIGATED | NON-IRRIGATED | Δ X |
|---|---|---|---|
| Harcor | 23.6 | 19.9 | 3.7 |
| SRF 200 | 27.7 | 19.0 | 8.7 |
| Corsoy 79 | 23.4 | 18.1 | 5.3 |
| Gnome | 31.2* | 26.6 | 4.6 |
| Hardin | 20.4 | 15.3 | 5.1 |
| Nebsoy | 20.8 | 17.0 | 3.8 |
| Wells II | 16.0 | 13.2 | 2.8 |
| Hodgson 78 | 15.5 | 12.5 | 3.0 |
| SRF 150P | 21.5 | 13.7 | 7.7 |

LSD (.05) = 0.6 for comparing within columns
LSD (.05) = 0.6 for comparing within rows
* 10-01.2

A population x variety interaction resulted in slight differences in maturity dates. Population levels had no effect on the maturity of Hodgson 78, Corsoy 79, Harcor, Nebsoy or Gnome. The low level of population caused delayed maturity in SRF 150P, SRF 200, and Wells II. The maturity of Hardin was later in normal compared to low populations.

Height. Irrigation significantly increased the height of all varieties, except Gnome, by an average of 20.2 percent. Gnome showed no significant change in height between water treatments.

The population x variety interaction resulted in differential heights among varieties between population levels. Normal populations resulted in increased height of SRF 200, Gnome, and Wells II. Low population levels resulted in height decreases in Corsoy 79 and Nebsoy. No significant differences in height were found for Hodgson 78, SRF 150P, Harcor, or Hardin.

Lodging. Irrigation significantly increased the lodging of all varieties except Gnome. The water x variety interaction was most evident in the degree of lodging response among varieties in different water treatments (Figure 12).

Table 23. Effects of the water x variety interaction on lodging score in 1981 (averaged over row spacing and population).

| | WATER TREATMENT | | | |
|---|---|---|---|---|
| VARIETY | IRRIGATED | NON-IRRIGATED | Δ X | Δ % |
| Harcor | 3.62 | 3.07 | .55 | 17.9 |
| SRF 200 | 3.72 | 2.58 | 1.14 | 44.2 |
| Corsoy 79 | 3.45 | 2.77 | .68 | 24.6 |
| Gnome | 1.62 | 1.54 | .08 | 5.3 |
| Hardin | 3.24 | 2.46 | .78 | 31.7 |
| Nebsoy | 2.02 | 1.77 | .25 | 14.1 |
| Wells II | 2.50 | 1.72 | .78 | 45.4 |
| Hodgson 78 | 2.91 | 1.94 | .97 | 50.0 |
| SRF 150P | 3.51 | 1.93 | 1.58 | 81.9 |

LSD (.05) = 0.12 for comparing within columns
LSD (.05) = 0.11 for comparing within rows

As Table 23 shows, SRF 150P and SRF 200 had the greatest differences in lodging scores between water treatments.

Seed Weight. Seed weights changed due to the water x variety interaction. Seed weights of SRF 150P, SRF 200, Harcor, and Wells II increased under irrigation. The seed weight of Gnome decreased due to irrigation. No

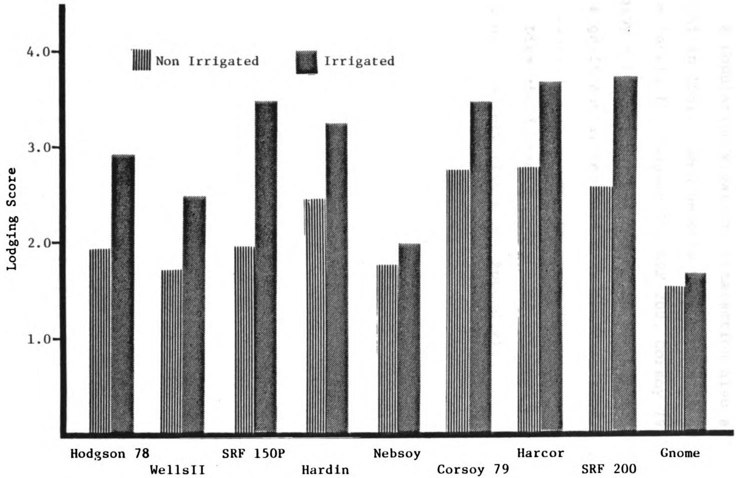


Figure 12 Lodging Scores by Variety and Irrigation Treatment in 1981
(Averaged over row spacing and population)

significant difference was seen in the seed weights of the other varieties.

A population x variety interaction also affected seed weight in 1981. Seed weights were higher in normal population levels for Hodgson 78, SRF 200, Corsoy 79, and Hardin. Nebsoy's seed weight was higher at low population levels. No significant differences were found in seed weights of SRF 150P, Harcor, Gnome, or Wells II.

Like yield, seed weights were affected by a water x row spacing x variety (Table A5, Appendix).

# CONCLUSIONS

1. In dry years, irrigation causes increases in soybean yields, heights, and lodging, as well as delaying the maturity.

2. The most important factor in increasing soybean yields is variety selection. Full season maturity Group II varieties had higher yields in southwestern Michigan than earlier maturity Group I varieties.

3. Yields are increased by an average of 14 percent when soybeans are planted in row widths of 51 cm or narrower.

4. Group I varieties, especially, should be planted in narrow rows.

5. Lodging continues to be a problem in irrigated soybean production. While decreasing plant population by 25 percent reduces lodging, effects on yield are unclear.

6. More research needs to be conducted to clarify the effects of the population x variety interaction on both yield and lodging.

# APPENDIX

Table A1. Criteria for herbicide injury rating.

SKIPS

1. ≤10 percent skips within plots
2. ≤20 percent skips within plots
3. ≤30 percent skips within plots
4. ≤40 percent skips within plots
5. >40 percent skips within plots

STUNTING

1. No apparent stunting
2. ≤20 percent moderate or 10 percent severe stunting
3. ≤40 percent moderate or 20 percent severe stunting
4. ≤60 percent moderate or 30 percent severe stunting
5. ≤80 percent moderate or 40 percent severe stunting

Table A2. Significance table for herbicide injury ratings.

| | IRRIGATED | | NON-IRRIGATED | |
|---|---|---|---|---|
| SOURCE | SKIP | STUNTING | SKIP | STUNTING |
| Row spacing | | ** | ** | * |
| Population | ** | ** | ** | ** |
| Pop x R.S. | ** | | ** | |
| Variety | ** | ** | ** | ** |
| R.S. x var | ** | * | ** | |
| Pop x var | | | | |
| R.S. x pop x var | | | | |

Table A3. Components of Yield - 1980.

| | | NON IRRIGATED | | | | IRRIGATED | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Row Width (cm) | Yield (Kg/ha) | Maturity (mo-day) | Lodging Score | Height (cm) | Yield (Kg/ha) | Maturity mo-day) | Lodging Score | Height (cm) |
| Hardin | 25 | 3406 | 9-22 | 1.8 | 73 | 3555 | 9-21 | 2.0 | 81 |
| | 51 | 2983 | 9-21 | 1.8 | 75 | 3178 | 9-19 | 2.2 | 80 |
| | 76 | 2465 | 9-19 | 2.1 | 73 | 2460 | 9-14 | 2.2 | 75 |
| Hodgson 78 | 25 | 2664 | 9-14 | 1.2 | 67 | 3046 | 9-14 | 1.4 | 76 |
| | 51 | 2553 | 9-12 | 1.1 | 69 | 2528 | 9-10 | 1.6 | 71 |
| | 76 | 1930 | 9-11 | 1.5 | 69 | 2088 | 9-10 | 1.8 | 73 |
| SRF 150 P | 25 | 2800 | 9-20 | 1.0 | 66 | 3472 | 9-21 | 1.9 | 81 |
| | 51 | 2943 | 9-21 | 1.2 | 71 | 3212 | 9-18 | 1.6 | 79 |
| | 76 | 2728 | 9-20 | 1.5 | 73 | 2860 | 9-19 | 1.8 | 79 |
| SRF 200 | 25 | 3059 | 9-23 | 1.6 | 75 | 3745 | 9-24 | 2.7 | 91 |
| | 51 | 2982 | 9-22 | 1.8 | 85 | 3304 | 9-22 | 2.6 | 90 |
| | 76 | 2823 | 9-22 | 2.3 | 82 | 2829 | 9-21 | 2.5 | 89 |
| Corsoy 79 | 25 | 3405 | 9-23 | 1.6 | 72 | 3672 | 9-24 | 2.5 | 88 |
| | 51 | 3266 | 9-23 | 2.2 | 73 | 3631 | 9-21 | 2.3 | 85 |
| | 76 | 2779 | 9-22 | 2.1 | 77 | 3065 | 9-22 | 2.5 | 85 |
| Harcor | 25 | 3636 | 9-25 | 2.5 | 78 | 3874 | 9-24 | 2.5 | 92 |
| | 51 | 3105 | 9-23 | 2.1 | 83 | 3556 | 9-23 | 2.3 | 81 |
| | 76 | 3071 | 9-23 | 2.8 | 81 | 3201 | 9-22 | 2.6 | 85 |
| Nebsoy | 25 | 2941 | 9-20 | 1.3 | 65 | 3010 | 9-18 | 1.4 | 75 |
| | 51 | 2931 | 9-20 | 1.3 | 73 | 2808 | 9-19 | 1.4 | 73 |
| | 76 | 2519 | 9-19 | 1.6 | 69 | 2643 | 9-19 | 1.7 | 76 |
| Gnome | 25 | 3518 | 9-28 | 1.0 | 55 | 3885 | 9-28 | 1.0 | 53 |
| | 51 | 3401 | 9-28 | 1.0 | 52 | 3750 | 9-27 | 1.0 | 53 |
| | 76 | 3262 | 9-28 | 1.0 | 47 | 3371 | 9-27 | 1.2 | 50 |
| Beeson 80 | 25 | 3205 | 9-24 | 1.4 | 73 | 3152 | 9-23 | 2.2 | 83 |
| | 51 | 3261 | 9-25 | 1.5 | 76 | 3577 | 9-24 | 1.8 | 85 |
| | 76 | 3012 | 9-23 | 1.7 | 77 | 2939 | 9-21 | 2.1 | 80 |
| Wells II | 25 | 3001 | 9-20 | 1.0 | 66 | 3299 | 9-19 | 1.2 | 82 |
| | 51 | 2826 | 9-19 | 1.0 | 70 | 3124 | 9-19 | 1.2 | 79 |
| | 76 | 2618 | 9-19 | 1.4 | 68 | 2670 | 9-17 | 1.2 | 77 |

Table A4. Summary of Water and Row Spacing Effects on Variety Performance - 1980

| | | NON IRRIGATED | | | | IRRIGATED | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Row Width (cm) | Pods/ Plant | Seeds/ Pod | Nodes/ Plant | Branches/ Plant | Pods/ Plant | Seeds/ Pod | Nodes/ Plant | Branches/ Plant |
| Hardin | Ave | 40.0 | 1.99 | 15.43 | 1.18 | 38.8 | 2.05 | 15.81 | 1.13 |
| | 25 | 37.0 | 2.02 | 15.50 | 1.34 | 39.1 | 1.95 | 16.20 | 1.50 |
| | 51 | 36.4 | 2.09 | 15.75 | 1.23 | 27.9 | 2.07 | 15.12 | 0.67 |
| | 76 | 46.7 | 1.85 | 15.05 | 0.97 | 49.3 | 2.14 | 16.11 | 1.22 |
| Hodgson 78 | Ave | 30.4 | 2.07 | 13.33 | 1.24 | 34.3 | 2.09 | 15.39 | 1.12 |
| | 25 | 30.9 | 1.98 | 13.35 | 1.50 | 31.3 | 2.28 | 14.03 | 1.30 |
| | 51 | 28.3 | 2.09 | 13.40 | 1.34 | 30.1 | 1.82 | 13.90 | 0.80 |
| | 76 | 32.0 | 2.15 | 13.25 | 0.84 | 41.6 | 2.17 | 18.25 | 1.25 |
| SRF 150 P | Ave | 28.6 | 2.58 | 16.15 | 1.11 | 32.0 | 2.40 | 17.00 | 1.46 |
| | 25 | 23.7 | 2.54 | 15.25 | 0.67 | 34.9 | 2.40 | 17.05 | 1.78 |
| | 51 | 28.2 | 2.65 | 16.35 | 1.50 | 30.9 | 2.33 | 16.59 | 1.27 |
| | 76 | 33.7 | 2.54 | 16.85 | 1.16 | 30.3 | 2.47 | 17.37 | 1.34 |
| SRF 200 | Ave | 27.2 | 2.83 | 16.18 | 1.48 | 31.1 | 2.77 | 17.20 | 1.59 |
| | 25 | 21.8 | 2.79 | 15.10 | 0.88 | 25.8 | 2.94 | 17.92 | 1.00 |
| | 51 | 34.0 | 2.91 | 18.00 | 2.05 | 34.6 | 2.58 | 17.36 | 2.29 |
| | 76 | 25.8 | 2.80 | 15.45 | 1.50 | 33.0 | 2.79 | 16.30 | 1.47 |
| Corsoy 79 | Ave | 41.1 | 2.00 | 14.83 | 1.57 | 45.4 | 1.97 | 16.03 | 1.52 |
| | 25 | 29.4 | 1.97 | 14.50 | 1.44 | 50.2 | 1.87 | 15.68 | 2.38 |
| | 51 | 34.8 | 2.06 | 14.95 | 0.56 | 37.9 | 2.06 | 16.50 | 1.29 |
| | 76 | 59.0 | 1.98 | 15.05 | 2.70 | 48.4 | 1.98 | 15.90 | 0.90 |
| Harcor | Ave | 41.2 | 2.08 | 14.72 | 1.52 | 42.4 | 1.97 | 16.59 | 2.68 |
| | 25 | 32.0 | 2.07 | 14.60 | 1.50 | 45.5 | 2.02 | 18.00 | 2.79 |
| | 51 | 31.1 | 2.03 | 12.60 | 0.89 | 44.2 | 1.99 | 17.17 | 2.50 |
| | 76 | 60.6 | 2.15 | 16.95 | 2.16 | 37.6 | 1.90 | 14.62 | 2.75 |
| Nebsoy | Ave | 26.6 | 2.29 | 15.05 | 0.58 | 38.2 | 2.22 | 15.64 | 0.48 |
| | 25 | 25.4 | 2.31 | 16.25 | 0.42 | 41.7 | 2.12 | 14.17 | 0.88 |
| | 51 | 25.2 | 2.22 | 13.95 | 0.52 | 39.8 | 2.32 | 16.95 | 0.43 |
| | 76 | 29.2 | 2.33 | 14.95 | 0.79 | 33.0 | 2.22 | 15.79 | 0.13 |
| Gnome | Ave | 37.5 | 2.32 | 13.80 | 2.56 | 45.9 | 2.20 | 14.61 | 3.63 |
| | 25 | 31.9 | 2.45 | 13.20 | 1.83 | 33.4 | 2.17 | 13.03 | 2.34 |
| | 51 | 45.2 | 2.18 | 15.50 | 2.38 | 61.5 | 2.21 | 17.17 | 6.09 |
| | 76 | 35.1 | 2.34 | 12.70 | 3.47 | 42.7 | 2.24 | 13.70 | 2.45 |
| Beeson 80 | Ave | 38.6 | 2.23 | 16.67 | 1.58 | 29.0 | 1.94 | 15.71 | 1.40 |
| | 25 | 31.6 | 2.18 | 16.50 | 1.50 | 26.4 | 2.18 | 13.95 | 1.83 |
| | 51 | 51.4 | 2.31 | 17.50 | 2.07 | 31.17 | 1.42 | 16.80 | 1.55 |
| | 76 | 32.9 | 2.19 | 16.00 | 1.16 | 29.6 | 2.24 | 14.75 | 0.82 |
| Wells II | Ave | 26.7 | 2.27 | 14.68 | 0.67 | 37.3 | 2.27 | 15.37 | 1.29 |
| | 25 | 23.4 | 2.22 | 14.70 | 0.38 | 40.0 | 2.36 | 15.63 | 2.00 |
| | 51 | 28.4 | 2.28 | 15.20 | 0.80 | 38.7 | 2.32 | 15.70 | 1.20 |
| | 76 | 28.6 | 2.31 | 14.15 | 0.82 | 33.4 | 2.22 | 14.79 | 0.67 |

Table A5. Summary of Water and Row Spacing Effects on Variety Performance - 1981

| Variety | Row Width (cm) | NON IRRIGATED Yield (Kg/ha) | NON IRRIGATED Maturity (mo-day) | NON IRRIGATED Lodging Score | NON IRRIGATED Height (cm) | NON IRRIGATED Seed Wt. (g/100) | IRRIGATED Yield (Kg/ha) | IRRIGATED Maturity (mo-day) | IRRIGATED Lodging Score | IRRIGATED Height (cm) | IRRIGATED Seed Size (g/100) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hodgson 78 | 25 | 3303 | 9-13 | 1.8 | 73 | 17.4 | 3457 | 9-16 | 3.0 | 90 | 17.6 |
| | 51 | 3247 | 9-13 | 1.8 | 75 | 17.6 | 3142 | 9-16 | 2.9 | 91 | 17.4 |
| | 76 | 2738 | 9-12 | 2.2 | 79 | 17.2 | 3145 | 9-15 | 2.9 | 89 | 17.3 |
| SRF 150 P | 25 | 3021 | 9-14 | 1.7 | 67 | 14.2 | 3614 | 9-22 | 3.6 | 87 | 14.7 |
| | 51 | 2941 | 9-14 | 1.9 | 73 | 13.8 | 3521 | 9-22 | 3.4 | 89 | 14.5 |
| | 76 | 2602 | 9-14 | 2.2 | 78 | 13.8 | 2994 | 9-20 | 3.6 | 87 | 14.5 |
| SRF 200 | 25 | 3532 | 9-19 | 2.2 | 84 | 16.0 | 4078 | 9-28 | 3.8 | 101 | 16.3 |
| | 51 | 3339 | 9-19 | 2.6 | 89 | 15.0 | 4498 | 9-28 | 3.7 | 103 | 16.7 |
| | 76 | 2972 | 9-19 | 3.0 | 92 | 15.3 | 3214 | 9-28 | 3.6 | 101 | 15.5 |
| Corsoy 79 | 25 | 3674 | 9-18 | 2.6 | 85 | 16.5 | 3865 | 9-23 | 3.5 | 104 | 16.2 |
| | 51 | 3536 | 9-18 | 2.8 | 87 | 16.2 | 3806 | 9-24 | 3.3 | 107 | 16.1 |
| | 76 | 2974 | 9-18 | 2.9 | 91 | 15.4 | 3315 | 9-23 | 3.5 | 105 | 16.2 |
| Harcor | 25 | 3599 | 9-21 | 2.9 | 85 | 16.6 | 4138 | 9-25 | 3.6 | 105 | 16.3 |
| | 51 | 3573 | 9-20 | 3.0 | 90 | 15.9 | 3973 | 9-23 | 3.4 | 107 | 15.8 |
| | 76 | 3048 | 9-19 | 3.3 | 91 | 15.9 | 3356 | 9-24 | 3.9 | 107 | 15.2 |
| Nebsoy | 25 | 3603 | 9-18 | 1.6 | 70 | 17.1 | 3621 | 9-21 | 2.0 | 89 | 17.1 |
| | 51 | 3232 | 9-16 | 1.8 | 74 | 17.6 | 3591 | 9-21 | 2.0 | 88 | 17.0 |
| | 76 | 2712 | 9-17 | 1.9 | 76 | 17.1 | 3401 | 9-21 | 2.0 | 89 | 17.5 |
| Gnome | 25 | 3730 | 9-27 | 1.3 | 55 | 18.0 | 3893 | 10-1 | 1.7 | 57 | 17.0 |
| | 51 | 3478 | 9-26 | 1.5 | 57 | 17.2 | 3375 | 9-30 | 1.5 | 56 | 17.1 |
| | 76 | 3081 | 9-27 | 1.8 | 56 | 17.1 | 3394 | 10-1 | 1.7 | 56 | 16.6 |
| Hardin | 25 | 3322 | 9-16 | 2.3 | 74 | 15.8 | 3869 | 9-22 | 3.2 | 100 | 15.8 |
| | 51 | 3695 | 9-15 | 2.3 | 79 | 15.9 | 3636 | 9-20 | 3.1 | 99 | 15.8 |
| | 76 | 2881 | 9-15 | 2.8 | 83 | 15.1 | 3305 | 9-19 | 3.4 | 96 | 15.4 |
| Wells II | | 3191 | 9-12 | 1.7 | 77 | 15.2 | 3622 | 9-17 | 2.5 | 94 | 16.2 |
| | | 3192 | 9-14 | 1.7 | 78 | 14.9 | 3548 | 9-15 | 2.5 | 94 | 15.0 |
| | | 2671 | 9-13 | 1.8 | 78 | 14.7 | 3016 | 9-16 | 2.4 | 94 | 15.1 |

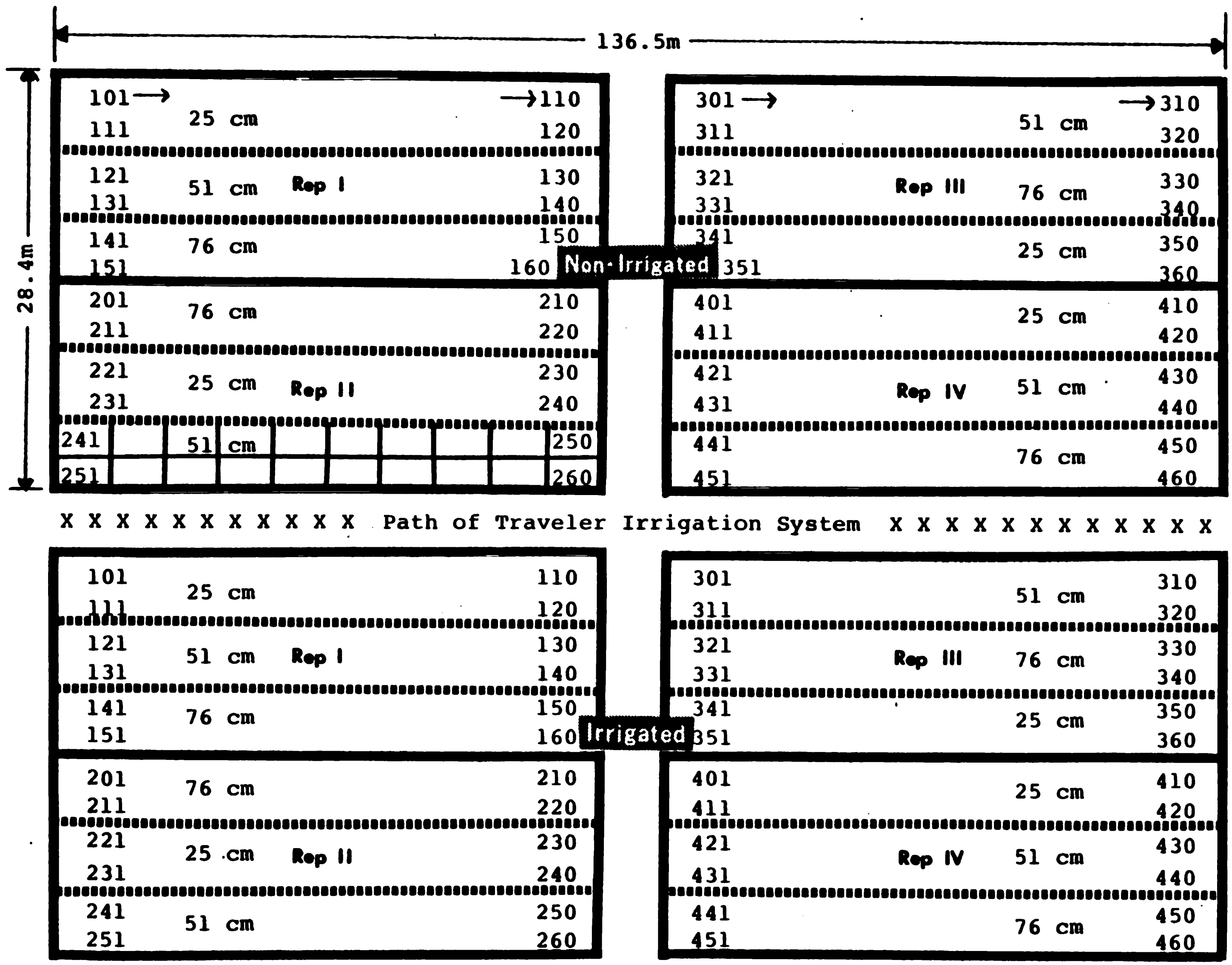


Figure A1. Plot Plan for the Soybean Irrigation Study

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