

MEASURING DEPTH AND DISTRIBUTION OF ROOTS)
FOR PREDICTING SOIL WATER DEPLETION

by

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A MASTER'S THESIS

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requirements for the degree

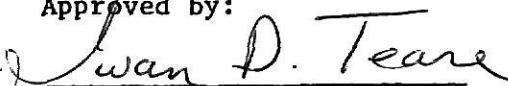
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INTRODUCTION

Research on root development has been relatively scarce due to sampling difficulty. Most of the root research studies have been conducted in the greenhouse, rhizotron, and growth chamber. Investigators have differed in their reports on root depth and distribution and dry matter accumulation in relation to physiological development stages using the same crop plants. The differences arose mainly because of variations in soil, crop, soil moisture status, climatic factors, and cropping practices. In most cases information obtained were inadequate and inconclusive for describing rate of development or rooting potential.

If we can establish a relationship between top growth of crops and their rooting system, we could predict soil water depletion in the profile with some certainty from above ground measurements. Progressive root depth and distribution combined with estimates of evapotranspiration and available soil water are necessary for reliable prediction of irrigation water needs and irrigation scheduling.

Reports on crop root studies indicated that dry matter accumulation and ion uptake were definitely related to soil water content. As roots absorb water, soil water tension is increased and water movement in the soil occurs. The presence of water in the soil is essential for translocation of plant nutrients to the roots. When available soil water is limiting, there is usually a reduction in dry matter accumulations and/or crop yield. Irrigation timing is therefore an important decision process for restoring available soil water for effective crop production, since nutrient ions must move from the soil to the absorption site of the root surface for plant uptake. Rooting volume becomes an important aspect in determining

water intake. In corn root studies, water uptake and root elongation decreased as moisture content per unit tension decreased (Peters, 1957). Grain sorghum was found to accumulate more root dry matter in the upper 32cm of soil than soybeans under supplemental sprinkler irrigation (Teare et al., 1973).

The purpose of this research was to correlate root depth and distribution of soybeans with morphological parameters of the tops at specific physiological stages under irrigated and nonirrigated conditions and to investigate root depth and distribution of soybeans, corn, and grain sorghum in relation to some soil water parameters (available soil water, soil water potential and hydraulic gradients) in the root zone.

Chapter I

RELATIVE GROWTH RATE OF SOYBEAN TOPS AND ROOTS IN RELATION TO SOIL WATER

W.C. Mayaki, I.D. Teare, and L.R. Stone

RELATIVE GROWTH RATE OF SOYBEAN TOPS AND
ROOTS IN RELATION TO SOIL WATER^{1/}

W.C. Mayaki, I.D. Teare, and L.R. Stone^{2/}

ABSTRACT

Relative growth rate of soybean [Glycine max (L.) Merr., cv. 'Williams'] tops and roots were measured in relation to physiological stage under two soil water regimes. Correlating root depth and distribution in a barrier free soil with physiological development of the tops will aid in estimating the timing and amount of irrigation water required. Plant height and tap root depth were measured at the time roots were sampled. Soil samples (centered on the crop row) 75cm wide, 7.5cm thick and 180cm deep (partitioned into 15cm increments) were collected and roots washed free using 35 mesh screen. Dry matter for the tops and roots was obtained by oven drying the plant sample at 100C. Soil water measurements were made using neutron moderation and gravimetric sampling.

Soybean tap roots reached a depth of 160cm in both irrigated and non-irrigated plots. Root length increased at a greater rate than plant height. Above ground dry matter accumulated at a greater rate in the

Additional index words: Available soil water, Leaf area index, Soil water potential.

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irrigated than nonirrigated soybeans. Approximately 89% of root dry matter was concentrated in the upper 0-15 cm of the irrigated soil profile during the early vegetative stage (V0-V3) compared with 85% in the upper 15cm of the nonirrigated profile. At physiological maturity (R10), 67% of the soybeans root dry matter was in the 0-15cm layer, 89% in the 0-90cm layer and 99% in the upper 0-150cm layer, 83% in the 0-90cm layer, and 99% in the 0-150cm increment of the nonirrigated soil profile. In nonirrigated soybeans the root depth/top height ratio was constant at approximately 2:1 throughout the season. The irrigated ratio was 2:1 up to initiation of pod development after which the ratio decreased sharply to approximately 1.4:1. The coefficient of determination (R^2) values for plant height versus root depth were 0.994 and 0.987 for the irrigated and nonirrigated soybeans, respectively. Irrigated and nonirrigated soybean root dry matter versus top dry matter had R^2 values of 0.969 and 0.924, respectively.

INTRODUCTION

Reports of root development have been limited due to sampling difficulty. Most root studies have been conducted in the greenhouse, rhizotron, or growth chamber (Muzik and Whitworth, 1962; Rogers, 1969; Taylor, 1971). Field root research has been conducted primarily on corn and cotton. Foth at Michigan (1962) made 8 observations throughout the corn growing season and found a definite association between root growth stage and top growth stage. Raper and Barber (1970a) compared soybean varieties in field root distribution studies using core and monolith techniques to sample the 0 to 80cm soil depth. Raper (1970) used the dry matter and nutrient accumulations of tops to examine the physiological effectiveness of the rooting system, but the 80cm depth was insufficient to allow evaluation of the root depth potentials.

Investigators have differed somewhat in their findings on root development in the same crop probably because of differences in soil upon which the crop was grown (Mitchell and Russell, 1971; Portas, 1973). Taylor and Gardner (1963) related root penetration of soil to soil strength in their study of cotton and peanut rooting systems. In corn, Foth (1962) reported that root weight declined after the initiation of seed development. Borst and Thatcher (1931) observed a similar phenomena in soybean roots. However, Mitchell and Russell (1971) reported that root weight in soybeans increased until the vegetative portion of the tops ceased increasing in dry matter then root dry matter decreased. Borst and Thatcher (1931) reported that under favorable soil conditions the soybean tap root attained a depth of 152cm, while Raper and Barber (1970a) observed that lateral roots of soybeans sometimes attained a greater depth than the tap root.

This research was directed at correlating root depth and distribution in the field with morphological parameters (plant height, leaf area index, top dry matter) of the soybean tops at specific physiological stages. If meaningful relationships between root depth in a barrier free soil and specific morphological parameters could be determined, rooting depth could be estimated from above-ground observations enabling more accurate prediction of irrigation requirements.

MATERIALS AND METHODS

The study area was on the Ashland Agronomy Research Farm 14km south of Manhattan, Kansas. The soil is a Muir silt loam developed from alluvium. The texture is silt loam to the 14cm depth; silty clay loam from 14cm through 50cm; silty clay from 50cm through 81cm; and silt loam below 81cm. The soil profile has slight plowpan features in the 14cm to 22cm layer and clay accumulation in the 50cm to 81cm layer, but is relatively free from root-restricting features.

Soybeans [Glycine max (L.) Merr., cv. 'Williams'] were planted on May 13 in rows 75cm apart and 12.2m long. The soybeans were thinned to a final population of 26 plants per meter. Soybean development was described according to the physiological stage as described by Hanway and Thompson (1971). There were slight differences in time of physiological stage between irrigated and nonirrigated soybeans until after stage R10. The nonirrigated soybeans reached harvest maturity (R11) 3 to 4 days before the irrigated soybeans.

Four plots 12 rows wide and 12.2m long were used; two irrigated and two nonirrigated. The irrigated plots received a total of 28cm water distributed near stages R4, R5.5, and R7. Water was applied by furrow

using metered 15cm diameter aluminum gated pipe. Soil water was determined in the 15 to 150cm soil profile at 15cm intervals using neutron moderation and in the top 15cm layer by gravimetric sampling. One access tube was placed in the center of each of the four plots. Soil water desorption curves were used in estimating mean soil water potential in the root zone. Available soil water in the root zone was estimated using -15 bars soil water potential as the lower limit of availability.

Plant samples were obtained for dry weight, leaf area, node count, and plant height measurements at the time of root sampling. The leaf area was measured using a leaf area meter.^{3/} Soil volumes (centered on the crop row) 75cm wide, 7.5cm thick, and 180cm deep (partitioned into 15cm increments), were collected and roots washed free using 35 mesh screen. Two complete samples were taken in each of the four plots; yielding four samples for the irrigated and four samples for the nonirrigated treatments. The roots were sampled twice a week at stages V0-R5, once a week at R5.5-R9 and an 18 day interval between R9 and R10. Root dry weight was determined by oven drying at 100C.

Seed yield and lodging data (1 represents all plants standing erect and 5 represents no plants standing erect) were obtained from 3m strips of the two center rows in each plot.

RESULTS AND DISCUSSION

Available soil water (ASW) in the soybean root zone, mean soil water potential (ψ_s) in the root zone, and water received (irrigation and rainfall)

^{3/} Automatic Area Meter, Model AAM-5 by Hayashi Denko Co., Ltd., Tokyo, Japan.

are plotted against physiological and chronological age in Fig. 1. Available soil water increased during the season because of increasing root zone depth. The seasonal water use (neglecting flux into or out of the root zone) was 60.7cm in the irrigated soybeans and 37.9cm in the nonirrigated. Hydraulic gradient data taken using mercury manometer tensiometers showed an upward gradient in both irrigated and nonirrigated soybeans after approximately July 1, indicating actual evapotranspiration was greater than profile water use values would indicate.

DESCRIPTION OF ROOTING SYSTEM

In view of the qualitative analysis of soybean root lateral distribution by Raper and Barber (1970a), we employed a quantitative analysis of the root biomass with depth. Plant height of the soybeans grown under irrigation increased at a greater rate than under nonirrigated conditions (Fig. 2). The rooting depth of soybeans increased rapidly after stage V3 (Fig. 2) and continued until approximately mid-July when the rate of root extension decreased slightly. Root depth difference between irrigated and nonirrigated soybeans was appreciable from mid-July through mid-August, reaching a maximum of approximately 12cm with the irrigated roots being deeper. The 160cm depth was reached in both treatments at R9.3 (27 Aug.). The nonirrigated soybeans likely benefited from the mid-August rainfall causing increased root growth.

About 89% of the root dry matter (DM) was concentrated in the upper 0-15cm at the late vegetative growth stage (V3) in the irrigated soybeans compared with 85% in the nonirrigated (Fig. 3). At physiological maturity (R10) 67% of the root DM was in the upper 0-15cm, 89% in the 0-90cm and 99% in the 0-150cm increment for the irrigated soybeans compared with 51%

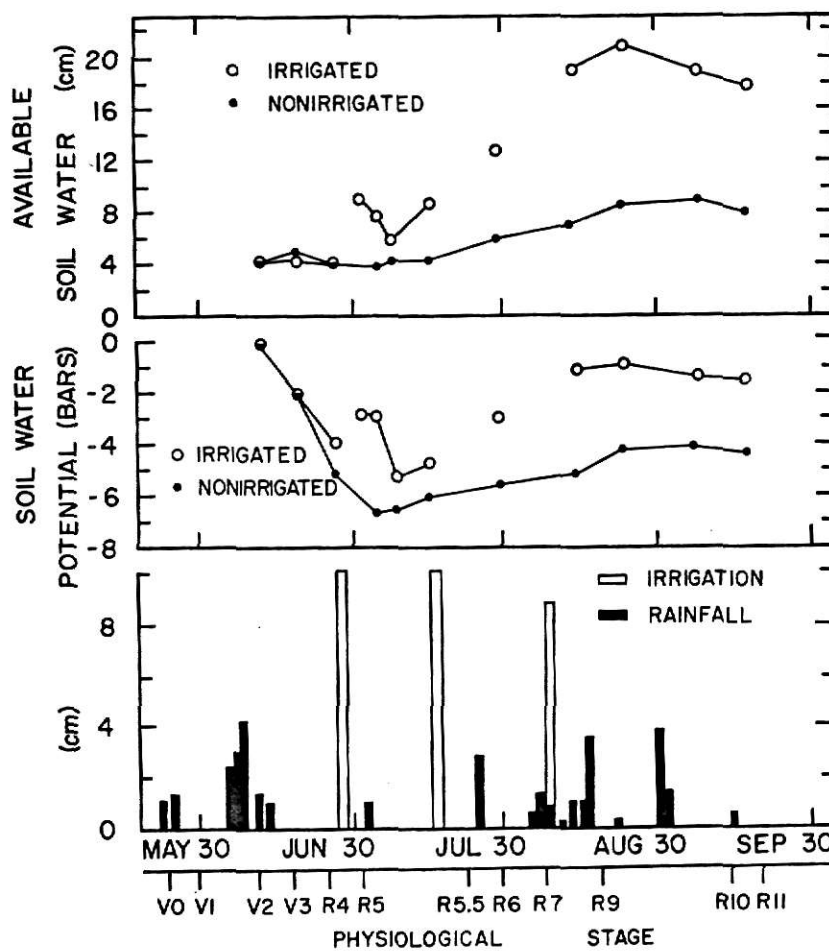


Figure 1. Root zone available soil water, mean soil water potential, and water received versus physiological and chronological age.

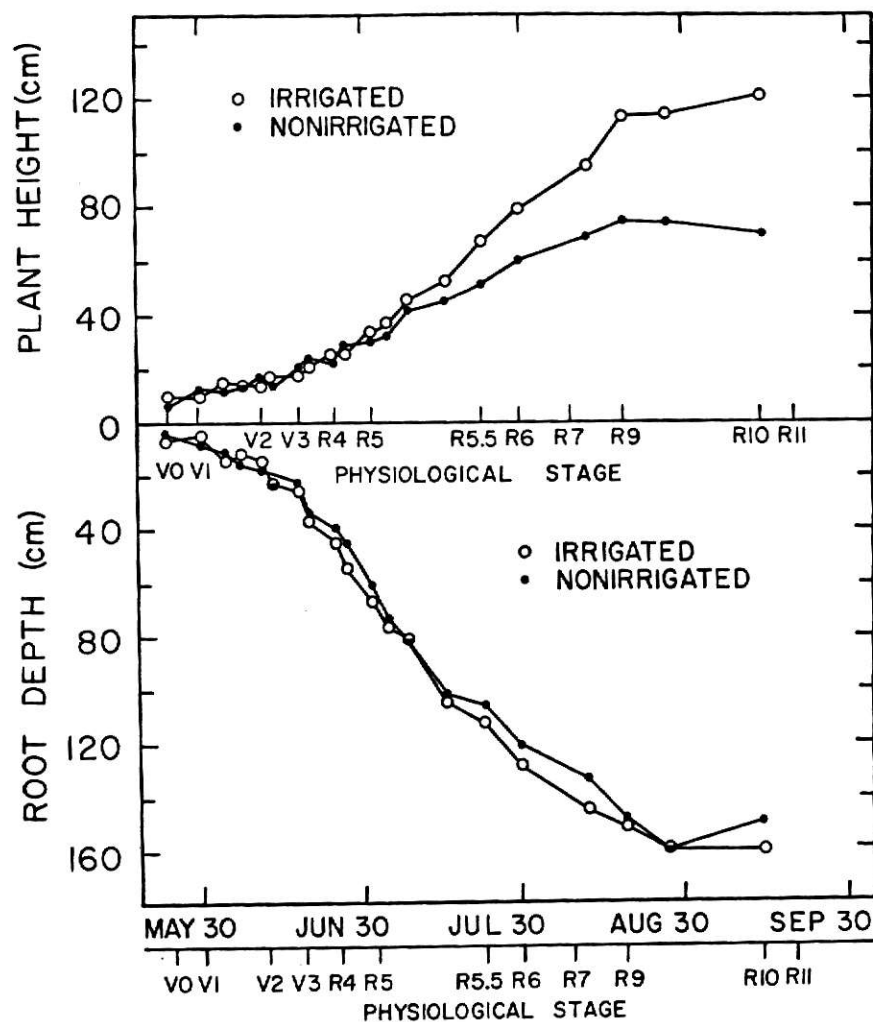


Figure 2. Soybean plant height and root depth in relation to physiological stage of development under irrigated and nonirrigated conditions.

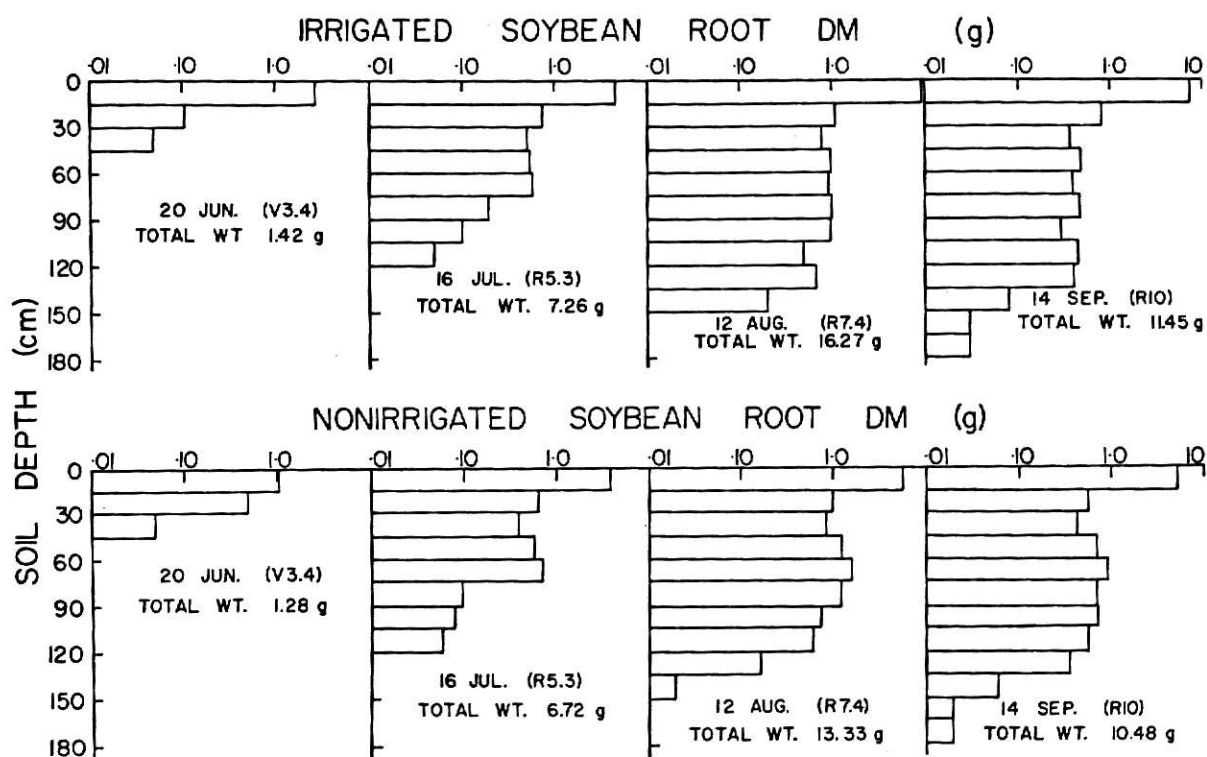


Figure 3. Soybean root dry matter at 15cm depth increments at 4 selected physiological stages of development.

of the root DM in the upper 0-15cm, 83% in the 0-90, and 99% in the 0-150cm increment for the nonirrigated soybeans. The root dry matter in the 45-90cm layer for the nonirrigated soybeans exceeded that for the irrigated between R4 and R9 (23 July-27 Aug.). This was a reflection of the dry period between June 15 and July 23, when the nonirrigated roots accumulated greater DM in the 45-90cm depths. After R7 the root DM below the 90cm of nonirrigated soybeans also was greater than that of the irrigated soybeans. The total root DM was similar in the nonirrigated and irrigated plots during the early and late stages of plant growth (Fig. 4). During July and most of August the irrigated roots DM exceeded nonirrigated root DM.

DESCRIPTION OF THE TOP GROWTH

The early stages (V0-V3) were characterized by slow length (Fig. 2) and dry matter (Fig. 4) increase of both roots and tops. The early top growth rates were approximately 0.64cm/day for the irrigated and .57cm/day for the nonirrigated. The average growth rate for the irrigated tops between R4 and R5.5 was about 1.38cm/day and 0.96cm/day for the nonirrigated tops. Seasonal average growth rate (V0-R10) was 1.01cm/day for the irrigated tops compared with 0.73cm/day for the nonirrigated tops.

Total DM accumulation of tops was partitioned into leaves, stems and pods (Fig. 5). Leaf DM for the irrigated tops peaked August 19 (R9). At that time leaves were 25.7% of the top DM; stems, 51.1%; and pods 23.2%. In the nonirrigated tops leaf DM peaked August 27 (R9.3), and the leaves were 23.2% of the top DM; stems, 28.5%; and pods, 38.3%. The pod and bean DM was about equal to that of stem and leaves combined at R10 for the irrigated tops while in the nonirrigated plots pod and bean DM was 1.5 times DM for the stems and leaves combined. The total dry matter

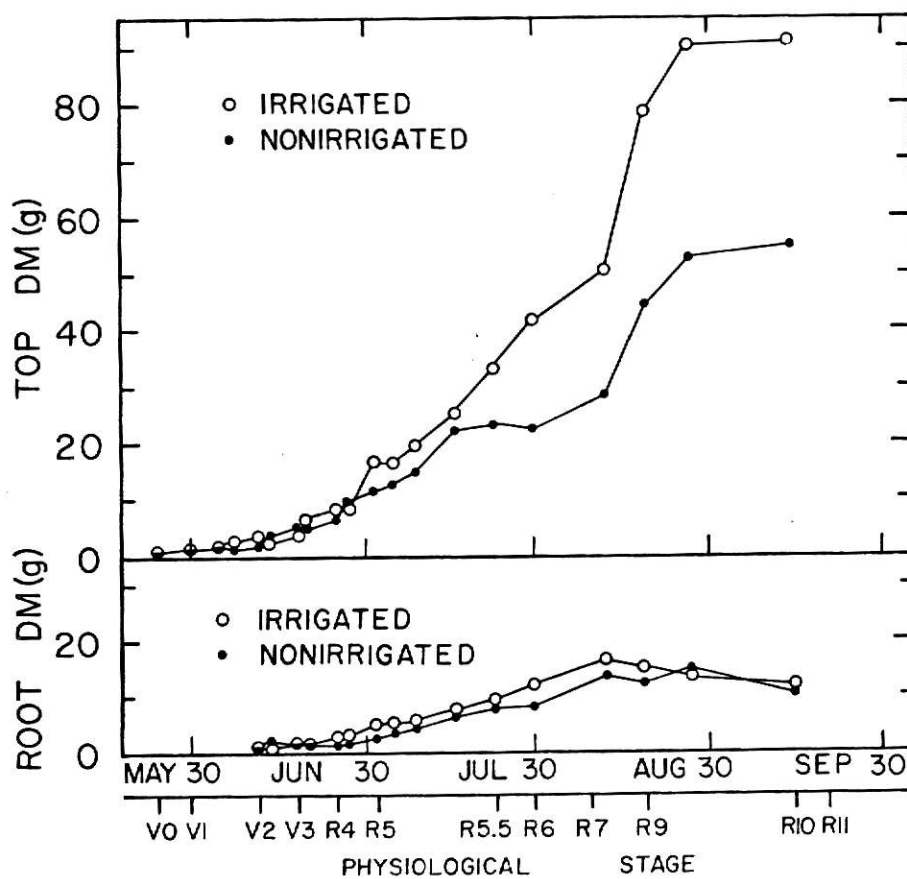


Figure 4. Total dry matter accumulation in the tops and roots of soybeans in relation to physiological stages of development, and under irrigated and nonirrigated conditions.

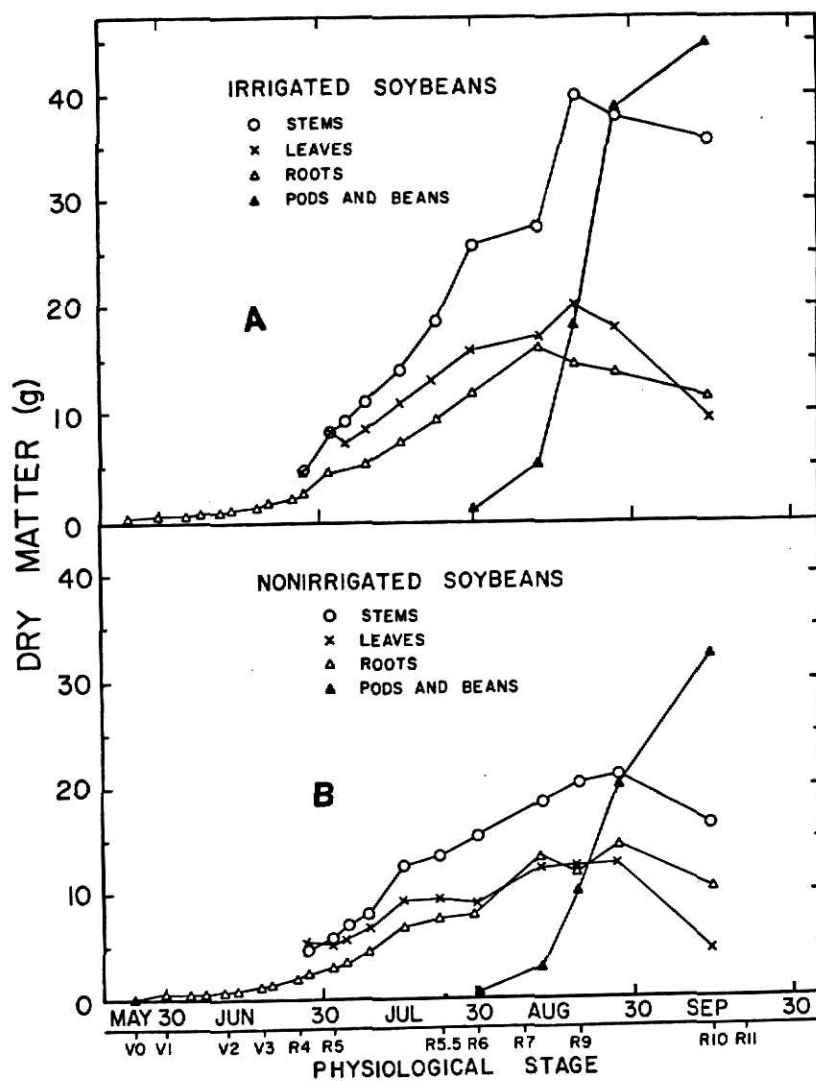


Figure 5. Seasonal changes in the dry matter accumulation of the soybean plant components under: (A) Irrigated condition and (B) Nonirrigated condition.

accumulation for the irrigated plots was 1.67 times that for the nonirrigated plots.

Leaf area index (LAI) (Fig. 6) increased gradually until V2 then increased rapidly to a peak at R7.4 for the nonirrigated and R9 for the irrigated soybeans. The LAI peak for the irrigated plots lagged behind the nonirrigated by about 7 days. Irrigated soybeans attained a maximum LAI of 7.7 compared to 4.8 for the nonirrigated. After R9.3 the LAI decreased rapidly in both treatments due to leaf senescence, but the top DM continued to increase because of dry matter accumulation in the pods and beans. Canopy closure did not occur in the nonirrigated plots, and physiological maturity was reached 3-4 days earlier than in the irrigated plots.

Pod development started at the same time in both treatments, but grew faster in the irrigated plots. Lodging factors were 1.8 in the irrigated compared to 1.0 in the nonirrigated soybeans, suggesting increased DM accumulation and height combined to cause lodging of soybeans with essentially the same sized root system. The average bean yields were 2661kg/ha and 2396kg/ha for irrigated and nonirrigated soybeans, respectively. The yield difference was significant at the 15% level. The weights and standard deviations of 100 seeds per treatment were $17.45g \pm 0.65$, and $18.35g \pm 0.25$ for irrigated and nonirrigated soybeans, respectively. This showed higher yields from the irrigated soybeans came from a greater number of seeds. Pod counts at maturity (R10) showed 45 pods/plant in the irrigated plots and 35 pods/plant in the nonirrigated plots.

RELATIONSHIP OF THE ROOTING SYSTEM WITH THE TOP GROWTH

In the study of drought resistance (30 day period after emergence), of soybeans Read and Bartlett (1972) reported that root relative growth rate

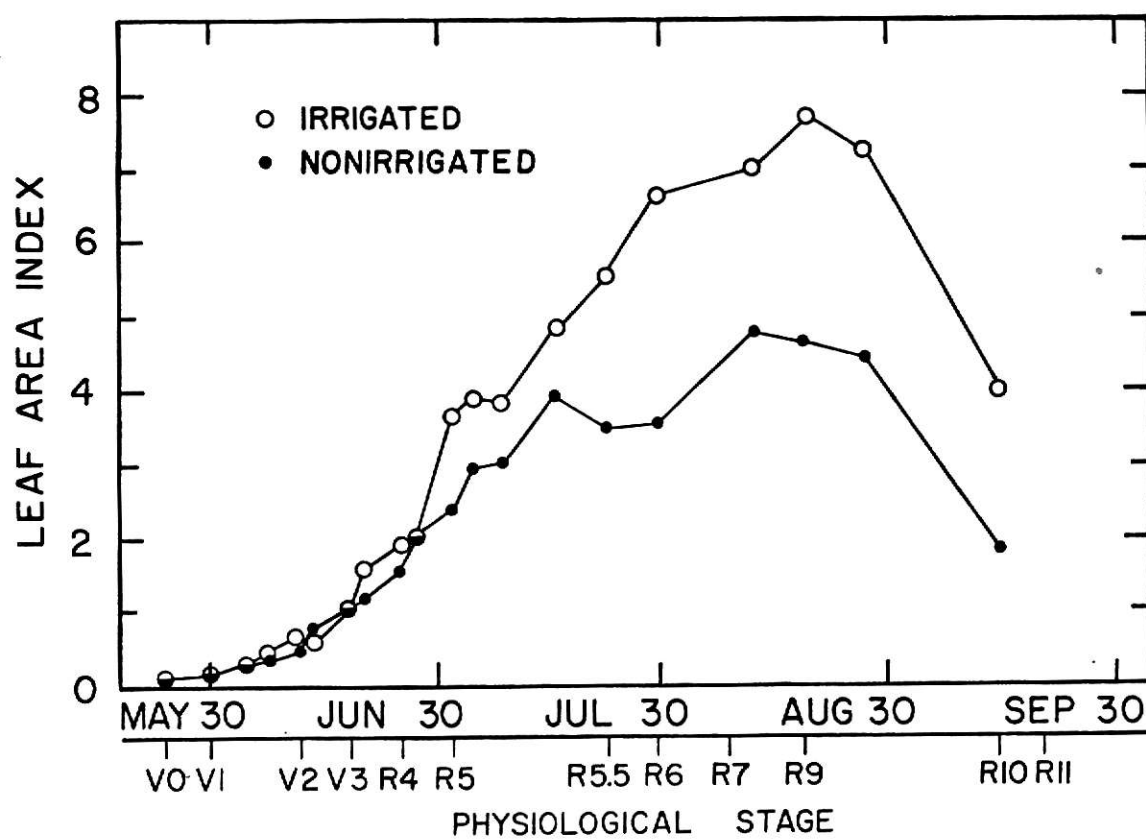


Figure 6. Leaf area index of soybean leaves in relation to physiological stage of development under irrigated and nonirrigated conditions.

(RGR, on a DM basis) increased with decreasing ψ_s , and that shoot RGR (also on a DM basis) decreased with decreasing ψ_s . We found a similar relationship between RGR and ψ_s in our soybean root study. Root RGR at R5.1-R9.3 (5 Jul.-27 Aug.) was inversely related to ψ_s while top RGR was directly related to ψ_s . Root DM accumulated at the rate of $3.5\text{g/g/day} \times 10^{-2}$ in the irrigated soybeans compared to $6.3\text{g/g/day} \times 10^{-2}$ in nonirrigated. The tops increased at the rate of $8.5\text{g/g/day} \times 10^{-2}$ in irrigated compared to $5.9\text{g/g/day} \times 10^{-2}$ in nonirrigated soybeans. Nakayama and van Bavel (1963) expressed root RGR in inches per day in their study of P^{32} uptake by irrigated sorghum. They reported RGR of 2 to 5cm/day for 3 month old sorghum. In both studies (Read and Bartlett, 1972; Nakayama and van Bavel, 1963), the RGR expressed was not specified for a particular physiological stage. At R5.1-R9.3 (7 May-27 Aug.), we observed vertical taproot RGR of 1.56 and 1.63cm/day in irrigated and nonirrigated soybeans, respectively. The corresponding top RGR was 1.45 and .77cm/day.

Regression analysis between root depth and plant height (Fig. 7) showed a better fit with quadratic regression for irrigated soybeans while linear regression best described the nonirrigated soybeans. The root depth/top height ratio was constant at approximately 2:1 throughout the season in nonirrigated soybeans. The ratio was 2:1 for much of the season in irrigated soybeans but decreased sharply in late season. Determination coefficients between root depth and plant height were 0.994 and 0.987 with standard error of 4.863 and 6.409 for irrigated and nonirrigated soybeans, respectively. The high determination coefficient between soybeans plant height and root depth suggested the possibility of predicting root depth; useful in estimating irrigation requirements for soybeans. However, it should be emphasized that plant growth characteristics may change with soil

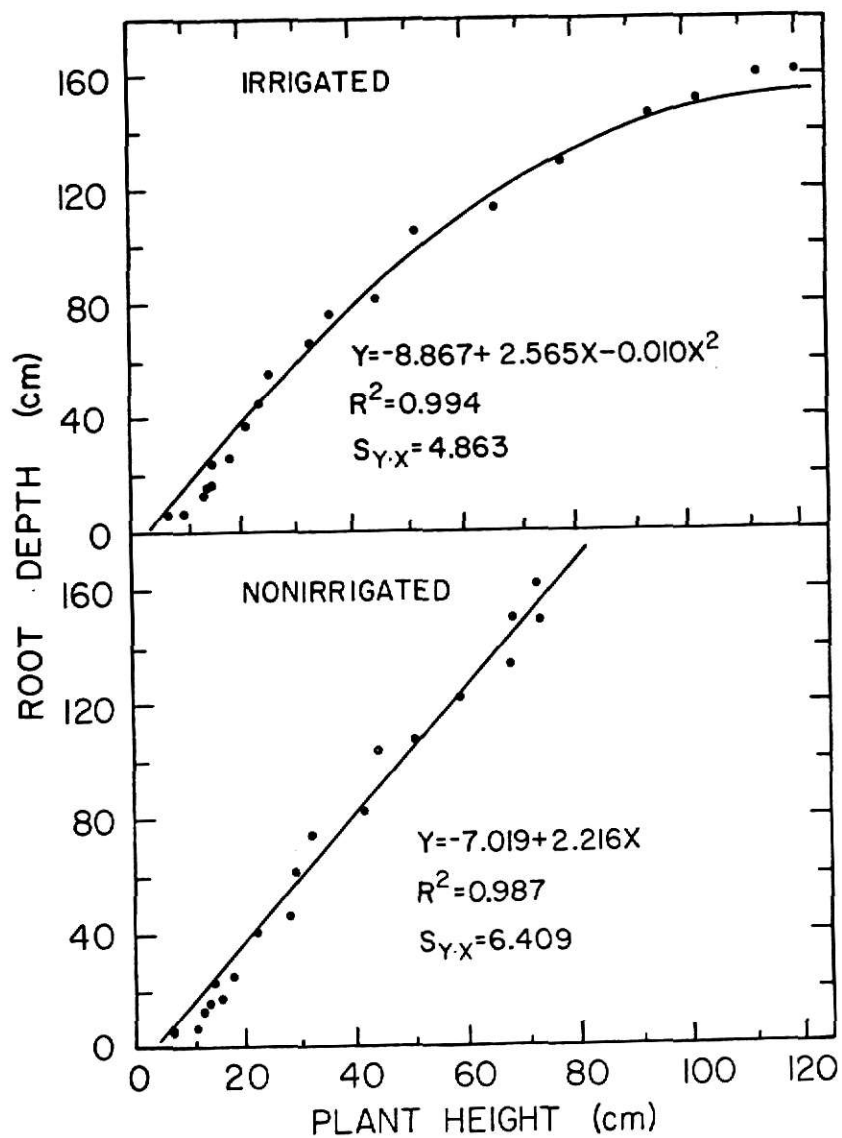


Figure 7. Correlations between soybean root depth and plant height under irrigated and nonirrigated conditions. A curvilinear relationship existed between root depth and plant height of the irrigated soybeans, and a linear relationship existed between root depth and plant height of the nonirrigated soybeans.

types, nutrient status of the soil, plant species, climatic factors, and cropping practices.

Regression analysis between root and top DM for both treatments (Fig. 8) showed a better fit with quadratic regression. Determination coefficients between root and top DM were .969 and .924 with standard errors of 1.019 and 1.403 for the irrigated and nonirrigated soybeans, respectively.

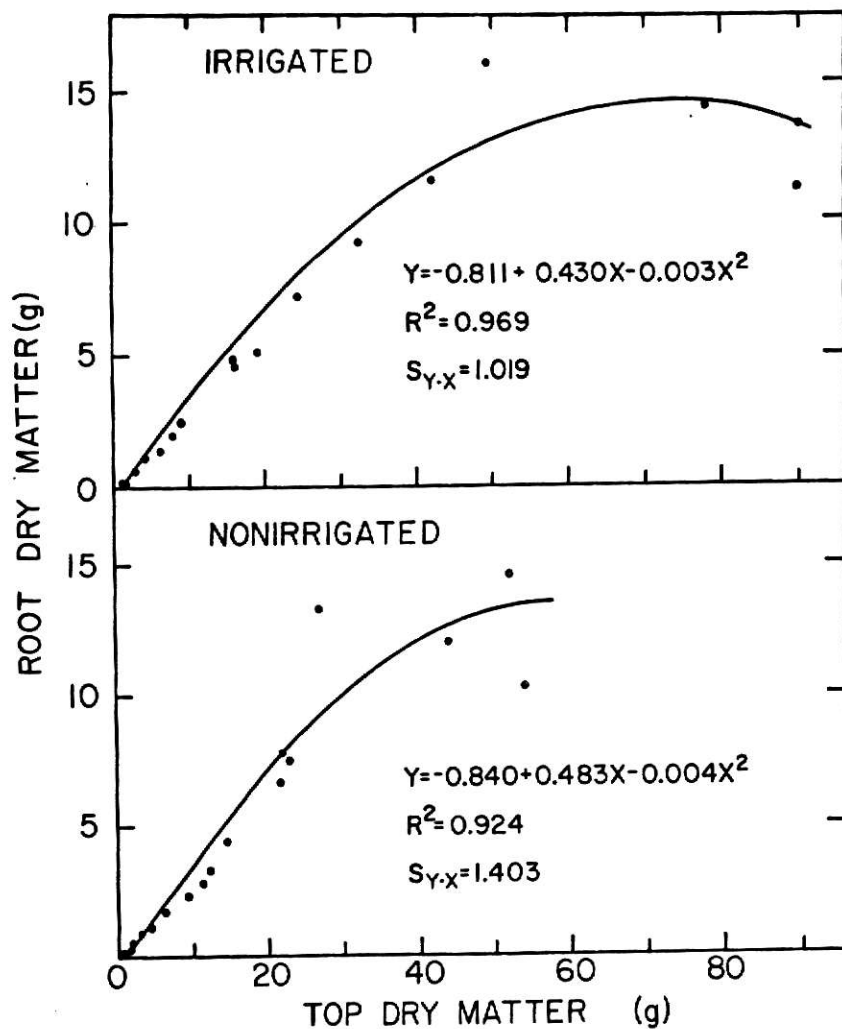


Figure 8. Correlations between root dry matter and top dry matter under irrigated and nonirrigated conditions. Curvilinear relationships existed between root dry matter and top dry matter in both regimes.

LITERATURE CITED

- Borst, H.L., and L.E. Thatcher. 1931. Life history and compositions of the soybean plant. Ohio Agr. Exp. Sta. Res. Bull. 494, 96p.
- Foth, H.D. 1962. Root and top growth of corn. Agron. J. 54:49-52.
- Gingrich, J.R., and M.B. Russell. 1957. A comparison of effects of soil moisture tension and osmotic stress on root growth. Soil Sci. 84: 185-194.
- Hanway, J.J., and H.E. Thompson. 1971. How a soybean plant develops. SR53 (Rev.), Iowa State University, pp. 1-17.
- Mitchell, R.L., and W.J. Russell. 1971. Root development and rooting patterns of soybean [*Glycine max* (L.) Merrill] evaluated under field conditions. Agron. J. 63:313-316.
- Muzik, T.J., and J.W. Whitworth. 1952. A technique for the periodic observation of root systems in situ. Agron. J. 54:56.
- Portas, C.A.M. 1973. Development of root systems during the growth of some vegetable crops. Plant and Soil 39:507-518.
- Raper, C.D., Jr. 1970. Significance of root characteristics in nutrient uptake and growth of soybeans. Ph.D. Thesis. Purdue Univ., Lafayette, Ind. University Microfilms, Ann Arbor, Michigan, p. 49.
- Raper, C.D., Jr., and S.A. Barber. 1970a. Rooting systems of soybeans. I. Difference in root morphology among varieties. Agron. J. 62: 581-584.
- Raper, C.D., Jr., and S.A. Barber. 1970b. Rooting systems of soybeans. II. Physiological effectiveness as nutrient absorption surfaces. Agron. J. 62:585-588.

- Read, D.J., and E.M. Bartlett. 1972. The physiology of drought resistance in the soybean plant (*Glycine max*). *J. Appl. Ecology* 9:487-498.
- Rogers, W.S. 1969. The East Malling root-observation laboratories, pp. 361-376. In W.J. Whittington (ed.), *Root Growth*. Butterworth and Co., Ltd., London.
- Taylor, H.M. 1971. Observing polar root growth. In *Biological Effects in the Hydrology Cycle*. Proceedings of the Third International Seminar for Hydrology Professors. Purdue University, West Lafayette, Indiana. July 18-30, 1971, pp. 163-172.
- Taylor, H.M., and H.R. Gardner. 1963. Penetration of cotton seedling taproots as influenced by bulk density, moisture content and strength of soil. *Soil Sci.* 96:153-156.

Chapter II

ROOT GROWTH OF SOYBEANS, CORN AND GRAIN SORGHUM IN RELATION TO IRRIGATION PRACTICES

W.C. Mayaki, L.R. Stone, and I.D. Teare

ROOT GROWTH OF SOYBEANS, CORN, AND GRAIN SORGHUM
IN RELATION TO IRRIGATION PRACTICES^{1/}

W.C. Mayaki, L.R. Stone, and I.D. Teare^{2/}

ABSTRACT

Root depth and distribution were investigated under irrigated and nonirrigated conditions for soybeans [Glycine max (L.) Merr., cv. 'Williams'], corn [Zea mays (L.), cv. 'Prairie Valley 825'] and grain sorghum [Sorghum bicolor (L.) Moench, cv. 'Pioneer 846']. The irrigated plots received a total of 30cm of water in 3 applications using furrow irrigation. Soil cores 6.7cm in diameter were taken in the crop row, 1/4 row, and 1/2 row for each crop at maturity. All crops of the treatments studied had roots in the 150-180cm zone except irrigated corn. Total root weight measured was 2.66g, 1.91g, and 4.19g in irrigated; 2.64g, 1.42g, and 2.86g in nonirrigated soybeans, corn, and grain sorghum, respectively. In irrigated crops, approximately 71%, 64% and 86% of the root dry matter was in the upper 30cm for soybeans, corn, and grain sorghum, respectively. In the nonirrigated crops, approximately 67%, 70% and 79% of the root dry matter was in the upper 30cm for soybeans, corn, and grain sorghum,

Additional index words: Hydraulic gradient, Soil water content, Soil water potential, Available soil water.

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respectively. Seasonal water use under irrigated conditions (neglecting flux into or out of the root zone) was 60.7cm, 62.9cm, and 49.6cm in soybeans, corn and grain sorghum, respectively. Seasonal water use was approximately 38cm for all three crops under nonirrigated conditions. Hydraulic gradients in the 130-150cm layer were between 0 and -1 during the season for all irrigated conditions. Hydraulic gradients decreased to -18 during August in nonirrigated soybeans. In nonirrigated corn hydraulic gradients decreased to -2 and remained there until late in the season.

INTRODUCTION

Soil water depletion and irrigation water application are necessarily tied to root depth and distribution. A knowledge of progressive root distribution is therefore useful in more efficient use of irrigation water. Combining the estimates of evapotranspiration and available soil water with root growth patterns gives a better estimate of water requirement (Jensen et al., 1969).

Root penetration is influenced by factors affecting root growth pressure, root anchorage and soil strength (Taylor and Gardner, 1963). As plant roots absorb soil water, water tension in the soil increases in the immediate proximity of the roots (Gingrich and Russell, 1957). In corn root studies, water uptake and root elongation decreased as moisture content per unit tension decreased (Peters, 1957).

Under supplemental sprinkler irrigation Teare et al. (1973) found about 51% of sorghum roots in the upper 0-32cm depth and about 45% of soybean roots in the upper 0-32cm depth at the end of the season. Kafkafi et al. (1965) reported that P^{32} absorption by dryland sorghum was related to its water consumption. Raper and Barber (1970b) showed that ion uptake in soybeans was related to root size. Studies on corn root development indicate that both root dry matter (DM) and ion uptake were linearly correlated with soil moisture content (Mederski and Wilson, 1960). Reikosky et al. (1972) showed that the increase in daily water use by the soybeans was reflected by the increased water uptake per unit root length and increase in the length of roots.

The purpose of this study was to evaluate root depth and distribution of irrigated and nonirrigated soybeans, corn, and grain sorghum.

MATERIALS AND METHODS

Root systems were studied for irrigated and nonirrigated conditions on the Ashland Agronomy Farm 14km south of Manhattan, Kansas. The soil is Muir silt loam which developed from alluvium. Crops studied were soybeans [Glycine max (L.) Merr., cv. 'Williams'], corn [Zea mays (L.), cv. 'Prairie Valley 825'], and grain sorghum [Sorghum bicolor (L.) Moench, cv. 'Pioneer 846']. The two water treatments were replicated three times for each of the three crops. Each plot consisted of ten rows spaced 75cm apart and 12.2m long. Soybeans and corn were planted on May 13, and grain sorghum on May 21. Final plant populations were 357,000, 63,000, and 218,000 plants per hectare for soybeans, corn, and grain sorghum, respectively.

Physiological stages were recorded as described by Hanway and Thompson (1971), Hanway (1966), and Vanderlip (1972) for soybeans, corn, and grain sorghum, respectively. A total of 30cm water were applied in three irrigations to each crop at specific physiological stages. Soybeans were irrigated at R4, R5.5 and R7; corn at 14 leaf stage, silk emergence, and blister stage; and grain sorghum at boot stage, half-bloom, and soft dough stage. Water was applied using furrows and gated pipe.

Soil cores 6.7cm in diameter were taken late in the season (Sept. 9-12) in the crop row, 1/4 row, and 1/2 row to 180cm soil depth. The 0 to 180cm depth was sectioned into 30cm increments. The cores were then washed through 35 mesh screen (.71mm opening), and the roots oven dried at 100C. Plant samples were taken for leaf area measurements^{3/} at various times in the season. Soil water content was determined using neutron

^{3/} Automatic Area Meter, Model AAM-5 by Hayashi Denko Co., Ltd., Tokyo, Japan.

moderation and gravimetric sampling. Soil water potential was estimated using soil water desorption curves. Mercury-manometer tensiometers were installed at 130 and 150cm and used to calculate the hydraulic gradient. One tensiometer battery was placed in each plot.

Seed yield and soybean lodging data (1 represents all plants standing erect and 5 represents no plants standing erect) were obtained from the two center rows of each plot.

RESULTS AND DISCUSSION

Description of Rooting Systems:

Root dry matter (DM) at physiological maturity is presented in Fig. 1 for soybeans, corn, and grain sorghum. The values are the total root weight in the 30cm increments for in row, 1/4 row, and 1/2 row soil cores, averaged for the three replicates. The in-row, 1/4 row, and 1/2 row values are listed in Table 1.

Total root DM of soybeans for irrigated and nonirrigated plots (physiological stage R10) (Fig. 1) was about the same; however, the distribution in relation to depth showed that approximately 71% of the irrigated roots DM was concentrated in the upper 30cm, 91% in the 0-90cm, and 99.6% in the 0-150cm increments. In nonirrigated soybeans, 67% of the root DM was found in the upper 30cm, 83% in the 0-90cm and 97% in the 0-150cm increments. Roots were deeper in the nonirrigated plots and there was a higher root DM accumulation between 30-180cm for the nonirrigated plots than for the irrigated indicating that water uptake from the lower depths was more significant in the nonirrigated soybeans. Observations indicated that the nonirrigated soybean lateral roots (roots originating from the main axis) were more proliferated (greater number of small roots)

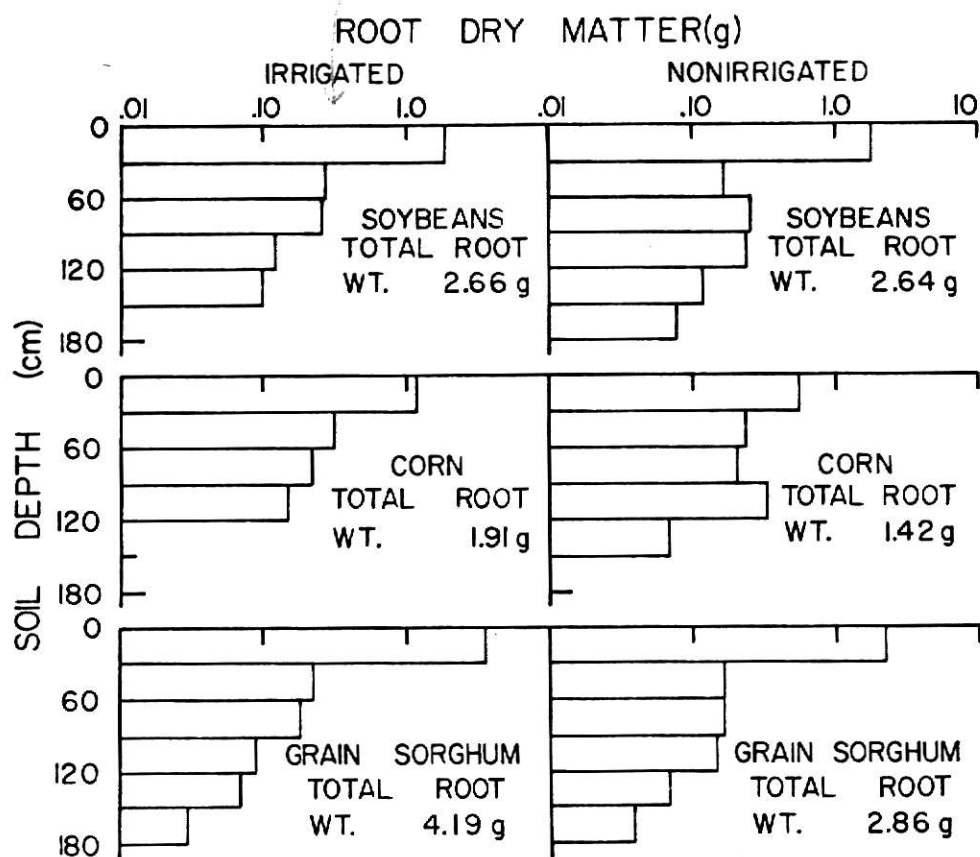


Figure 1. Root dry matter at 30cm depth increments at physiological maturity for soybeans, corn, grain sorghum under irrigated and nonirrigated conditions.

Table 1. Average root dry matter g/1.06dm³ of soil for soybeans, corn and grain sorghum under irrigated and nonirrigated conditions.

Irrigated					Nonirrigated				
Soil depth (cm)	R	1/4R	1/2R	Total	Soil depth (cm)	R	1/4R	1/2R	Total
Soybeans									
0-30	1.64	.21	.05	1.90	0-30	1.45	.18	.14	1.77
30-60	.12	.11	.04	.27	30-60	.07	.03	.07	.17
60-90	.15	.08	.03	.26	60-90	.14	.09	.03	.26
90-120	.07	.03	.02	.12	90-120	.07	.09	.07	.24
120-150	.06	.03	.01	.10	120-150	.08	.03	.02	.12
150-180	.00	.01	.00	.01	150-180	.07	.01	.00	.08
Total	2.04	.47	.15	2.66	Total	1.88	.43	.33	2.64
Corn									
0-30	1.07	.08	.07	1.22	0-30	.36	.14	.05	.55
30-60	.15	.05	.10	.30	30-60	.06	.09	.09	.24
60-90	.08	.06	.08	.22	60-90	.08	.06	.07	.21
90-120	.05	.05	.05	.15	90-120	.09	.13	.12	.34
120-150	.01	.00	.00	.01	120-150	.03	.02	.02	.07
150-180	.00	.00	.00	.00	150-180	.00	.01	.00	.01
Total	1.36	.24	.30	1.91	Total	.62	.44	.35	1.42
Grain sorghum									
0-30	3.38	.14	.08	3.60	0-30	2.03	.09	.14	2.26
30-60	.06	.08	.08	.22	30-60	.04	.07	.06	.17
60-90	.04	.06	.08	.18	60-90	.06	.06	.05	.17
90-120	.01	.03	.05	.09	90-120	.07	.06	.02	.15
120-150	.03	.02	.02	.07	120-150	.03	.02	.02	.07
150-180	.01	.02	.00	.03	150-180	.01	.02	.01	.04
Total	3.53	.35	.31	4.19	Total	2.24	.32	.30	2.86

which was reflected by a higher root weight in 1/2 row samples in the nonirrigated plots compared to the irrigated. Root weight in row for the irrigated plots exceeded that for the nonirrigated. No roots were measured in the 1/2 row between the 150-180cm increment for either treatment, nor in the same depth increment in row for the irrigated plots.

Soil cores were taken in corn at stage 10 (physiological maturity, 9 Sept.). The total root dry matter accumulation during the season in the upper 150cm was 1.91g for the irrigated corn compared to 1.42g for the nonirrigated. The root DM distribution (Fig. 1) shows that in irrigated corn about 64% of the root DM was in the upper 30cm, 92% in the 0-90cm increment and 99.6% in the 0-150cm increment. In the nonirrigated corn 39% of the total root DM was in the upper 30cm, 70% in the 0-90cm increment, and 99% in the 0-150cm increment. There was a higher root weight in the 90-150cm in the nonirrigated corn than in the irrigated. Field observation showed a greater root proliferation in the nonirrigated than in the irrigated treatment. In-row root weight was greater for irrigated plots than for nonirrigated. Root weights in the 1/4 row and 1/2 row were greater in the nonirrigated than irrigated plots (Table 1). No roots were measured for irrigated corn in the 150-180cm depth, and only .01g measured for the nonirrigated corn.

Soil cores were taken in grain sorghum at stage 9 (physiological maturity) 105 days after emergence. In both the irrigated and the non-irrigated treatments root DM was found in the 150-180cm depth. The total root DM measured was 4.19g and 2.86g for the irrigated and nonirrigated sorghum, respectively (Fig. 1). In the irrigated grain sorghum, approximately 86% of the total root weight was concentrated in the upper 30cm, 95% in the 0-90cm and 99% in the 0-150cm increment. In the nonirrigated

plots about 79% was found in the upper 30cm, 91% in the 0-90cm and 99% in the 0-150cm increment. The total root DM in row was 3.53g for the irrigated compared with 2.24g for the nonirrigated plots, but was about the same in 1/4 row and 1/2 row for the two treatments. No roots were found in 1/2 row in the 150-180cm depth increment for the irrigated plots.

Comparison Between Crops:

Root depth and distribution were studied and results compared between soybeans, corn, and grain sorghum. Only grain sorghum roots reached the 150-180cm zone in both irrigated and nonirrigated plots. The nonirrigated soybean roots extended into the 150-180cm zone compared to the 120-150cm zone in the irrigated, and nonirrigated corn roots extended more into the 120-150cm zone than the irrigated corn roots. Grain sorghum accumulated higher root DM in both irrigated and nonirrigated than either corn or soybeans. The total root weight for grain sorghum was about 2 times that for corn in the corresponding treatment (Table 1). However, irrigated grain sorghum had the greatest proportion of its root DM in the 0-30cm increment. Total root DM in the nonirrigated grain sorghum and irrigated and nonirrigated soybeans was about the same.

Available soil water (ASW) in the 0-150cm soil profile, mean soil water potentials (ψ_s) in the profile, and water received are shown versus date in Fig. 2. Data points after irrigation are not connected for ASW and ψ_s , because no observations were made immediately following irrigation. During the period June 15 through July 23 the only measurable rainfall was 1.0cm on July 3. About 40 days in June and July the air temperature exceeded 32C, and reached a maximum of 41C on July 21. During those 40 days, afternoon relative humidity ranged between 20 and 40%. This period

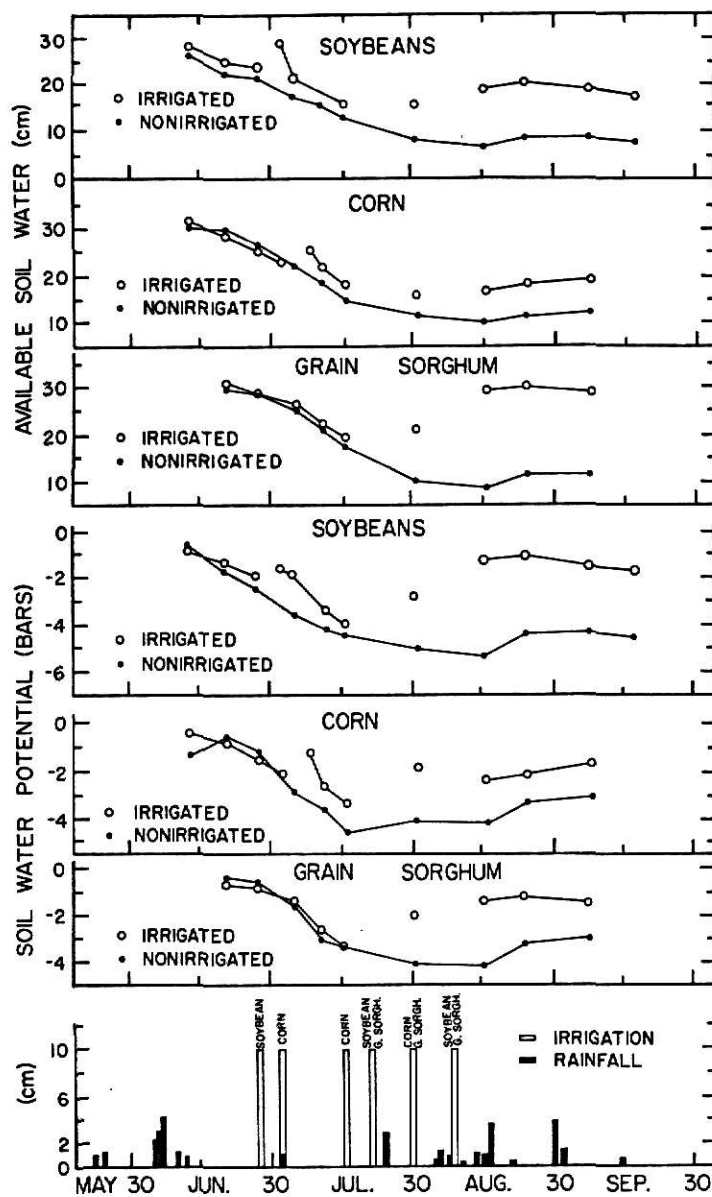


Figure 2. Available soil water (ASW), mean soil water potential (ψ_s), and water received (rainfall and irrigation) during the season.

coincided with physiological stages V3-R5.5 in soybeans, and stages 2-5 for corn and grain sorghum. The total water used by irrigated crops during the season (disregarding soil water flux into or out of the root zone) was 60.7cm, 62.9cm, and 49.6cm by soybeans, corn, and grain sorghum, respectively. In the nonirrigated crops water use during the season was 37.9cm, 37.8cm, and 37.3cm by soybeans, corn, and grain sorghum, respectively.

Teare et al. (1973) found seasonal evapotranspiration of about 6cm greater in soybeans than in grain sorghum, and that grain sorghum was about 3 times as efficient in water use as soybeans. In the same study, grain sorghum reduced water loss through stomata closure and conserved more soil water than soybeans. Soil water content at the beginning and at the end of the season is shown in Fig. 3. The higher soil water content near the surface late in the season was due to late season rainfall (Fig. 2).

The hydraulic gradient in the 130-150cm depth increment are presented in Fig. 4 for soybeans, corn, and grain sorghum. A negative gradient indicates upward water movement and a positive gradient indicates downward water movement. In the irrigated soybeans the hydraulic gradient did not fluctuate greatly and remained near zero (although it was negative after July 22). In nonirrigated soybeans, the gradient decreased to -18 during August. Data were discontinued after August 19 because the limit of tensiometer reliability had been reached (Perrier and Evans, 1961). In the irrigated corn, similar hydraulic gradients were obtained as in irrigated soybeans. In nonirrigated corn the gradients decreased to approximately -2 and remained there until late in the season. The hydraulic gradient dropped to approximately -1 in irrigated grain sorghum between July 17 and August 16. The grain sorghum received 3 irrigations in a relatively short time in late July and early August; the irrigation coupled

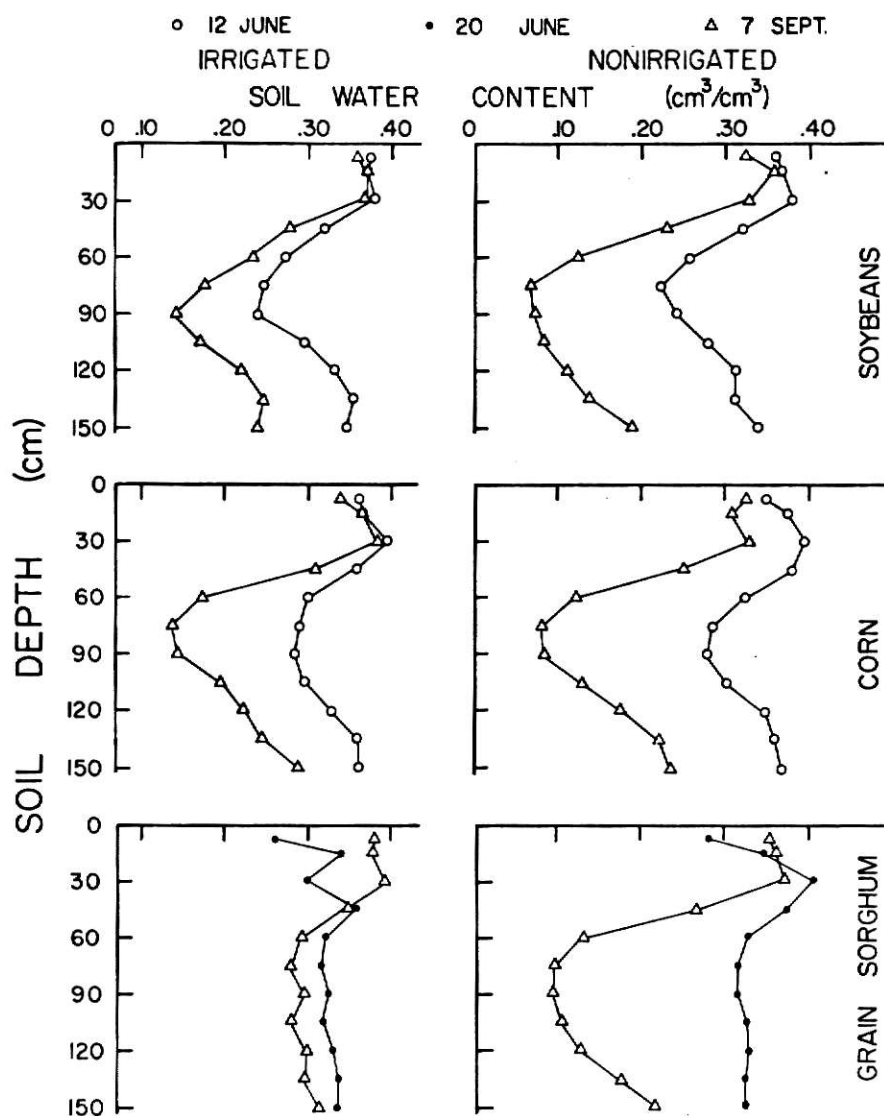


Figure 3. Soil water content (cm^3/cm^3) at the beginning (12 and 20 June), and at the end (7 Sept.) of the season under irrigated and nonirrigated conditions.

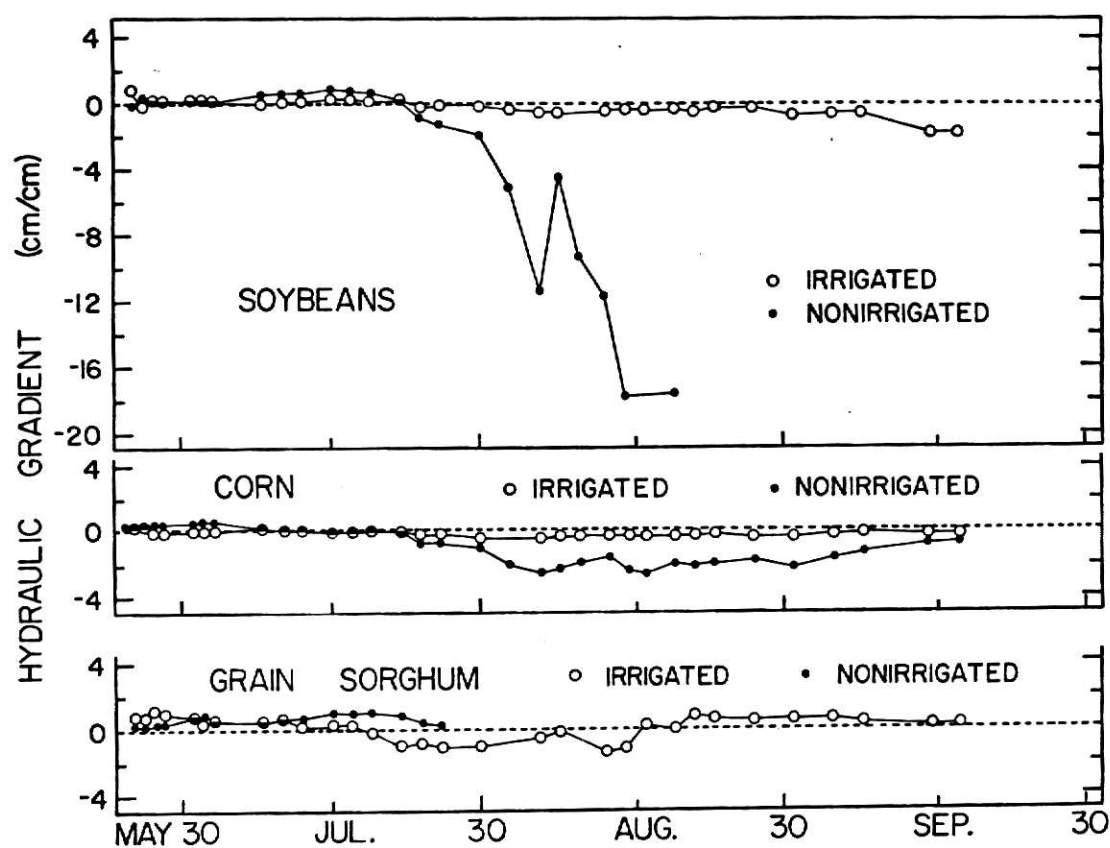


Figure 4. Hydraulic gradients in the 130-150cm increment during the season in soybean, corn, and grain sorghum under irrigated and nonirrigated conditions.

with August rainfall (Fig. 2) restored the soil water and changed the hydraulic gradient to a positive value after August 16. In the nonirrigated grain sorghum, tensiometer failure precluded the taking of data after July 26.

Top Growth Parameters:

Comparison of top growth parameters (averages for the three replications) between irrigated and nonirrigated crops is presented in Table 2. It was of general interest to compare visible above-ground parameters between treatments. In soybeans the irrigated plants were about 32cm taller, more branched, had slightly higher number of nodes/plant, higher leaf area index (LAI), and higher number of pods/plant than the nonirrigated plants. The grain yield in the irrigated soybeans was 2661kg/ha compared to 2396kg/ha in the nonirrigated which was not significant at 5% level of probability.

The irrigated corn plots, again, exceeded the nonirrigated plots in height and LAI, but, the number of nodes/plant was about the same (13 nodes/plant). Irrigated corn height was about 39cm above the nonirrigated. Grain yield in the irrigated corn was 9178kg/ha compared to 2882kg/ha for nonirrigated. This 3 fold difference was significant at the 5% level of probability.

Irrigated grain sorghum had slightly higher values in LAI than the nonirrigated sorghum. The irrigated plants were about 8cm taller than the nonirrigated plants. The differences were slight because of the inherent nature of the sorghum material to continue development when water was available (August rains). Grain yield in the irrigated sorghum

Table 2. Descriptive above ground plant parameters measured under irrigated and nonirrigated conditions for soybeans, corn and grain sorghum.

Growth stage	Plant parameter	Irrigated		Nonirrigated	
		$\bar{X}$	S	$\bar{X}$	S
Soybeans					
R10					
9/5/74	Height (cm)	113.9	15.5	81.6	1.9
"	Pods/pl.	44.6	2.6	35.2	5.5
"	Nodes/pl.	30.0	4.8	25.5	2.6
"	Branch/pl.	2.1	.6	1.0	.4
	LAI (max.)	3.3		2.9	
	Bean yield (kg/ha)	2661	187	2396	103
Corn					
Stage 10					
9/3/74	Height (cm)	222.4	3.0	183.3	8.6
"	Nodes/pl.	13.3	.5	13.5	.4
	LAI (max.)	4.4		3.3	
	Seed yield (kg/ha)	9178	431	2882	1380
Grain sorghum					
Stage 10					
9/3/74	Height (cm)	98.9	4.4	91.1	2.5
"	Nodes/pl.	13.1	.3	13.6	.9
7/26/74	LAI (max.)	5.3		5.0	
	Grain yield (kg/ha)	6837	297	6795	341

was 6837kg/ha compared to 6795kg/ha in the nonirrigated which was not significant at 5% probability level.

Soybeans and grain sorghum have the tendency to resist unfavorable weather conditions and low available soil water. The resistance of soybeans to drought is due to the plant's ability to develop thicker cuticles in the leaf, deposit hemicellulose in the old cells thereby decreasing water need, and develop a large root system (Clement, 1937; Clark and Levitt, 1956; Read and Bartlett, 1972). A resistance to drought is apparently not as prominent in corn as in soybeans and grain sorghum. The low rainfall period coincided with the tasseling and silking stages and caused a severe yield reduction (6296kg/ha) in nonirrigated compared to irrigated corn.

LITERATURE CITED

- Clark, J.A., and J. Levitt. 1956. The basis of drought resistance in the soybean plant. *Physiologia Pl.* 9:598-606.
- Clement, H.F. 1937. Studies in drought resistance of the soybean. *Res. Stud. Wash. St. Univ.* 5:1-16.
- Foth, H.D. 1962. Root and top growth of corn. *Agron. J.* 54:49-52.
- Gingrich, J.R., and M.B. Russell. 1957. A comparison of effects of soil moisture tension and osmotic stress on root growth. *Soil Science* 84:185-194.
- Hanway, J.J. 1966. How a corn plant develops. SR48, Iowa State University, Ames, Iowa.
- Hanway, J.J., and H.E. Thompson. 1967. How a soybean plant develops. SR53 (Rev.), Iowa State University, Ames, Iowa.
- Jensen, M.E., J.L. Wright, and B.J. Pratt. 1969. Estimating soil moisture depletion from climate, crop and soil data. Winter Meetings Am. Soc. of Agr. Engineers, paper no. 69-941, Chicago, Illinois, pp. 1-18.
- Kafkafi, U., Z. Karhi, N. Albasal, and J. Roodick. 1965. Root activity of dryland sorghum as measured by radiophosphorous uptake and water consumption. *Proc. Symposium on Isotopes and Radiation in Soil-Plant Nutrition Studies. Intern. Atomic Energy, Vienna, Austria*, pp. 481-488.
- Mederski, H.J., and J.H. Wilson. 1960. Relation of soil moisture to ion absorption by corn roots. *Soil Sci. Soc. Amer. Proc.* 24:149-152.
- Peters, D.B. 1957. Water uptake of corn roots as influenced by soil moisture content and soil moisture tension. *Soil Sci. Soc. Amer. Proc.* 21:481-484.

Raper, C.D., Jr., and S.A. Barber. 1970a. Rooting systems of soybeans.

I. Differences in root morphology among varieties. Agron. J. 62: 581-584.

Raper, C.D., Jr., and S.A. Barber. 1970b. Rooting systems of soybeans.

II. Physiological effectiveness as nutrient absorption surfaces. Agron. J. 62:585-588.

Read, D.J., and E.M. Bartlett. 1972. The physiology of drought resistance in the soybean plant (Glycine max). I. The relationship between drought resistance and growth. J. App. Ecol. 9:487-498.

Reicosky, D.C., R.J. Millington, A. Klute, and D.B. Peters. 1972.

Patterns of water uptake and root distribution of soybeans (Glycine max.) in the presence of a water table. Agron. J. 64:292-297.

Taylor, H.M., and H.R. Gardner. 1963. Penetration of cotton seedling taproots as influenced by bulk density, moisture content, and strength of soil. Soil Sci. 96:153-156.

Teare, I.D., E.T. Kanemasu, W.L. Powers, and H.S. Jacobs. 1973. Water use efficiency and its relation to crop canopy area, stomatal regulation, and root distribution. Agron. J. 65:207-211.

Vanderlip, R.L. 1972. How a sorghum plant develops. Kans. Agr. Exp. Sta. Contribution No. 1203.

APPENDICES

APPENDIX I

Table I-A. Soybean root DM (g) at different dates of sampling, and at different soil depths.

Depth (cm)	Nonirrigated						Irrigated					
	Plot						Plot					
	41/1	41/2	21/1	21/2	$\bar{X}$	S	40/1	40/2	20/1	20/2	$\bar{X}$	S
<u>5/24/74</u>												
0-15	.01	.03	.22	.18	.11	.106	.13	.16	.24	.18	.18	.047
<u>5/30/74</u>												
0-15	.13	.10	.15	.14	.13	.022	.15	.10	.11	.09	.11	.026
15-30	.01	.02	.02	.02	.02	.005	.03	.01	.01	.03	.02	.012
Total					<u>.15</u>						<u>.13</u>	
<u>6/4/74</u>												
0-15	.20	.23	.16	.28	.22	.051	.29	.16	.13	.21	.20	.070
15-30	.03	.05	.04	.05	.04	.010	.02	.01	.02	.02	.02	.005
Total					<u>.26</u>						<u>.22</u>	
<u>6/7/74</u>												
0-15	1.48	1.41	1.64	1.48	1.51	.097	1.93	1.76	1.57	1.44	1.68	.215
15-30	.26	.50	.43	.45	.41	.104	.23	.29	.31	.37	.30	.058
30-45	.06	.01	.01	.02	.03	.024	.05	.02	.04	.04	.04	.013
Total					<u>1.95</u>						<u>2.02</u>	
<u>6/11/74</u>												
0-15	.51	.36	.35	.55	.44	.102	.49	.57	1.31	.24	.65	.460
15-30	.08	.08	.07	.02	.06	.029	.03	.04	.03	.03	.03	.005
Total					<u>.50</u>						<u>.68</u>	

Table I-A (continued).

Depth (cm)	Nonirrigated						Irrigated					
	Plot						Plot					
	41/1	41/2	21/1	21/2	$\bar{X}$	S	40/1	40/2	20/1	20/2	$\bar{X}$	S
<u>6/13/74</u>												
0-15	.75	.66	1.23	.77	.85	.256	.68	.49	.81	.55	.63	.142
15-30	.07	.03	.02	.03	.04	.022	.03	.03	.04	.05	.04	.010
Total					<u>.89</u>						<u>.67</u>	
<u>6/18/74</u>												
0-15	1.23	.96	1.18	.74	1.03	.225	.67	1.22	1.18	1.12	1.05	.255
15-30	.14	.12	.14	.05	.11	.043	.05	.09	.15	.10	.10	.041
Total					<u>1.14</u>						<u>1.15</u>	
<u>6/20/74</u>												
0-15	1.41	.92	1.18	.82	1.08	.266	.81	1.39	1.59	1.26	1.26	.331
15-30	.21	.16	.10	.11	.15	.051	.17	.06	.07	.13	.11	.052
30-45	.05	.03	.03	.08	.05	.024	.03	.02	.05	.09	.05	.031
Total					<u>1.28</u>						<u>1.42</u>	
<u>6/25/74</u>												
0-15	1.35	1.85	1.10	1.41	1.43	.312	1.21	1.85	1.24	2.11	1.60	.449
15-30	.09	.24	.05	.27	.16	.109	.09	.35	.25	.28	.24	.110
30-45	.05	.19	.06	.20	.13	.081	.06	.18	.19	.11	.14	.061
Total					<u>1.72</u>		-	-	.08	.08	<u>2.06</u>	0

Table I-A (continued).

Depth (cm)	Nonirrigated					Irrigated						
	Plot					S	Plot					
	41/1	41/2	21/1	21/2	$\bar{x}$		40/1	40/2	20/1	20/2	$\bar{x}$	S
<u>6/27/74</u>												
0-15	2.06	1.39	1.66	2.09	1.80	.336	2.07	2.65	1.80	1.67	2.05	.435
15-30	.28	.25	.20	.22	.24	.035	.25	.06	.23	.17	.18	.085
30-45	.14	.17	.15	.15	.15	.013	.18	.09	.14	.16	.14	.039
45-60	.16	.24	.15	.08	.16	.066	.20	.14	.07	.17	.15	.056
Total					<u>2.35</u>						<u>2.52</u>	
<u>7/2/74</u>												
0-15	1.93	2.74	1.72	1.65	2.01	.501	3.90	3.56	2.98	3.71	3.54	.397
15-30	.25	.39	.33	.24	.30	.071	.21	.21	.55	.40	.34	.165
30-45	.13	.23	.10	.24	.18	.071	.21	.16	.35	.46	.30	.136
45-60	.07	.16	.12	.32	.17	.108	.14	.22	.38	.05	.20	.140
60-75	.10	.08	.21	.12	.13	.057	.19	.26	.20	.30	.24	.052
Total					<u>2.79</u>						<u>4.62</u>	
<u>7/5/74</u>												
0-15	2.91	1.63	2.62	2.20	2.34	.556	3.19	3.69	2.02	3.73	3.16	.728
15-30	.40	.16	.38	.28	.31	.110	.46	.49	.30	.30	.39	.102
30-45	.27	.24	.26	.16	.23	.050	.28	.20	.27	.48	.31	.120
45-60	.25	.27	.31	.14	.24	.073	.14	.61	.16	.17	.27	.227
60-75	.21	.21	.13	.20	.19	.039	.18	.09	.11	.18	.14	.047
75-90	.02	.01	.12	.06	.05	.050	.02	.05	.23	.08	.10	.093
Total					<u>3.36</u>						<u>4.37</u>	

Table I-A (continued).

Depth (cm)	Nonirrigated					Irrigated						
	Plot					S	Plot					
	41/1	41/2	21/1	21/2	$\bar{X}$		40/1	40/2	20/1	20/2	$\bar{X}$	S
<u>7/9/74</u>												
0-15	1.98	3.31	3.81	2.46	2.89	.824	3.59	3.52	3.50	3.81	3.61	.142
15-30	.48	.40	.51	.51	.48	.052	.32	.37	.83	.79	.58	.270
30-45	.45	.39	.58	.33	.44	.107	.33	.13	.35	.18	.25	.109
45-60	.32	.30	.56	.18	.34	.159	.48	.17	.44	.21	.33	.158
60-75	.15	.22	.23	.09	.17	.066	.21	.09	.28	.10	.17	.091
75-90	.01	.08	.03	.14	.07	.058	.06	.02	.31	.05	.11	.134
90-105	.01	.02	.02	.03	.02	.008	.04	.02	.29	.03	.10	.130
Total					<u>4.41</u>						<u>5.15</u>	
<u>7/16/74</u>												
0-15	4.45	4.41	3.11	4.10	4.02	.625	4.35	4.44	5.65	3.88	4.58	.754
15-30	.50	.59	.81	.70	.65	.134	.85	.79	.75	.62	.75	.097
30-45	.49	.42	.32	.43	.42	.071	.50	.67	.41	.40	.50	.125
45-60	.89	.59	.12	.78	.60	.340	.63	.35	.30	.79	.52	.233
60-75	1.06	.56	.53	.80	.74	.247	.59	.56	.44	.70	.57	.107
75-90	.10	.09	.30	.20	.10	.066	.14	.12	.24	.24	.19	.064
90-105	.05	.06	.19	.03	.08	.073	.04	.02	.15	.19	.10	.083
105-120	.02	-	.13	.04	.06	.059	.05	.02	.06	.09	.05	.030
Total					<u>6.67</u>						<u>7.26</u>	

Table I-A (continued).

Depth (cm)	Nonirrigated						Irrigated					
	Plot						Plot					
	41/1	41/2	21/1	21/2	$\bar{X}$	S	40/1	40/2	20/1	20/2	$\bar{X}$	S
<u>7/23/74</u>												
0-15	3.56	5.28	3.83	3.18	3.96	.918	7.30	7.88	3.32	6.25	6.19	2.027
15-30	.98	.41	.50	.35	.56	.287	1.07	.75	.69	.76	.82	.171
30-45	.91	.36	.37	.26	.48	.294	.42	.53	.36	.55	.47	.090
45-60	1.39	.87	.53	.36	.79	.454	.66	.55	.28	.46	.49	.161
60-75	1.65	.57	.41	1.04	.92	.450	.66	.56	.30	.33	.46	.176
75-90	.75	.41	.27	.24	.42	.214	.32	.36	.33	.31	.33	.022
90-105	.11	.09	.92	.05	.29	.097	.54	.13	.32	.46	.36	.180
105-120	.02	.02	.25	.03	.08	.113	.44	.07	.14	.20	.21	.161
Total					<u>7.50</u>						<u>9.33</u>	
<u>7/30/74</u>												
0-15	4.66	5.59	3.90	3.57	4.43	.898	6.87	11.45	5.36	7.28	7.74	2.609
15-30	.78	.73	.72	.66	.72	.049	.76	1.28	.75	.87	.92	.249
30-45	.59	.68	.49	.40	.54	.121	.53	.53	.44	.43	.48	.055
45-60	.64	.80	.93	.21	.65	.313	.36	.49	.44	.52	.45	.070
60-75	1.16	1.24	1.27	.46	1.03	.384	.95	.49	.19	.59	.56	.313
75-90	.14	.37	.53	.20	.31	.176	1.07	1.39	.40	.32	.80	.520
90-105	.08	.17	.56	.18	.25	.213	.37	.41	.27	.58	.41	.129
105-120	.03	.07	.46	.17	.18	.194	.47	.10	.33	.23	.28	.157
120-135	-	.01	.09	.05	.05	.040	.37	.03	.11	.07	.15	.154
Total					<u>8.16</u>						<u>11.79</u>	

Table I-A (continued).

Depth (cm)	Nonirrigated					S	Irrigated					
	Plot						Plot					
	41/1	41/2	21/1	21/2	$\bar{X}$		40/1	40/2	20/1	20/2	$\bar{X}$	S
<u>8/12/74</u>												
0-15	4.18	4.19	8.33	6.76	5.86	3.097	11.05	8.95	7.04	9.92	9.24	1.699
15-30	.86	.99	1.11	1.01	.99	.119	1.58	.81	.81	1.06	1.07	.363
30-45	.68	.48	1.00	1.32	.87	.259	.99	1.19	.30	.55	.76	.406
45-60	1.18	1.48	1.17	1.14	1.24	.159	1.64	.91	.40	.92	.97	.510
60-75	2.21	2.47	.85	.88	1.60	.858	1.40	1.12	.46	.68	.92	.424
75-90	.35	1.71	.95	1.88	1.22	.708	1.50	1.37	.53	.57	.99	.514
90-105	.24	1.02	.91	.81	.74	.347	1.05	.83	1.26	.73	.97	.236
105-120	.03	.68	1.00	.78	.62	.827	.27	.41	.61	.61	.48	.166
120-135	.01	.10	.26	.31	.17	.139	1.02	.72	.51	.44	.67	.260
135-150	-	.04	.03	.03	.02	.006	.50	.03	.25	.03	.20	.224
Total					<u>13.33</u>						<u>16.27</u>	
<u>8/19/74</u>												
0-15	7.30	6.88	8.23	6.10	7.13	.89	9.00	8.48	8.64	11.23	9.34	1.28
15-30	1.01	1.56	1.07	0.91	1.14	.29	0.96	1.64	1.06	1.13	1.20	.30
30-45	0.50	0.43	0.39	0.31	0.41	.08	0.47	0.90	0.70	0.89	0.74	.20
45-60	0.67	1.02	1.02	0.39	0.78	.31	0.41	0.62	0.52	0.51	0.52	.09
60-75	1.38	0.78	1.80	1.25	1.30	.36	0.84	0.47	0.54	0.56	0.60	.14
75-90	0.51	0.50	0.51	0.24	0.44	.13	0.72	1.25	0.56	0.35	0.72	.38
90-105	0.28	0.13	0.51	0.27	0.30	.16	0.65	0.31	0.65	0.45	0.52	.17
105-120	0.18	0.15	0.78	0.37	0.37	.29	0.50	0.35	0.40	0.42	0.42	.06
120-135	0.14	0.02	0.31	0.16	0.16	.12	0.50	0.23	0.52	0.25	0.38	.16
135-150	0.06	0.03	0.09	0.02	0.05	.03	0.22	0.05	0.14	0.10	0.13	.07
150-165	0.02	0.02	0.06	0.01	0.03	.02	0.01	0.02	0.05	0.01	0.03	.02
Total					<u>12.09</u>						<u>14.60</u>	

Table I-A (continued).

Depth (cm)	Nonirrigated					Irrigated						
	Plot					S	Plot					
	41/1	41/2	21/1	21/2	$\bar{X}$		40/1	40/2	20/1	20/2	$\bar{X}$	S
<u>8/27/74</u>												
0-15	7.94	8.27	9.22	10.68	9.03	1.06	10.66	11.31	6.85	7.33	9.04	2.27
15-30	0.62	0.92	0.71	0.62	0.72	.14	0.56	1.05	1.46	1.12	1.05	.37
30-45	0.65	0.90	0.42	0.57	0.64	.20	0.63	0.99	0.85	0.36	0.71	.28
45-60	0.57	3.86	0.56	0.49	1.37	1.66	0.51	0.46	0.54	0.34	0.46	.09
60-75	1.37	0.57	0.53	0.88	0.84	.39	0.77	0.42	0.29	0.23	0.43	.24
75-90	0.92	0.49	0.35	0.45	0.55	.25	1.14	0.59	0.56	0.25	0.64	.37
90-105	0.70	0.11	0.44	0.40	0.41	.24	0.61	0.24	0.51	0.37	0.43	.16
105-120	0.23	0.45	0.92	0.80	0.60	.32	0.47	0.19	0.24	0.55	0.36	.17
120-135	0.28	0.17	0.26	0.65	0.34	.21	0.39	0.20	0.41	0.44	0.36	.11
135-150	0.12	0.03	0.04	0.12	0.08	.05	0.14	0.02	0.09	0.10	0.09	.05
150-165	0.02	-	0.04	0.01	0.02	.02	0.13	0.04	0.03	0.03	0.06	.05
165-180	0.03	-	0.02	0.01	0.02	.01	0.07	0.01	0.01	0.02	0.03	.03
Total					<u>14.62</u>						<u>13.66</u>	
<u>9/14/74</u>												
0-15	5.64	5.92	4.32	5.65	5.38	.72	7.52	5.87	9.06	8.19	7.66	1.35
15-30	.60	0.22	0.54	0.92	.57	.29	0.62	.56	1.12	0.99	.82	.27
30-45	.40	0.31	0.64	0.43	.44	.14	0.38	.48	0.46	0.16	.37	.15
45-60	.49	0.55	1.09	0.75	.72	.27	0.54	.26	0.67	0.47	.48	.17
60-75	1.95	0.28	0.47	1.03	.93	.75	0.35	.68	0.32	0.21	.39	.20
75-90	1.46	0.17	0.62	0.54	.70	.54	0.39	.59	0.67	0.23	.47	.20
90-105	1.57	0.10	0.89	0.33	.72	.66	0.29	.17	0.49	0.20	.29	.14
105-120	0.62	0.10	1.12	0.45	.57	.42	0.27	.71	0.32	0.46	.44	.20
120-135	0.52	0.12	0.18	0.57	.35	.23	0.47	.59	0.39	0.10	.39	.21
135-150	0.09	0.01	0.07	0.08	.06	.04	0.06	.14	0.08	0.02	.08	.05
150-165	0.02	0.01	0.02	0.02	.02	.01	0.06	.01	0.02	0.01	.03	.02
165-180	0.02	0.01	0.01	0.02	.02	.01	0.04	.03	0.02	0.02	.03	.01
Total					<u>10.48</u>						<u>11.45</u>	

Table I-B. Soybean plant parameters measured during the season in irrigated and nonirrigated plots.

	Nonirrigated						Irrigated					
	41/1	41/2	21/1	21/2	$\bar{X}$	S	40/1	40/2	20/1	20/2	$\bar{X}$	S
5/24/74												
Top DM (g)	.11	.23	.22	.18	.19	.05	.13	.16	.24	.18	.18	.05
Top ht. (cm)	6.4	7.1	6.8	6.6	6.73	.30	6.1	6.8	7.4	6.6	6.77	.54
LAI	.03	.06	.04	.04	.04	.01	.03	.03	.04	.04	.03	.01
No. nodes	2	2	2	2	2	0.00	2	2	2	2	2	0.00
Root dep. (cm)	4.8	6.6	4.1	7.1	5.64	1.43	5.8	6.6	6.8	6.1	6.35	.46
5/30/74												
Top DM (g)	.63	.87	.96	.93	.85	.15	.72	.75	.67	.68	.70	.04
Top ht. (cm)	8.5	9.6	10.0	10.5	9.56	.85	9.8	9.4	9.1	11.2	9.88	.93
LAI	.16	.16	.22	.17	.18	.03	.13	.17	.18	.21	.17	.03
No. nodes	3	3	3	3	3	0.00	3	3	3	3	3	0.00
Root dep. (cm)	8.8	6.6	7.9	5.8	7.26	1.34	8.2	8.2	7.9	9.5	8.45	.71
6/4/74												
Top DM (g)	1.37	.67	1.10	.99	1.03	.29	.93	1.20	.88	1.04	1.01	.14
Top ht. (cm)	12.70	11.18	11.81	12.07	11.94	.63	12.19	15.24	13.59	12.57	13.40	1.36
LAI	.44	.23	.33	.33	.33	.09	.29	.37	.24	.33	.31	.06
No. nodes	4	3.5	4	3.5	3.75	.29	4	4	4	4	4.00	0.00
Root dep. (cm)	8.64	13.34	19.43	11.68	13.27	4.54	13.46	12.19	15.75	18.54	14.99	2.79

Table I-B (continued).

	Nonirrigated					S	Irrigated					S
	41/1	41/2	21/1	21/2	$\bar{X}$		40/1	40/2	20/1	20/2	$\bar{X}$	
6/7/74												
Top DM (g)	1.48	1.41	1.64	1.49	1.51	.10	1.93	1.76	1.57	1.44	1.68	.21
Top ht. (cm)	13.84	11.94	14.86	13.08	13.43	1.23	16.13	10.79	12.70	12.07	12.92	2.28
LAI	.44	.39	.47	.43	.43	.03	.54	.47	.36	.40	.44	.08
No. nodes	5	5	4	5	4.75	.50	5	4.5	5	4.5	4.75	.29
Root dep. (cm)	14.23	16.13	17.27	14.48	15.53	1.44	14.61	11.68	12.95	13.97	13.30	1.28
6/11/74												
Top DM (g)	2.42	1.68	2.17	2.32	2.15	.33	3.02	2.03	2.17	2.56	2.45	.44
Top ht. (cm)	14.80	14.10	15.4	17.4	15.43	1.42	16.1	14.6	14.8	12.6	14.53	1.45
LAI	.57	.39	.50	.60	.52	.09	.81	.50	.53	.52	.59	.15
No. nodes	5.5	5	5.5	5.5	5.38	.25	6	5	5	5	5.25	.50
Root dep. (cm)	15.1	21.5	18.7	16.0	17.83	2.89	16.6	20.6	15.0	13.8	16.50	2.96
6/13/74												
Top DM (g)	3.92	4.12	3.04	3.00	3.52	.58	3.36	3.05	3.19	2.69	3.07	.28
Top ht. (cm)	16.45	13.90	14.55	12.35	14.31	1.70	14.3	14.2	14.00	16.00	14.63	.93
LAI	.66	.96	.69	.75	.77	.14	.76	.58	.69	.65	.67	.08
No. nodes	5.5	6	5.5	6	5.75	.29	6	5.5	5.5	5.5	5.63	.25
Root dep. (cm)	20.50	22.65	26.05	25.00	23.55	2.48	24.35	20.50	27.10	24.35	24.08	2.71

Table I-B (continued).

	Nonirrigated					Irrigated						
	41/1	41/2	21/1	21/2	$\bar{X}$	S	40/1	40/2	20/1	20/2	$\bar{X}$	S
6/18/74												
Top DM (g)	5.75	5.11	5.00	2.52	4.60	1.42	3.42	4.66	5.25	4.42	4.44	.76
Top ht. (cm)	19.9	17.2	19.0	14.6	17.68	2.34	18.0	18.6	17.8	16.8	17.80	.75
LAI	1.37	1.31	1.13	.60	1.10	.35	.78	1.14	1.28	1.05	1.06	.21
No. nodes	7.5	7	7	6	6.88	.63	6	7	7	6.5	6.63	.48
Root dep. (cm)	28.0	24.2	27.3	21.3	25.20	3.08	22.6	26.8	28.6	26.6	26.15	2.53
6/20/74												
Top DM (g)	7.77	4.85	3.68	3.36	4.92	2.01	3.12	8.11	7.92	6.67	6.46	2.31
Top ht. (cm)	22.5	20.3	15.8	16.8	18.85	3.11	18.9	21.5	20.5	22.8	20.93	1.65
LAI	1.99	1.09	1.04	.86	1.25	.51	.96	2.14	1.79	1.67	1.64	.50
No. nodes	7.5	6.5	7	6	6.75	.65	7	8	8	7.5	7.63	.48
Root dep. (cm)	41.35	39.25	24.90	36.6	35.53	7.35	38.75	36.05	36.95	36.10	36.96	1.26
6/25/74												
Top DM (g)	8.09	7.24	3.43	6.73	6.37	2.04	5.14	8.43	7.54	10.93	8.01	2.39
Top ht. (cm)	23.00	22.25	19.25	23.50	22.00	1.90	22.75	24.25	23.75	24.25	23.75	.71
LAI	2.13	1.59	.85	1.69	1.57	.53	1.32	1.79	1.56	2.55	1.81	.53
No. nodes	11	8.5	7	8	8.63	1.70	8	9.5	8.5	13.5	9.88	2.50
Root dep. (cm)	37.3	40.10	39.2	44.4	40.25	3.00	44.2	42.4	46.6	49.2	45.60	2.95

Table I-B (continued).

	Nonirrigated					Irrigated						
	41/1	41/2	21/1	21/2	$\bar{x}$	S	40/1	40/2	20/1	20/2	$\bar{x}$	S
6/27/74												
Top DM (g) ^{*/}	10.93	10.18	7.61	8.29	9.25	1.56	6.90	11.57	8.52	9.48	9.12	1.95
Top ht. (cm)	31.25	27.25	26.25	27.75	28.13	2.17	26.5	22.0	25.75	27.5	25.44	2.40
LAI	2.42	2.36	1.76	1.80	2.09	.35	1.49	2.55	1.97	2.05	2.02	.43
No. nodes	11	9.5	8.5	8.5	9.38	1.18	9.5	11.5	9.5	16	11.63	3.07
Root dep. (cm)	53.75	49.35	36.75	51.35	47.80	7.58	52.00	55.35	51.55	62.00	50.23	11.03
Leaf DM (g)	5.15	5.33	4.02	4.22	4.68	.66	3.18	5.83	4.42	4.72	4.54	1.09
Stem DM (g)	5.93	4.85	3.59	4.07	4.61	1.02	3.72	5.74	4.10	4.76	4.58	.88
7/2/74												
Top DM (g) ^{*/}	10.60	14.11	7.28	13.20	11.30	3.06	18.19	15.76	18.44	13.61	16.50	2.27
Top ht. (cm)	32.25	31.50	27.25	25.50	29.13	3.27	35.50	34.00	30.75	30.00	32.56	2.62
LAI	2.16	3.12	1.43	2.76	2.37	.74	4.12	3.64	4.01	2.82	3.65	.59
No. nodes	10.5	13	9.5	13.5	11.63	1.93	13	12	14	12	12.75	.96
Root dep. (cm)	60.4	63.35	64.75	62.10	62.65	1.85	65.4	67.15	66.10	69.80	67.11	1.93
Leaf DM (g)	5.08	6.73	3.54	6.81	5.54	1.55	8.81	7.74	9.60	7.14	8.32	1.10
Stem DM (g)	5.52	7.38	3.74	6.39	5.76	1.54	9.38	8.02	8.84	6.42	8.16	1.29

^{*/}Top DM includes leaf DM and stem DM.

Table I-B (continued).

	Nonirrigated						Irrigated					
	41/1	41/2	21/1	21/2	$\bar{X}$	S	40/1	40/2	20/1	20/2	$\bar{X}$	S
7/5/74												
Top DM (g) ^{*/}	16.22	11.59	11.31	11.48	12.65	2.38	14.37	18.30	9.65	22.66	16.25	5.55
Top ht. (cm)	37.85	39.40	34	32.65	35.98	3.17	39.00	39.50	34.75	32.50	36.44	3.38
LAI	3.38	2.59	2.55	3.17	2.92	.42	3.06	3.73	1.92	4.86	3.39	1.23
No. nodes	16	14.5	13.5	13.5	14.38	1.18	13.5	14	10	18	13.88	3.28
Root dep. (cm)	79.35	73.60	80.25	68.8	75.50	5.35	78.85	79.50	74.60	77.10	77.51	2.19
Leaf DM (g)	7.09	5.49	5.23	4.76	5.64	1.01	5.99	7.97	3.91	10.55	7.10	2.83
Stem DM (g)	9.13	6.10	6.08	6.72	7.01	1.44	8.38	10.33	5.74	12.11	9.14	2.73
7/9/74												
Top DM (g) ^{*/}	10.35	18.89	16.34	12.88	14.62	3.76	22.93	18.21	14.85	21.29	19.32	3.56
Top ht. (cm)	39.0	48.25	40.0	38.85	41.53	4.51	51	44	40.25	44.0	44.81	4.49
LAI	2.22	3.65	3.54	2.50	2.98	.72	4.05	3.76	3.00	4.64	3.86	.68
No. nodes	10	13.5	15	12	12.63	2.14	18	13	13.5	19.5	16.00	3.24
Root dep. (cm)	76.50	78.0	79.90	99.10	83.38	10.58	82.85	76.50	94.10	75.45	82.23	8.57
Leaf DM (g)	4.76	8.21	7.47	5.49	6.48	1.62	9.40	8.00	6.43	9.23	8.26	1.37
Stem DM (g)	5.59	10.68	8.87	7.39	8.13	2.16	13.53	10.21	8.42	12.06	11.06	2.22
7/16/74												
Top DM (g) ^{*/}	19.96	30.47	15.89	20.56	21.72	6.19	25.92	27.68	29.04	16.81	24.86	5.52
Top ht. (cm)	48.75	44.25	37.75	46.5	44.31	4.75	54.5	54	52.5	46	51.75	3.93
LAI	5.27	3.05	3.05	3.32	3.67	1.07	3.32	5.27	5.65	3.09	4.33	1.31
No. nodes	14.5	25.5	18.5	19	19.38	4.55	19.5	20	21	13.5	18.50	3.39
Root dep. (cm)	105.25	93.45	114.15	102.50	103.84	8.53	107.75	98.50	107.35	108.25	105.46	4.66
Leaf DM (g)	8.37	13.41	6.93	8.17	6.95	.26	11.12	12.52	12.17	7.40	10.80	2.34
Stem DM (g)	11.59	17.46	8.96	12.39	12.60	3.56	14.80	15.16	16.87	9.41	14.06	3.23

Table I-B (continued).

	Nonirrigated					S	Irrigated					S
	41/1	41/2	21/1	21/2	$\bar{x}$		40/1	40/2	20/1	20/2	$\bar{x}$	
7/23/74												
Top DM (g) ^{**/}	18.94	31.13	20.44	21.41	22.98	5.53	37.87	35.57	25.01	30.06	32.13	5.77
Top ht. (cm)	48.5	51.75	52	49.75	50.50	1.67	71.25	65.75	68.5	60.25	66.44	4.70
LAI	3.08	3.96	3.66	3.15	3.46	.42	6.51	6.30	4.48	4.95	5.56	1.00
No. nodes	16	24	18.5	21.5	20.00	3.49	21	25	19	18.5	20.88	2.95
Root dep. (cm)	103.49	109.75	109.15	104.50	106.72	3.19	106.25	118.75	115.00	114.25	113.56	5.26
Leaf DM (g)	7.53	12.88	8.88	8.51	9.45	2.36	15.15	14.92	10.45	13.01	13.38	2.18
Stem DM (g)	11.41	18.25	11.56	12.90	13.53	3.22	22.64	20.63	14.45	16.85	18.64	3.68
Pod DM (g)	-	-	-	-	-	-	.08	.02	.11	.20	.07	.04
7/30/74												
Top DM (g) ^{**/}	22.89	14.67	30.83	20.72	22.28	6.68	36.00	52.95	35.89	45.20	42.51	8.21
Top ht. (cm)	61	54.5	66	55.5	59.25	5.33	61	84	86	82	78.25	11.62
LAI	3.80	2.25	4.90	3.09	3.51	1.12	5.41	7.91	5.90	7.18	6.60	1.15
No. nodes	16.5	14	27.5	17	18.75	5.88	28	26	26	23.5	25.88	1.84
Root dep. (cm)	115.25	121.25	128.25	123.65	122.10	5.41	135.00	129.25	129.25	125.55	129.76	3.90
Leaf DM (g)	9.21	5.35	12.01	8.70	8.82	2.73	13.02	19.22	13.09	17.72	15.76	3.18
Stem DM (g)	13.52	9.32	18.04	11.40	13.07	3.73	22.15	32.07	22.42	26.74	25.84	4.65
Pod DM (g)	.16	-	.78	.62	.52	.32	.83	1.66	.38	.74	.90	.54

^{**/}Top DM includes leaf DM, stem DM, and pod DM.

Table I-B (continued).

	Nonirrigated						Irrigated					
	41/1	41/2	21/1	21/2	$\bar{X}$	S	40/1	40/2	20/1	20/2	$\bar{X}$	S
8/12/74												
Top DM (g) ^{**/}	20.21	26.63	60.39	29.33	34.14	17.91	46.74	46.40	46.06	59.97	49.79	6.79
Top ht. (cm)	57.75	68.50	84.50	61.0	67.94	11.92	93	94	97	92	94.00	2.16
LAI	2.88	4.11	7.96	4.17	4.78	2.20	6.21	6.21	7.01	8.54	6.99	1.10
No. nodes	19.5	23	37.5	24.5	26.13	7.87	20.5	24.5	29.5	30	26.13	4.50
Root dep. (cm)	116.90	137.35	145.25	138.25	134.44	12.21	148.75	147.50	146	141.50	145.94	3.16
Leaf DM (g)	7.59	10.13	20.55	11.61	12.47	5.64	17.12	15.32	15.80	20.52	17.19	2.35
Stem DM (g)	12.19	14.58	32.42	14.70	18.47	9.37	25.04	27.96	24.49	32.80	27.57	3.80
Pod DM (g)	.43	1.92	7.42	3.02	3.20	3.01	4.58	3.12	5.77	6.65	5.03	1.53
8/19/74												
Top DM (g) ^{**/}	34.79	41.00	55.71	44.44	43.99	8.78	73.38	67.85	78.17	93.29	78.17	10.92
Top ht. (cm)	63	73.25	85	47.5	67.19	15.91	113	107.25	115.25	114.5	112.50	3.62
LAI	4.09	4.24	5.09	5.05	4.62	.53	6.64	6.90	8.03	9.24	7.70	1.19
No. nodes	25.5	25	28	34.5	28.25	4.37	29	33	37	35	33.50	3.42
Root dep. (cm)	156.75	143.25	153.40	145.25	149.66	6.45	155.25	155	157.75	139.75	151.94	8.22
Leaf DM (g)	11.20	12.22	14.19	12.37	12.50	1.24	17.06	17.65	20.54	25.16	20.10	3.70
Stem DM (g)	17.75	19.99	24.60	19.59	20.48	2.91	36.97	34.67	38.56	49.48	39.92	6.57
Pod DM (g)	5.84	8.79	16.92	12.48	11.01	4.78	19.35	15.53	19.07	18.65	18.15	1.77

Table I-B (continued).

	Nonirrigated					S	Irrigated					S
	41/1	41/2	21/1	21/2	$\bar{X}$		40/1	40/2	20/1	20/2	$\bar{X}$	
8/27/74												
Top DM (g) ^{**/}	58.52	37.87	68.80	42.62	51.95	14.29	83.29	86.81	88.93	99.49	89.63	6.97
Top ht. (cm)	71.25	63.25	79.00	78.5	73.00	7.40	114.50	101.25	79.00	78.5	113.31	8.30
LAI	5.38	2.92	5.34	4.00	4.41	1.18	7.46	6.19	7.20	8.07	7.23	.78
No. nodes	33	22.50	32.50	22	27.50	6.07	32.5	29.50	27.5	30.5	30.00	2.08
Root dep. (cm)	169.75	160.40	163.90	149.16	160.80	8.67	170.64	159.40	149.16	162.40	160.40	8.87
Leaf DM (g)	14.67	8.63	15.99	11.12	12.60	3.35	17.92	16.44	17.64	19.42	17.86	1.22
Stem DM (g)	23.35	16.26	25.67	18.19	20.87	4.38	37.74	35.88	35.89	42.48	38.00	3.11
Pod DM (g)	20.50	12.98	27.14	22.60	20.80	5.91	27.63	34.49	35.40	37.58	33.78	4.30
9/14/74												
Top DM (g) ^{**/}	44.58	63.30	49.94	58.32	54.04	8.37	56.84	92.47	105.18	106.42	90.23	23.13
Top ht. (cm)	66	69.5	67.5	72.5	68.88	2.81	110	123	128	120	120.25	7.59
LAI	1.42	1.81	1.85	2.24	1.83	.34	1.86	4.30	4.77	4.93	3.97	1.43
No. nodes	25.5	29	28.5	26.5	27.38	1.65	26	28.5	30.5	43.5	32.13	7.80
Root dep. (cm)	166.40	128.92	162.40	144.16	150.47	17.32	145.16	182.88	164.40	151.16	160.90	16.71
Leaf DM (g)	4.02	5.08	4.10	5.40	4.65	.69	5.27	10.58	11.58	10.71	9.54	2.88
Stem DM (g)	14.67	19.23	14.91	17.49	16.58	2.18	23.55	33.47	41.22	44.67	35.73	9.37
Pod DM (g)	25.89	38.99	30.93	35.43	32.81	5.67	28.02	48.42	52.38	51.04	44.97	11.42

Table I-C. Soybean pod and bean yield/562cm² of soil surface.

Pods and beans (g) sample					n=4	
Date	Nonirrigated		Irrigated			
	<u>X</u>	<u>S</u>	<u>X</u>	<u>S</u>		
7/30/74	.39	.37	.68	.21		
8/12	3.20	3.01	5.03	1.53		
8/19	11.01	4.79	18.15	1.77		
8/27	20.81	5.91	33.78	4.30		
9/14	32.81	5.67	44.97	11.42		
<u>Bean yield kg/ha</u>					<u>n=2</u>	
2323 ± 103					2528 ± 145	
2396 ^{*/}					2661 ^{*/}	

^{*/} Average bean yield (3 plots) from Dr. L.R. Stone's plots.

Table I-D. Soybean plant height and girth at the middle and base of stem 114 days after emergence (R9.5).

Date	Irrigated			Nonirrigated		
	Height (cm)	Basal girth (cm)	Middle girth (cm)	Height (cm)	Basal girth (cm)	Middle girth (cm)
9/9/74	112.5	1.05	0.63	83.0	0.76	0.55
	121.2	0.82	0.62	86.2	0.90	0.55
	117.5	1.17	0.66	65.5	0.62	0.52
	113.5	1.09	0.68	77.6	0.84	0.52
	109.1	1.12	0.65	68.8	0.69	0.57
$\bar{X}$	114.8	1.05	0.65	76.2	0.76	0.54
S	4.7	0.14	0.02	8.909	0.11	0.02

Table I-E. Soybeans: maturity date, lodging factor, pods and bean, and seed samples measured at R10.

Plot	Maturity date	Lodging factor	Wt. of 100 seedling (g)	Sample wt. (g)
41	266	1.0	18.6	1009
40	274	1.8	18.1	1159
21	266	1.0	18.1	1049
20	272	1.8	16.8	1040

Table I-F. Irrigation water and schedule.

Date	Stage	Water (in.)	Water (cm)
6/28	R4	4	10.0
7/17	R5.5	4	10.0
8/8	R7	3	7.5
Total		11	27.5

Table I-GI (continued).

Plot	Soil depth (cm)											
	Grav.(15)	15	30	45	60	75	90	105	120	135	150	
July 5												
	Water content (PV)											
4	30.46	35.60	35.70	31.44	22.16	23.99	22.58	29.30	30.58	35.19	37.34	
20	24.81	31.35	27.88	14.16	13.11	12.66	21.34	27.33	30.07	34.14	33.46	
23	30.27	35.19	35.97	23.35	14.16	18.37	20.02	28.02	34.69	33.09	35.60	
39	31.56	33.59	33.82	32.59	30.35	22.03	18.87	24.36	31.90	36.75	33.09	
40	28.59	33.50	33.14	34.28	31.49	23.63	16.63	23.26	30.12	31.49	29.57	
Avg.	32.05	33.85	33.30	27.16	22.25	20.14	19.89	26.45	31.47	34.13	33.81	
Incr. avg.	32.95	33.58	30.23	24.71	21.20	20.02	23.17	28.96	32.80	33.97		
Incr. SWP	-70	-50	-4.00	-11.00	-98	-40	-20	-20	-18	-10		
	Avg. root depth 77.52 cm											
	Total ASW 21.77 cm											
	Avg. SWP -2.93 bar											
	Profile avg. SWP -1.83 bar											
July 11												
4	20.47	30.07	32.36	26.83	17.23	19.79	18.55	27.56	32.22	33.96	35.60	
20	17.23	24.91	23.08	11.06	9.09	10.10	18.78	26.23	28.66	33.87	32.13	
23	20.66	27.65	32.18	18.46	9.50	14.85	17.36	26.10	34.28	31.63	34.96	
39	21.28	26.10	29.57	29.71	26.28	17.14	15.22	22.12	31.44	37.30	32.50	
40	21.84	28.02	29.62	31.67	26.32	17.59	12.66	19.74	29.02	31.31	--	
Avg.	20.30	27.35	29.36	23.54	17.68	15.89	16.51	24.35	31.12	33.61	33.80	
Incr. avg.	23.82	28.36	26.45	20.61	16.78	16.20	20.43	27.74	32.36	33.71		
Incr. SWP	-5.00	-3.30	-7.00	-15	-1.50	-60	-20	-28	-20	-20	-10	
	Avg. root depth 81.24 cm											
	Total ASW 19.10 cm											
	Avg. SWP -5.40 bar											
	Profile avg. SWP -3.32 bar											

Table I-G2 (continued).

Plot	Soil depth (cm)										
	Grav.(15)	15	30	45	60	75	90	105	120	135	150
June 27											
		Water content (PV)									
2	27.13	26.42	32.45	31.90	22.30	20.06	16.59	23.58	24.68	26.32	33.14
21	26.81	28.70	33.04	30.53	20.79	20.24	18.64	24.40	28.29	29.07	33.23
22	27.23	27.33	27.70	16.54	14.62	13.52	21.66	23.35	29.71	34.00	31.67
38	27.38	28.88	26.96	16.50	15.95	14.85	24.63	28.84	34.23	31.26	35.51
41	25.27	30.44	36.43	39.26	36.20	28.56	32.59	31.49	35.15	30.12	33.78
Avg.	26.76	28.35	31.32	26.95	21.97	19.45	22.82	26.33	30.41	30.15	33.47
Incr. avg.	27.56	29.84	29.14	24.46	20.71	21.14	24.58	28.37	30.28	31.81	
Incr. SWP	-2.8	-2.20	-4.58	-11.50	-9.95	-9.33	-1.17	-2.20	-2.25	-1.10	
July 5											
		Avg. root depth 45.92 cm									
		Total ASW 21.90 cm									
		Avg. SWP -5.27 bar									
		Profile avg. SWP -2.31 bar									
2	19.42	24.91	30.07	26.83	14.90	12.61	13.25	21.52	23.03	24.59	30.48
21	20.87	25.96	28.93	26.69	16.08	16.82	15.63	20.88	26.92	29.07	31.90
22	19.14	25.09	24.72	12.93	8.77	9.68	19.56	22.85	30.53	33.36	31.26
38	26.53	27.56	22.85	10.60	9.68	11.28	21.89	27.10	32.82	30.12	35.24
41	20.68	28.29	33.23	34.87	33.87	26.87	30.48	28.52	33.68	30.48	32.54
Avg.	21.33	26.36	27.96	22.38	16.66	15.45	20.16	24.17	29.40	29.52	32.28
Incr. avg.	23.84	27.16	25.17	19.52	16.06	17.81	22.16	26.78	29.46	30.90	
Incr. SWP	-4.20	-4.50	-8.10	-15	-1.70	-0.50	-2.20	-2.21	-0.30	-0.11	
Avg. root depth 74.49 cm											
Total ASW 18.22 cm											
Avg. SWP -6.70 bar											
Profile avg. SWP -3.48 bar											

Table I-G2 (continued).

		Soil depth (cm)											
Plot	Grav.(15)	15	30	45	60	75	90	105	120	135	150		
July 11													
Water content (PV)													
2	20.05	23.54	28.47	26.32	11.88	9.14	10.00	18.74	21.94	23.86	28.98		
21	20.71	25.18	27.92	25.41	12.11	10.78	11.70	18.46	26.51	28.15	31.22		
22	18.61	22.48	21.84	11.70	6.85	7.49	16.54	21.57	27.88	31.72	29.80		
38	21.27	25.91	21.02	9.41	7.22	8.54	19.24	26.19	31.67	28.88	34.51		
41	19.89	27.65	31.40	31.76	29.94	30.93	25.18	24.50	31.72	29.62	32.22		
Avg.	20.11	24.95	26.13	20.92	13.60	13.38	16.53	25.20	27.94	28.45	31.35		
Incr. avg.	22.53	25.54	23.52	17.26	13.49	14.96	20.86	26.57	28.20	29.90			
Incr. SWP	-6.00	-5.50	-10.00	-15	-2.30	-1.17	-0.21	-0.21	-0.21	-0.46	-0.14		
Avg. root depth 82.38 cm													
Total ASW 16.23 cm													
Avg. SWP -6.59 bar													
Profile avg. SWP -4.05 bar													
July 16													
2	20.03	22.03	27.92	25.18	11.15	7.40	8.13	15.67	20.06	21.30	28.29		
21	19.05	23.49	27.19	23.67	10.19	7.67	8.86	15.76	25.27	27.56	29.75		
22	17.39	22.80	21.98	11.33	6.03	6.53	13.20	18.51	26.60	30.90	28.34		
38	18.72	25.14	19.88	8.40	6.07	7.12	14.94	23.54	30.16	27.51	33.14		
41	19.49	25.68	31.03	32.13	27.33	16.36	21.16	20.98	30.39	29.98	31.35		
Avg.	18.94	23.83	25.60	20.14	12.15	9.02	13.26	18.89	26.50	27.45	30.17		
Incr. avg.	21.38	24.72	22.87	16.14	10.58	11.14	16.08	22.70	26.98	28.81			
Incr. SWP	-6.50	-5.90	-10.00	-15	-3.00	-1.30	-1.00	-0.25	-0.40	-0.20			
Avg. root depth 103.84 cm													
Total ASW 13.25 cm													
Avg. SWP -6.10 bar													
Profile avg. SWP -4.36 bar													

APPENDIX I-H1

Plant Height and Root Depth Regression Equations

X = Plant height

Y = Root depth

Irrigated

1. $Y = 8.757 + 1.408X$

$R^2 = .953$

$S_{Y \cdot X} = 12.703$

2. $Y = -8.867 + 2.565X - .010X^2$

$R^2 = .994$

$S_{Y \cdot X} = 4.863$

3. $Y = -9.157 + 2.601X - .011X^2 - .000X^3$

$R^2 = .994$

$S_{Y \cdot X} = 5.010$

Nonirrigated

1. $Y = -7.019 + 2.216X$

$R^2 = .987$

$S_{Y \cdot X} = 6.409$

2. $Y = -7.877 + 2.292X - .001X^2$

$R^2 = .987$

$S_{Y \cdot X} = 6.576$

3. $Y = -3.628 + 1.534X + .026X^2 - .0002X^3$

$R^2 = 9.89$

$S_{Y \cdot X} = 6.421$

* / Best fit for regression used in the paper.

APPENDIX I-H2

Root and Top DM Regression Equations

X = Top DM

Y = Root DM

Irrigated

$$\begin{aligned} 1. \quad Y &= 1.256 + .165X \\ R^2 &= .814 \\ S_{Y \cdot X} &= 2.430 \end{aligned}$$

$$\begin{aligned} 2. \quad Y &= -.811 + .430X - .003X^2 \\ R^2 &= .969 \\ S_{Y \cdot X} &= 1.019 \end{aligned}$$

$$\begin{aligned} 3. \quad Y &= -.071 + .233X - .004X^2 - .00005X^3 \\ R^2 &= .988 \\ S_{Y \cdot X} &= .665 \end{aligned}$$

Nonirrigated

$$\begin{aligned} 1. \quad Y &= 0.376 + .265X \\ R^2 &= .872 \\ S_{Y \cdot X} &= 1.770 \end{aligned}$$

$$\begin{aligned} 2. \quad Y &= -.840 + .483X - .004X^2 \\ R^2 &= .924 \\ S_{Y \cdot X} &= 1.403 \end{aligned}$$

$$\begin{aligned} 3. \quad Y &= .156 + .099X + .018X^2 - .0003X^3 \\ R^2 &= .953 \\ S_{Y \cdot X} &= 1.131 \end{aligned}$$

* / Best fit for regression used in the paper.

APPENDIX II

Table II-A1. Soybean root DM from core samples 6.7cm in diameter taken at R9-R9.5.

Nonirrigated					Irrigated				
Depth (cm)	R	1/4R	1/2R	DM (g)	Depth (cm)	R	1/4R	1/2R	DM (g)
<u>Plot 2</u>					<u>Plot 4</u>				
0-30	1.29	.21	.11	1.61	0-30	1.86	.15	.05	2.06
30-60	.05	.03	.14	.22	30-60	.04	.03	.08	.15
60-90	.09	.10	.03	.22	60-90	.15	.13	.03	.31
90-120	.07	.08	.07	.22	90-120	.09	.05	.01	.15
120-150	.20	.02	.00	.22	120-150	.10	.05	.01	.16
150-180	.12	.01	.00	.13	150-180	.01	.03	.00	.04
	<u>1.82</u>	<u>0.45</u>	<u>0.35</u>	<u>2.62</u>		<u>2.25</u>	<u>0.44</u>	<u>0.18</u>	<u>2.87</u>
<u>Plot 22</u>					<u>Plot 23</u>				
0-30	1.72	.27	.17	2.16	0-30	1.39	.07	.09	1.55
30-60	.05	.05	.06	.16	30-60	.22	.20	.04	.46
60-90	.10	.09	.02	.21	60-90	.11	.06	.03	.20
90-120	.04	.17	.08	.29	90-120	.09	.02	.01	.12
120-150	.02	.02	.02	.06	120-150	.03	.00	.02	.05
150-180	.00	.01	.00	.01	150-180	.00	.00	.00	.00
	<u>1.93</u>	<u>.61</u>	<u>.35</u>	<u>2.89</u>		<u>1.84</u>	<u>.35</u>	<u>.19</u>	<u>2.38</u>
<u>Plot 38</u>					<u>Plot 39</u>				
0-30	1.35	.07	.14	1.56	0-30	1.67	.40	.02	2.09
30-60	.10	.02	.01	.13	30-60	.10	.09	.01	.20
60-90	.23	.07	.04	.34	60-90	.20	.06	.02	.28
90-120	.11	.02	.07	.20	90-120	.03	.02	.03	.08
120-150	.01	.04	.03	.08	120-150	.04	.03	.00	.07
150-180	.08	.01	.00	.09	150-180	.00	.01	.00	.01
	<u>1.88</u>	<u>.23</u>	<u>.29</u>	<u>2.40</u>		<u>2.04</u>	<u>.61</u>	<u>.08</u>	<u>2.73</u>

Table II-A2. Corn root DM from core samples 6.7cm in diameter taken at stages 9-10.

Nonirrigated					Irrigated				
Depth (cm)	R	1/4R	1/2R	DM (g)	Depth (cm)	R	1/4R	1/2R	DM (g)
<u>Plot 6</u>					<u>Plot 7</u>				
0-30	.47	.06	.07	.60	0-30	.85	.11	.15	1.11
30-60	.07	.13	.15	.35	30-60	.05	.06	.23	.34
60-90	.14	.01	.05	.20	60-90	.03	.09	.17	.29
90-120	.15	.11	.08	.34	90-120	.01	.08	.10	.19
120-150	.01	.02	.00	.03	120-150	.00	.00	.01	.01
150-180	.00	.00	.01	.01	150-180	.01	.00	.00	.01
	<u>.84</u>	<u>.33</u>	<u>.36</u>	<u>1.53</u>		<u>.95</u>	<u>.34</u>	<u>.66</u>	<u>1.95</u>
<u>Plot 16</u>					<u>Plot 26</u>				
0-30	.21	.17	.05	.43	0-30	1.24	.07	.02	1.33
30-60	.06	.09	.05	.20	30-60	.22	.04	.06	.32
60-90	.08	.06	.05	.19	60-90	.19	.05	.05	.29
90-120	.06	.03	.09	.18	90-120	.10	.02	.02	.14
120-150	.06	.01	.01	.08	120-150	.01	.00	.00	.01
150-180	.01	.00	.00	.01	150-180	.00	.00	.00	.00
	<u>.48</u>	<u>.36</u>	<u>.25</u>	<u>1.09</u>		<u>1.76</u>	<u>.18</u>	<u>.15</u>	<u>2.09</u>
<u>Plot 46</u>					<u>Plot 36</u>				
0-30	.39	.19	.04	.62	0-30	1.13	.06	.03	1.22
30-60	.05	.04	.07	.16	30-60	.19	.03	.02	.24
60-90	.03	.11	.12	.26	60-90	.03	.05	.01	.09
90-120	.06	.26	.19	.51	90-120	.04	.04	.02	.10
120-150	.02	.04	.03	.09	120-150	.01	.01	.005	.03
150-180	.00	.00	.00	.00	150-180	.00	.00	.00	.00
	<u>.55</u>	<u>.64</u>	<u>.45</u>	<u>2.22</u>		<u>1.40</u>	<u>.19</u>	<u>.09</u>	<u>1.68</u>

Table II-A3. Grain sorghum root DM from core samples 6.7cm in diameter at stages 9-10.

Nonirrigated					Irrigated				
Depth (cm)	R	1/4R	1/2R	DM (g)	Depth (cm)	R	1/4R	1/2R	DM (g)
<u>Plot 28</u>					<u>Plot 13</u>				
0-30	1.74	.12	.13	1.99	0-30	2.96	.14	.10	3.20
30-60	.03	.04	.04	.11	30-60	.12	.12	.08	.32
60-90	.01	.03	.03	.07	60-90	.06	.06	.09	.21
90-120	.02	.10	.02	.14	90-120	.01	.04	.05	.10
120-150	.02	.03	.02	.07	120-150	.04	.01	.01	.06
150-180	.01	.01	.01	.03	150-180	.00	.00	.00	.00
	<u>1.83</u>	<u>.33</u>	<u>.25</u>	<u>2.41</u>		<u>3.19</u>	<u>.37</u>	<u>.33</u>	<u>3.89</u>
<u>Plot 48</u>					<u>Plot 31</u>				
0-30	3.07	.05	.07	3.19	0-30	4.47	.11	.07	4.65
30-60	.03	.09	.06	.18	30-60	.03	.03	.09	.15
60-90	.07	.10	.10	.27	60-90	.03	.06	.09	.18
90-120	.02	.01	.01	.04	90-120	.01	.04	.03	.08
120-150	.01	.02	.00	.03	120-150	.01	.01	.01	.03
150-180	.00	.01	.00	.01	150-180	.01	.01	.00	.02
	<u>3.20</u>	<u>.28</u>	<u>.24</u>	<u>3.72</u>		<u>4.56</u>	<u>.26</u>	<u>.29</u>	<u>5.11</u>
<u>Plot 50</u>					<u>Plot 49</u>				
0-30	1.27	.10	.23	1.60	0-30	2.71	.16	.07	2.94
30-60	.06	.09	.07	.22	30-60	.03	.08	.07	.18
60-90	.09	.06	.02	.17	60-90	.03	.06	.06	.15
90-120	.16	.06	.04	.26	90-120	.01	.02	.07	.10
120-150	.04	.03	.04	.11	120-150	.03	.05	.04	.12
150-180	.02	.05	.02	.09	150-180	.02	.04	.01	.07
	<u>1.64</u>	<u>.39</u>	<u>.42</u>	<u>2.45</u>		<u>2.83</u>	<u>.41</u>	<u>.32</u>	<u>3.56</u>

Table II-B1. Soybean plant parameters taken at physiological maturity (R10).

Plant no.	Irrigated				Nonirrigated			
	Plant ht. (cm)	No. pods	No. nodes	No. branch	Plant ht. (cm)	No. pods	No. nodes	No. branch
<u>Plot 4</u>					<u>Plot 2</u>			
1	119	54	22	0	87	34	25	1
2	152	29	21	2	82	36	25	1
3	117	46	24	2	81	31	26	2
4	133	54	26	6	73	14	17	0
5	133	50	25	3	81	35	24	1
6	129	52	29	7	77	37	33	2
7	138	14	20	0	77	32	26	1
8	132	71	29	3	81	35	24	2
9	142	70	27	5	72	21	20	0
10	118	19	21	0	82	46	33	1
$\bar{X}$	131.3	45.9	24.4	2.8	79.3	32.1	25.3	1.1
<u>Plot 23</u>					<u>Plot 22</u>			
1	113	33	22	0	97	39	23	1
2	110	55	48	3	97	45	31	1
3	90	33	27	1	76	32	22	1
4	111	61	40	3	90	40	26	1
5	96	28	22	0	75	43	37	3
6	98	61	42	3	86	31	21	0
7	96	32	30	2	74	44	29	1
8	109	42	32	1	74	73	45	2
9	92	21	19	0	78	38	25	1
10	100	50	43	3	80	30	23	2
$\bar{X}$	101.5	41.6	32.5	1.6	82.5	41.5	28.2	1.3
<u>Plot 39</u>					<u>Plot 38</u>			
1	116	47	30	2	97	31	20	0
2	102	30	22	0	93	31	19	0
3	99	29	22	0	69	12	14	0
4	108	48	33	2	80	27	19	0
5	95	84	77	7	96	35	26	1
6	114	43	23	0	90	33	21	0
7	106	26	20	0	69	22	20	1
8	114	41	25	1	80	27	23	1
9	110	75	54	6	68	35	28	1
10	124	45	24	1	86	66	41	2
$\bar{X}$	108.8	46.3	33.0	1.9	82.8	31.9	23.1	0.6

Table II-B2. Corn plant parameters taken at physiological maturity (stage 10).

Irrigated				Nonirrigated			
Plant no.	Ht. to tassel (cm)	Ht. to last node (cm)	No. nodes	Plant no.	Ht. to tassell (cm)	Ht. to last node (cm)	No. nodes
<u>Plot 7</u>				<u>Plot 6</u>			
1	237	205	14	1	194	162	13
2	207	180	13	2	199	168	15
3	242	215	14	3	193	162	13
4	242	197	13	4	186	153	13
5	220	186	14	5	193	167	14
6	215	180	14	6	192	163	14
7	223	190	14	7	154	131	13
8	221	178	12	8	211	168	14
9	237	205	14	9	209	166	14
10	200	160	12	10	196	165	13
$\bar{X}$	224.4	189.6	13.4	$\bar{X}$	192.7	160.5	13.6
<u>Plot 26</u>				<u>Plot 16</u>			
1	212	169	12	1	175	136	13
2	214	177	13	2	158	123	14
3	219	176	11	3	207	165	14
4	206	178	12	4	190	147	13
5	208	166	13	5	198	153	13
6	221	180	14	6	192	152	13
7	232	191	13	7	165	133	15
8	214	178	14	8	185	148	15
9	223	183	13	9	134	98	14
10	245	200	13	10	208	172	14
$\bar{X}$	21.9	179.8	12.8	$\bar{X}$	181.2	142.7	13.8
<u>Plot 36</u>				<u>Plot 46</u>			
1	222	176	12	1	203	159	14
2	224	192	14	2	194	154	15
3	224	196	14	3	165	135	14
4	231	185	13	4	174	138	13
5	231	191	13	5	186	155	13
6	243	214	16	6	189	149	13
7	235	206	14	7	152	117	10
8	221	177	13	8	171	132	12
9	223	190	14	9	177	140	14
10	185	147	14	10	148	116	12
$\bar{X}$	223.9	187.4	13.7	$\bar{X}$	175.9	116.0	13.0

Table II-B3. Grain sorghum plant parameters taken at physiological maturity (stage 10).

Irrigated				Nonirrigated			
Plant no.	Ht. to top (cm)	Ht. to canopy (cm)	No. nodes	Plant no.	Ht. to top (cm)	Ht. to canopy (cm)	No. nodes
<u>Plot 13</u>				<u>Plot 28</u>			
1	101	69	12	1	92	67	13
2	95	56	12	2	97	69	15
3	95	65	13	3	93	69	14
4	108	66	13	4	85	66	15
5	88	62	13	5	90	67	14
6	92	62	15	6	93	74	13
7	100	68	14	7	89	66	15
8	121	58	13	8	99	67	14
9	99	67	12	9	96	72	14
10	94	65	14	10	106	72	13
$\bar{X}$	99.3	63.5	13.1	$\bar{X}$	94.0	68.9	14
<u>Plot 31</u>				<u>Plot 48</u>			
1	107	78	14	1	88	64	12
2	86	61	13	2	93	68	12
3	114	79	12	3	78	65	12
4	114	76	10	4	72	54	11
5	104	73	14	5	99	68	13
6	120	87	13	6	83	63	13
7	96	74	14	7	91	59	13
8	98	67	14	8	96	66	14
9	100	76	13	9	98	71	12
10	92	65	11	10	98	65	14
$\bar{X}$	103.1	73.6	12.8	$\bar{X}$	89.6	64.3	12.6
<u>Plot 49</u>				<u>Plot 50</u>			
1	84	61	12	1	89	69	13
2	90	62	13	2	90	57	15
3	98	71	15	3	92	63	14
4	98	70	14	4	87	70	15
5	84	57	14	5	86	60	14
6	96	70	13	6	88	69	14
7	107	71	13	7	79	62	14
8	100	73	14	8	90	69	15
9	94	67	14	9	96	71	13
10	92	66	13	10	102	73	16
$\bar{X}$	94.3	66.8	13.5	$\bar{X}$	89.8	66.3	14.3

Table II-C1 and C2.*/

Table II-C3. Soil water content (PV), available soil water (ASW), and soil water potential (ψ s) in irrigated corn.

Plot	Soil depth (cm)										
	Grav.(15)	15	30	45	60	75	90	105	120	135	150
June 12											
		Water content (PV)									
7	34.30	35.83	39.58	40.00	33.59	31.26	29.34	26.14	31.86	35.01	37.25
26	36.92	38.44	41.23	39.12	32.45	29.02	30.99	29.94	32.40	34.64	34.37
36	37.20	35.88	37.89	28.24	23.76	26.23	24.18	33.18	34.87	38.30	37.34
Avg.	36.14	36.72	39.57	35.79	29.93	28.84	28.17	29.75	33.04	35.98	36.32
Incr. avg.	36.43	38.15	37.68	32.86	29.39	28.51	28.51	28.96	31.40	34.51	36.15
Incr. SWP	-.20	-.10	-.4	-2.1	-.3	-.15	-.13	-.2	-.3	-.10	
June 20											
		Total ASW 31.95 cm									
		Avg. SWP -.40 bar									
7	25.23	28.29	35.19	36.38	32.13	30.80	28.24	26.00	31.67	35.06	36.66
26	23.67	31.49	40.27	38.12	30.53	28.02	30.90	29.75	32.27	34.74	35.24
36	26.04	29.11	36.75	28.93	23.35	25.55	23.76	33.14	34.69	38.16	38.71
Avg.	24.98	29.63	37.40	34.48	28.67	28.12	27.63	29.63	32.88	35.99	36.87
Incr. avg.	27.31	33.52	35.94	31.58	28.40	27.88	27.88	28.63	31.26	34.44	36.43
Incr. SWP	-2.8	-.65	-1.0	-3.0	-.35	-.18	-.13	-.2	-.17	-.10	
		Total ASW 28.26 cm									
		Avg. SWP -.86 bar									

*/ See Table I-G1 and I-G2 for soybean data.

Plot	Soil depth (cm)											
	Grav. (15)	15	30	45	60	75	90	105	120	135	150	
June 27												
				Water content (PV)								
7	23.60	24.77	30.35	32.63	30.03	29.25	26.28	25.59	30.94	34.37	36.47	
26	23.91	27.65	34.74	36.15	29.57	26.83	29.80	28.66	32.22	33.64	34.46	
36	22.37	25.27	30.94	24.95	20.70	23.35	21.48	31.44	32.50	36.75	36.98	
Avg.	23.29	25.90	32.01	31.24	26.77	26.48	25.85	28.56	31.89	34.92	35.97	
Incr. avg.	24.60	28.96	31.63	29.01	26.63	26.17	27.21	30.23	33.41	35.45		
Incr. SWP	-3.8	-2.8	-2.9	-4.5	-4.2	-2.2	-1.5	-2.2	-2.2	-1.0		
July 2												
				Total ASW								
				Avg. SWP								
7	24.82	22.80	29.80	31.35	25.78	23.81	22.80	23.72	30.80	33.36	35.74	
26	23.91	25.50	32.72	33.41	26.10	23.72	28.38	28.29	31.08	33.00	33.09	
36	19.24	24.27	27.83	17.55	15.08	20.66	19.28	29.02	32.18	35.88	37.30	
Avg.	22.66	24.19	30.12	27.44	22.32	22.73	23.49	27.01	31.35	34.08	35.38	
Incr. avg.	23.43	27.16	28.78	24.88	22.53	23.11	25.25	29.18	32.72	34.73		
Incr. SWP	-4.9	-1.6	-4.8	-10.0	-8	-28	-2	-2	-2	-1.0		
				Total ASW								
				Avg. SWP								
				22.84 cm								
				-2.16 bar								

Table II-C3 (continued).

		Soil depth (cm)													
Plot	Grav.(15)	15	30	45	60	75	90	105	120	135	150				
July 8															
				Water content (PV)											
7	30.23	33.09	35.19	34.96	25.91	22.35	20.70	22.53	29.11	32.50	35.01				
26	33.82	35.38	38.48	35.70	26.69	24.54	27.74	28.20	30.62	31.86	33.50				
36	30.70	34.14	33.96	20.75	16.27	20.56	19.42	28.88	32.04	35.60	36.88				
Avg.	31.58	34.20	35.88	30.47	22.96	22.48	22.62	26.54	30.59	33.32	35.13				
Incr. avg.	32.89	35.04	33.18	26.72	22.72	22.55	24.58	28.57	31.96	34.23					
Incr. SWP	-.75	-.35	-2.2	-7.0	-.75	-.3	-.18	-.2	-.2	-.2	-.10				
		Total ASW 25.20 cm													
		Avg. SWP -1.20 bar													
July 11															
7	25.34	29.07	33.55	33.82	24.59	20.75	20.43	20.07	29.11	32.50	35.01				
26	29.16	30.30	36.47	22.12	24.91	21.62	25.73	26.55	29.71	31.54	32.27				
36	25.38	27.97	30.07	16.27	11.24	16.91	17.09	28.06	30.94	35.60	26.79				
Avg.	26.63	29.11	33.36	24.07	20.25	19.76	21.08	24.89	29.92	33.21	31.36				
Incr. avg.	27.87	31.24	28.72	22.16	20.01	20.42	22.99	27.41	31.57	32.29					
Incr. SWP	-2.3	1.8	-4.8	-15.0	-1.05	-.4	-.2	-.2	-.2	-.2	-.10				
		Total ASW 21.81 cm													
		Avg. SWP -2.61 bar													

Table II-C3 (continued).

Plot	Soil depth (cm)												
	Grav.(15)	15	30	45	60	75	90	105	120	135	150		
July 16													
				Water content (PV)									
7	20.06	24.13	29.07	28.84	17.82	14.58	17.46	20.61	27.28	31.17	34.42		
26	22.36	26.14	33.59	30.90	15.76	16.13	23.26	26.32	28.24	30.07	32.45		
36	21.21	24.22	26.78	13.25	8.31	10.96	12.66	25.91	29.20	33.91	35.06		
Avg.	21.21	24.83	29.81	24.33	13.96	13.89	17.79	24.28	28.24	31.72	33.98		
Incr. avg.	23.02	27.32	27.07	19.15	13.93	15.84	21.04	26.26	29.98	32.85			
Incr. SWP	-5.0	-4.2	-6.3	-15.0	-2.12	-0.6	-0.25	-0.2	-0.28	-0.10			
				Total ASW 17.91 cm									
				Avg. SWP -3.41 bar									
July 30													
7	21.97	24.59	28.93	28.34	17.32	10.69	12.06	15.95	21.84	27.74	29.89		
26	24.86	27.38	33.04	29.80	14.53	12.06	17.73	22.85	25.78	26.23	30.53		
36	26.35	26.19	27.01	13.07	8.40	9.50	8.31	18.92	23.76	29.43	33.82		
Avg.	24.39	26.05	29.66	23.74	13.42	10.75	12.70	19.24	23.79	27.80	31.41		
Incr. avg.	25.22	27.86	26.70	18.58	12.09	11.73	15.97	29.50	25.80	29.61			
Incr. SWP	-3.8	-3.5	-6.3	-15.0	-2.7	-1.1	-0.5	-0.2	-0.43	-0.15			
				Total ASW 15.89 cm									
				Avg. SWP -1.87 bar									

Table II-C3 (continued).

Plot	Soil depth (cm)											150
	Grav.(15)	15	30	45	60	75	90	105	120	135		
Aug. 14												
				Water content (PV)								
7	34.34	32.50	32.91	28.75	16.50	10.37	11.83	15.63	21.07	26.19	28.75	
26	38.99	36.20	38.76	32.95	15.72	11.79	18.32	17.41	23.99	24.54	29.16	
36	34.08	34.19	34.60	19.70	9.73	10.69	10.14	21.52	23.58	27.79	31.86	
Avg.	35.80	34.30	35.42	27.13	13.98	10.95	13.43	18.19	22.88	26.17	29.92	
Incr. avg.	35.05	34.86	31.28	20.56	12.47	12.19	15.81	20.54	24.53	28.05		
Incr. SWP	-.32	.30	-3.6	-15.0	-2.65	-1.1	-.5	-.3	-.5	-.2		
				Total ASW	16.80 cm							
				Avg. SWP	-2.45 bar							
Aug. 23												
7	29.48	32.63	35.83	30.85	16.59	10.69	11.47	15.67	21.34	26.19	28.79	
26	36.69	35.42	39.40	36.66	17.41	12.47	19.01	21.94	23.54	24.13	28.88	
36	31.44	33.55	35.79	24.31	16.59	17.64	12.70	22.39	23.44	27.42	31.49	
Avg.	32.54	33.87	37.01	30.61	16.86	13.60	14.39	20.00	22.77	25.91	29.72	
Incr. avg.	33.21	35.44	33.81	15.31	15.23	14.00	17.20	21.39	24.34	27.82		
Incr. SWP	-.7	-.35	1.7	-15.0	-1.9	-.8	-.45	-.3	-.52	-.20		
				Total ASW	17.98 cm							
				Avg. SWP	-2.19 bar							

Table II-C4. Soil water content (PV), available soil water (ASW), and soil water potential (ψ s) in nonirrigated corn.

Soil depth (cm)													
Plot	Grav.(15)	15	30	45	60	75	90	105	120	135	150		
June 12													
					Water content (PV)								
6	34.69	36.34	38.12	33.68	29.57	25.64	27.15	23.99	31.12	35.15	38.35		
16	34.34	37.75	38.39	38.44	31.49	27.74	23.31	29.84	33.00	35.15	36.15		
46	35.85	38.85	42.69	42.23	36.70	32.31	33.46	36.93	40.59	38.53	36.84		
Avg.	34.96	37.65	39.73	38.12	32.59	28.56	27.97	30.25	34.90	36.28	37.11		
Incr. avg.	36.31	38.69	38.93	23.57	30.58	28.27	29.11	32.58	35.59	36.70			
Incr. SWP	-.22	-.05	-.2	-11.4	-.2	-.16	-.18	-.13	-.12	-.10			
Total ASW 30.60 cm													
Avg. SWP -1.28 bar													
June 20													
6	24.92	28.15	34.87	32.45	28.24	24.40	26.64	23.03	31.58	35.06	37.66		
16	24.46	29.48	35.60	37.02	31.12	27.42	23.58	29.39	33.87	34.87	36.02		
46	29.04	31.35	40.31	40.82	34.05	31.12	31.35	35.38	39.58	38.39	36.11		
Avg.	26.14	29.66	36.93	36.76	31.14	27.65	27.19	29.27	35.01	36.11	36.60		
Incr. avg.	27.90	33.30	36.85	33.95	29.40	27.42	28.23	32.14	35.56	36.36			
Incr. SWP	-2.3	-.75	-.67	-1.7	-.3	-.18	-.15	-.18	-.13	-.10			
Total ASW 29.73 cm													
Avg. SWP -.65 bar													

June 20

Table II-C4 (continued).

Plot	Soil depth (cm)										
	Grav. (15)	15	30	45	60	75	90	105	120	135	150
June 27											
		Water content (PV)									
6	26.49	25.14	30.39	29.57	24.86	21.66	25.04	21.39	28.88	34.05	35.92
16	24.85	26.37	30.62	34.19	29.71	27.10	22.58	28.98	33.46	34.83	34.64
46	24.25	26.55	35.97	39.22	31.99	29.62	29.30	33.82	38.21	36.93	35.24
Avg.	25.20	26.02	32.33	34.33	28.85	26.13	25.64	28.06	33.52	35.27	35.27
Incr. avg.	25.61	29.18	33.33	31.59	27.49	25.89	26.85	30.79	34.40	35.27	
Incr. SWP	-3.3	-2.8	-2.2	-2.7	-0.4	-0.2	-0.15	-0.2	-0.16	-0.10	
		Total ASW 26.87 cm									
		Avg. SWP -1.22 bar									
July 5											
6	18.46	26.23	29.34	19.74	13.48	14.07	20.88	19.19	26.92	32.08	33.68
16	19.95	24.77	27.56	30.12	24.40	21.07	17.96	26.55	32.27	33.73	33.78
46	23.09	25.14	31.49	35.15	29.30	24.82	24.91	30.16	37.62	37.16	33.59
Avg.	20.50	25.38	29.46	28.34	22.39	19.99	21.25	25.30	32.27	34.32	33.68
Incr. avg.	22.94	27.42	28.90	25.37	21.19	20.62	23.28	28.79	33.30	34.00	
Incr. SWP	-8.2	-4.2	-4.7	-10.0	-0.99	-0.35	-0.2	-0.2	-0.18	-0.10	
		Total ASW 21.85 cm									
		Avg. SWP -2.91 bar									

Table II-C4 (continued).

Plot	Soil depth (cm)											
	Grav.(15)	15	30	45	60	75	90	105	120	135	150	
July 11												
				Water content (PV)								
6	18.00	23.95	27.51	17.46	9.73	9.00	17.18	18.00	26.10	30.94	34.10	
16	19.22	23.54	26.64	26.55	16.45	15.08	15.44	25.73	30.99	32.31	33.23	
46	20.79	23.99	31.12	32.22	20.52	19.56	20.20	26.42	36.56	36.43	33.68	
Avg.	19.34	23.83	28.42	25.41	15.57	14.55	17.61	23.38	31.22	33.23	33.67	
Incr. avg.	21.59	26.13	26.92	20.49	15.06	16.08	20.50	27.30	32.23	33.45		
Incr. SWP	-5.8	-4.9	-7.3	-15.00	1.9	-6.3	-28	-2	-2	-1		
				Total ASW 18.29 cm								
				Avg. SWP -3.63 bar								
July 16												
6	18.37	23.54	26.32	17.04	9.04	7.31	12.11	14.39	23.67	28.20	31.58	
16	19.66	21.94	22.58	24.68	13.57	10.94	12.93	23.49	29.30	31.86	31.44	
46	20.65	22.94	30.30	31.17	16.91	14.30	16.04	23.95	35.28	35.60	32.13	
Avg.	19.56	22.81	26.40	24.30	13.17	10.85	13.69	20.61	29.42	31.89	31.72	
Incr. avg.	21.19	24.61	13.20	18.74	12.01	12.27	17.15	25.02	30.66	31.81		
Incr. SWP	-6.5	-5.6	-15.0	-15.0	-2.6	-1.1	-45	-23	-25	-10		
				Total ASW 14.65 cm								
				Avg. SWP -4.68 bar								

Table II-C5 (continued).

Soil depth (cm)													
Plot	Grav. (15)	15	30	45	60	75	90	105	120	135	150		
July 5													
				Water content (PV)									
13	19.80	24.31	32.77	33.46	28.15	25.50	29.66	27.19	36.43	35.70	35.88		
31	21.73	30.21	34.37	30.39	28.88	28.66	28.84	30.62	30.71	30.58	29.94		
49	24.37	26.23	32.50	29.39	26.32	24.91	32.27	29.71	27.19	28.52	30.76		
Avg.	21.97	26.92	33.21	31.08	27.78	26.36	30.26	29.17	31.44	31.60	32.19		
Incr. avg.	24.45	30.07	32.15	29.43	27.07	28.31	29.72	30.31	31.52	31.90			
Incr. SWP	-4.2	-2.2	-2.7	-4.5	-.40	-.20	-.12	-.20	-.20	-.10			
				Total ASW	26.05 cm								
				Avg. SWP	-1.48 bar								
July 11													
13	---	23.49	31.03	26.10	20.29	20.11	26.42	26.00	34.46	33.46	35.97		
31	23.35	29.07	33.09	28.38	25.23	25.27	27.24	29.75	29.39	29.57	29.02		
49	22.93	25.04	30.94	23.90	16.91	18.05	28.79	27.88	26.37	27.28	30.16		
Avg.	23.14	25.87	31.69	26.13	20.81	21.14	27.48	27.88	30.07	30.10	31.72		
Incr. avg.	24.51	28.78	28.91	23.47	20.98	24.31	27.68	28.98	30.09	30.91			
Incr. SWP	-4.0	-2.7	-4.6	-12.7	-.90	-.25	-.15	-.20	-.25	-.12			
				Total ASW	22.16 cm								
				Avg. SWP	-2.59 bar								

Table II-C5 (continued).

		Soil depth (cm)										
		Grav.(15)	15	30	45	60	75	90	105	120	135	150
July 16												
		Water content (PV)										
13		18.58	22.53	28.70	23.54	13.52	15.99	24.59	23.40	32.91	32.04	34.60
31		23.24	27.97	30.85	21.80	21.02	21.34	26.74	29.43	29.52	30.07	29.62
49		21.45	23.44	30.90	23.22	12.56	11.88	21.80	24.82	25.41	26.83	29.43
Avg.		21.09	24.65	30.15	22.85	15.70	16.40	24.38	25.88	29.28	29.65	31.22
Incr. avg.		22.87	27.40	26.50	19.28	16.05	20.39	25.13	27.58	29.47	30.44	
Incr. SWP		-4.8	-4.0	-6.5	-15	-1.7	-4.0	-20	-20	-30	-12	
		Total ASW 19.21 cm										
		Avg. SWP -3.32 bar										
July 30												
13		30.28	32.54	37.84	32.86	21.25	16.82	22.44	18.69	26.78	27.42	32.08
31		30.10	33.46	35.60	25.68	20.66	18.14	22.94	25.68	26.23	27.65	26.74
49		32.48	33.27	37.94	34.78	25.96	20.84	19.79	17.00	20.24	23.99	27.24
Avg.		30.95	33.09	37.13	31.11	22.62	18.60	21.72	20.46	24.42	26.35	28.69
Incr. avg.		32.02	35.11	34.12	26.87	20.61	20.16	21.09	22.44	25.39	27.52	
Incr. SWP		-90	-30	-1.7	-6.8	-95	-40	-12	-30	-50	-20	
		Total ASW 21.13 cm										
		Avg. SWP -2.07 bar										

Table II-D1. Hydraulic gradients (i) in the 130-150 depth increment in soybean plots.

Date	Nonirrigated						Irrigated					
	Plot			Plot			Plot			Plot		
	2	22	38	$\bar{X}(i)$	S	4	23	39	$\bar{X}(i)$	S	4	23
June 24	.06	-	-	-	-	.00	-	-	-	-	.00	-
1974 25	-.44	.19	-.07	-.11	.32	.00	2.25	.00	.75	1.30	.00	2.25
26	.12	.13	.06	.10	.04	-.06	-.13	-.07	-.09	.04	-.06	-.13
27	.12	-.07	.07	.04	.10	.00	.00	.00	.00	.00	.00	.00
28	.12	-.13	.13	.04	.15	.00	.00	.00	.00	.00	.00	.00
July 1	.12	.06	.07	.08	.03	.25	.13	.00	.13	.13	.25	.13
2	.00	-.07	.25	.06	.17	.19	.07	.00	.09	.10	.19	.07
3	.00	.00	.31	.10	.18	.12	-.06	.00	.02	.09	.12	-.06
8	.12	1.07	-.07	.37	.61	.06	-.06	-.13	.04	.10	.06	-.06
10	.12	1.38	-.19	.44	.83	.12	-.13	-.13	-.05	.14	.12	-.13
12	.06	1.75	-.38	.48	1.12	.06	-.06	-.19	-.06	.13	.06	-.06
15	.00	1.50	.63	.71	.75	.06	-.07	.57	.19	.34	.06	-.07
17	-.43	1.82	.19	.53	1.16	.12	-.06	.57	.21	.32	.12	-.06
19	-.75	1.88	-.25	.29	1.40	.00	-.13	.44	.10	.30	.00	-.13
22	-1.18	1.94	-.07	.23	1.58	-.12	-.19	.57	.09	.42	-.12	-.19
24	-1.37	-.56	-1.13	-1.02	.42	-.56	-.25	-.56	-.46	.18	-.56	-.25
26	-1.81	-1.25	-1.32	-1.46	.31	-.37	-.19	-.32	-.29	.09	-.37	-.19
30	-.12	-3.31	-3.00	-2.14	1.76	-.12	-.25	-.57	-.31	.23	-.12	-.25
Aug. 2	-5.62	-4.38	-5.88	-5.29	.80	-1.06	-.50	-.06	-.54	.50	-1.06	-.50
5	-9.00	-13.00	-12.94	-11.65	2.29	-1.44	-.69	.00	-.71	.72	-1.44	-.69
7	-7.81	3.69	-9.81	-4.64	7.29	-1.50	-.75	.00	-.75	.75	-1.50	-.75
9	-9.50	-5.32	-13.57	-9.46	4.13	-	-	-	-	-	-	-
12	-10.87	-8.13*	-16.81	-11.94	4.44	-.81	-.82	-.19	-.61	.36	-.81	-.82
14	-13.87	-21.75*	-18.50*	-18.04	3.96	-1.00	-.57	-.19	-.59	.41	-1.00	-.57
16	-15.43	-20.44*	19.63*	-	-	-1.00	-.69	-.19	-.63	.41	-1.00	-.69

* / Values for total head > 800cm water.

Table II-D1 (continued).

Date	Nonirrigated						Irrigated				
	Plot						Plot				
	2	22	38	$\bar{X}(1)$	S		4	23	39	$\bar{X}(1)$	S
Aug. 19	-12.87	-18.94*	-21.57*/	-17.79	4.46		-.62	-.63	-.25	-.50	.22
21	-17.00	-21.13*/	-19.19*/	-	-		-1.12	-.69	-.19	-.67	.47
23	-14.50	-21.06*/	-20.88*/	-	-		-.56	-.69	-.07	-.44	.33
27	-19.25*/	-19.13*/	-19.00*/	-	-		-.12	-1.06	-.13	-.44	.54
31	-19.12*/	-18.75*/	-15.94*/	-	-		-1.06	-1.38	-.19	-.88	.62
Sept. 4	-20.69*/	-21.38*/	-20.19*/	-	-		-.68	-1.50	.00	-.73	.75
7	-20.19*/	-21.00*/	-20.00*/	-	-		-.56	-1.69	-.07	-.77	.83
14	-20.44*/	-20.75*/	-18.75*/	-	-		-.62	-2.07	.00	-.90	1.06
17	-19.50	-20.38	-18.19	-	-		-.50	-2.06	-.19	-.92	1.00

Table II-D2. Hydraulic gradients (i) in the 130-150cm depth increment in corn plots.

Date	Nonirrigated					Irrigated				
	Plot					Plot				
	6	16	46	$\bar{X}(i)$	S	7	26	36	$\bar{X}(i)$	S
June 24	.18	.07	-	.13	.08	.12	-	-	-	-
1974 25	.06	.06	.44	.19	.22	.06	.00	.06	.04	.03
26	.06	.00	.44	.17	.24	.00	.13	-.06	.02	.10
27	.06	.19	.38	.21	.16	.00	-.19	.13	-.02	.16
28	.00	.19	.44	.21	.22	.00	-.07	.00	-.02	.04
July 1	-.06	.00	1.06	.33	.63	.00	.06	-.13	-.02	.10
2	.00	.13	1.13	.42	.62	.00	-.07	.00	-.02	.04
3	.00	.06	1.19	.42	.67	-.06	-.06	-.06	-.06	.00
8	-.18	.25	.38	.15	.29	-.19	-.06	.32	.02	.27
10	-.18	.31	.32	.15	.29	.00	-.13	.07	-.02	.10
12	-.31	.25	.25	.06	.32	-.06	-.13	.07	-.04	.10
15	-.50	.38	.00	-.04	.44	-.18	-.13	.07	-.08	.13
17	-.56	.19	.13	-.08	.42	-.25	.13	.13	-.08	.19
19	-.75	.13	.13	-.16	.51	-.31	-.13	.13	-.10	.22
22	-1.00	.00	.32	-.23	.69	-.19	-.13	-.06	-.13	.07
24	-.94	-.63	-.25	-.61	.35	-.37	-.19	-.25	-.27	.09
26	-1.00	-.38	-.44	-.61	.34	-.44	-.19	-.13	-.25	.16
30	-1.31	-1.57	-.88	-1.25	.35	-.81	-.19	-.44	-.48	.31
Aug. 2	-2.37	-2.44	-1.57	-2.13	.48	-	-	-	-	-
5	-2.37	-3.38	-2.38	-2.71	.58	-.62	-.39	-.44	-.48	.12
7	-2.19	-3.00	-2.13	-2.44	.49	-.56	-.32	-.44	-.44	.12
9	-1.62	-2.63	-1.81	-2.02	.54	-.56	-.32	-.38	-.42	.12
12	-1.00	-2.44	-1.94	-1.79	.73	-.81	-.19	-.19	-.40	.36
14	-2.31	-3.13	-2.25	-2.56	.49	-.56	-.25	-.38	-.40	.16
16	-2.12	-3.38	-2.38	-2.63	.67	-.56	-.25	-.25	-.35	.18
19	-1.37	-2.75	-2.31	-2.14	.70	-.43	-.44	-.38	-.42	.03
21	-1.43	-3.19	-2.19	-2.27	.88	-.56	-	-.31	-.44	.18

Table II-D2 (continued).

Date	Nonirrigated					Irrigated				
	Plot					Plot				
	6	16	46	$\bar{X}(t)$	S	7	26	36	$\bar{X}(t)$	S
Aug. 23	-1.31	-2.63	-2.19	-2.04	.67	-.56	.07	-.31	-.27	.32
27	-1.56	-2.19	-1.94	-1.90	.32	-.81	-.25	-.38	-.48	.29
31	-1.68	-2.57	-2.69	-2.31	.55	-.81	-.38	-.44	-.54	.23
Sept. 4	-.81	-1.94	-2.44	-1.73	.84	-.62	-.06	-.31	-.33	.28
7	-.44	-1.50	-2.38	-1.44	.97	-.43	-.25	-.06	-.25	.19
14	-.18	-.75	-1.56	-.83	.69	-.50	-.19	-.32	-.34	.16
17	-.25	-.81	-1.13	-.73	.45	-.37	-.31	-.32	-.33	.03

Table II-D3. Hydraulic gradients (i) in the 130-150cm depth increment in grain sorghum plots.

Date	Nonirrigated					Irrigated				
	Plot					Plot				
	28	48	$\bar{X}$	S		13	31	49	$\bar{X}$	S
June 24	-	-	-.29	-		.25	-	-	-	-
1974 25	.25	.32	.29	.05		.13	1.13	.88	.71	.52
26	.13	.31	.22	.13		.13	1.19	.63	.65	.53
27	.13	.50	.32	.26		.19	1.81	1.19	1.06	.82
28	.19	.44	.32	.18		.13	1.13	1.32	.86	.64
July 1	1.07	.63	.85	.31		.13	1.25	.75	.71	.56
2	.32	.88	.60	.40		.13	1.00	.50	.54	.44
3	.25	.75	.50	.35		.13	1.00	.57	.57	.44
8	.13	.57	.35	.31		.13	.69	.50	.44	.28
10	.19	.82	.51	.45		.13	1.13	.31	.52	.53
12	.25	.69	.47	.31		.31	.56	.06	.31	.25
15	.06	1.69	.88	1.15		-.32	.53	.25	.15	.43
17	-.06	1.63	.79	1.20		-.06	.38	.13	.15	.22
19	-.25	2.13	.94	1.68		-.69	.25	-.56	-.33	.51
22	-.44	1.94	.75	1.68		-1.38	-.19	-1.81	-1.13	.84
24	-.75	1.19	.22	1.37		-1.19	.19	-2.19	-1.06	1.20
26	-.44	.25	-.10	.49		-1.07	.00	-2.56	-1.21	1.29
30	-1.00	1.81*/	-	-		-	.07	-2.56	-1.25	1.86
Aug. 2	-2.44	11.57*/	-	-		-	-	-	-	-
5	-10.88	3.00*/	-	-		-.88	.88	-2.00	-.67	1.45
7	-6.07	-.32*/	-	-		-.88	1.13	-1.13	-.29	1.24
9	-7.07	-1.25*/	-	-		-	-	-	-	-
12	-7.32	.00*/	-	-		.06	-2.25	-2.63	-1.61	1.46
14	-12.75	-4.69*/	-	-		-.13	-1.88	-2.00	-1.34	1.05
16	-13.13	-.88	-	-		-.13	1.57	-1.38	.02	1.48

*/Values for total head >800cm of water.

Table II-D3 (continued).

Date	Nonirrigated				Irrigated				
	Plot		$\bar{X}$	S	Plot				
	28	48			13	31	49	$\bar{X}$	S
Aug. 19	-10.32	.00 ^{*/}	-	-	.00	1.13	-1.44	-.10	1.29
21	-11.81 ^{*/}	-.31 ^{*/}	-	-	.00	1.07	.88	.65	.57
23	-10.19 ^{*/}	.00 ^{*/}	-	-	-.07	1.00	.69	.54	.55
27	-15.13 ^{*/}	.00 ^{*/}	-	-	-.19	1.00	.25	.35	.60
31	-13.25 ^{*/}	.13 ^{*/}	-	-	-.25	.94	.56	.42	.61
Sept. 4	-15.00 ^{*/}	.19 ^{*/}	-	-	-.32	1.13	.75	.52	.75
7	-14.69 ^{*/}	.32 ^{*/}	-	-	-.25	-	.63	.19	.62
14	-13.50 ^{*/}	-.25 ^{*/}	-	-	-.44	-	.63	.10	.76
17	-12.31 ^{*/}	.81 ^{*/}	-	-	-.44	-	.63	.10	.76

Table II-E. Irrigation schedule for soybeans, corn, and grain sorghum.

Crop	Date irrigated	Water (cm)	Plot size
Soybeans	6/28, 7/22, 8/9	10.0/application	10 30-in. row x 40 ft.
Corn	7/3, 7/17, 7/31	10.0/application	10 30-in. row x 40 ft.
Grain sorghum	7/22, 7/31, 8/9	10.0/application	10 30-in. row x 40 ft.

GENERAL APPENDIX--Gen.

Table Gen-1. Soybeans physiological stages of development (Hanway and Thompson, 1971).

Stage no.	Description	1974	
		Month	Day
	Planting	May	13
	Emergence		20
V0	Unifoliate leaves emergence		24
V1	Develop 1st trifoliate leaves		31
V2	Four nodes	June	14
V3	Six nodes		21
R4	Beginning bloom		25
R5	Full bloom	July	1
R5.5	Beginning of pod development		22
R6	Rapid pod growth		30
R7	Beans beginning to develop	Aug.	8
R8	Beans beginning to develop at top 4 nodes		14
R9	Beans full size		19
R10	Physiological maturity	Sept.	14
R11	Harvest maturity		19

Table Gen-2. Corn physiological stages of development (Hanway, 1966).

Stage no.	Description	1974	
		Month	Day
	Planting	May	13
0	All emerged that will due to crust (approximately 2/3 May 13 planting)		20
0.5	2 leaves fully emerged		24
1	4 leaves fully emerged		31
1.5	6 leaves fully emerged	June	9
2	8 leaves fully emerged		16
2.5	10 leaves fully emerged		21
3	12 leaves fully emerged		27
3.5	14 leaves fully emerged	July	5
4	16 leaves fully emerged		10
5	Silks emerging		17
6	Blister stage		31
7	Dough stage	Aug.	12
8	Beginning dent stage		23
9	All kernels fully developed	Sept.	1
10	Physiological maturity		9
	Harvest maturity		26

Table Gen-3. Grain sorghum physiological stages of development (Vanderlip, 1972).

Stage no.	Description	1974	
		Month	Day
	Planting	May	21
0	Emergence		29
1	3-leaf stage	June	6
2	5-leaf stage		14
3	Growing point differentiation		24
4	Flag leaf visible	July	8
5	Boot stage		21
6	Half-bloom		30
7	Soft-dough	Aug.	10
8	Hard-dough		23
9	Physiological maturity	Sept.	5
	Harvest maturity		11

Table Gen-4. Rainfall at Ashland Agronomy Farm, 1974.

Date	Inches	Cm	Date	Inches	Cm
3/11	.61	1.55	8/7	.03	.08
4/3	.25	.65	8/8	.34	.86
4/11	.20	.51	8/11	.10	.25
4/20	2.20	5.59	8/14	.43	1.09
4/29	.71	1.80	8/16	.39	.98
4/30	.65	1.65	8/17	1.40	3.56
5/9	.32	.81	8/22	.12	.30
5/10	.44	1.12	8/24	.02	.05
5/11	.18	.46	8/31	1.50	3.81
5/14	.52	1.32	9/2	.55	1.40
5/18	.12	.30	9/6	.05	.13
5/23	.43	1.09	9/15	.20	.51
5/25	.53	1.35	10/6	1.05	2.67
6/6	.96	2.44	10/11	Trace	
6/7	1.20	3.05	10/22	.72	1.83
6/8	1.65	4.19	10/25	.42	1.07
6/11	.54	1.37	10/28	.46	1.17
6/13	.38	.96	10/29	.30	.76
7/3	.38	.96	10/31	1.30	3.30
7/25	1.10	2.79	10/31	.28	.71
7/31	.01	.02	11/2	.03	.08
8/5	.22	.56	11/3	.24	.61
8/6	.52	1.32			

Table Gen-5. Values of soil water content, soil water potential, and bulk density of Muir silt loam.*

Soil water potential (bars)	Depth (cm)									
	0-15	15-30	30-45	45-60	60-75	75-90	90-105	105-120	120-135	135-150
	Soil water content cm^3/cm^3									
-1	.391	.377	.405	.404	.379	.377	.377	.386	.411	.410
-2	.359	.361	.392	.395	.304	.258	.223	.275	.327	.286
-8	.329	.345	.375	.375	.194	.141	.141	.122	.206	.192
-1.4	.316	.336	.366	.368	.179	.133	.130	.112	.174	.161
-2.0	.301	.328	.357	.362	.171	.127	.125	.104	.160	.153
-5.0	.204	.237	.269	.266	.089	.065	.085	.056	.093	.059
-10.0	.189	.207	.235	.236	.081	.058	.078	.053	.085	.052
-15.0	.173	.193	.196	.223	.076	.057	.073	.049	.078	.051
	Soil bulk density g/cm^3									
	1.37	1.29	1.38	1.30	1.28	1.28	1.30	1.37	1.32	1.38

*/Randall Brady's values for Muir silt loam (Ashland Bottoms).

MEASURING DEPTH AND DISTRIBUTION OF ROOTS
FOR PREDICTING SOIL WATER DEPLETION

by

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B. Sc., Kansas State University, 1969

AN ABSTRACT OF A MASTER'S THESIS

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Relative growth rate of soybean [Glycine max (L.), cv. 'Williams'] tops and roots was measured in relation to physiological stage under irrigated and nonirrigated conditions to investigate the relationship between the two (tops and roots). This relationship would aid in estimating the timing and amount of water required for irrigation of the crop in a barrier free soil. Observation of root depth and dry matter accumulation were made from soil monoliths 75cm wide, 7.5cm thick, and 180cm deep (partitioned into 15cm increments). Roots were washed using 35 mesh screen and oven dried at 100C. Soil water measurements were made using neutron moderation and gravimetric sampling. Soybean roots reached 160cm depth in both treatments, but the irrigated soybeans grew down slightly faster than the nonirrigated during the drought in June and July. Dry matter of the irrigated tops accumulated faster than the nonirrigated soybean tops. Approximately 89% of the root dry matter was concentrated in the upper 0-15cm of the irrigated soybeans at the early vegetative stage (V0-V3) compared with 85% in the nonirrigated. At physiological maturity (R10), 67% of the root dry matter was in the 0-15cm, 89% in the 0-90cm, and 99% in the 0-150cm increment for the irrigated soybeans compared with 51% of root dry matter in the upper 0-15cm, 83% in the 0-90cm, and 99% in the 0-150cm increment for the nonirrigated soybeans. Coefficient of determination (R^2) values for the relation between plant height and root depth were 0.994 and 0.987 for irrigated and nonirrigated soybeans, respectively.

Root distribution in relation to water depletion, available soil water, and hydraulic gradient was investigated under irrigated and nonirrigated conditions for soybeans, corn, and grain sorghum. The irrigated plots received 30cm of water in 3 applications under furrow irrigation using gated pipes. Soil cores 6.7cm in diameter were taken in-row, 1/4 row

and 1/2 row for each crop at maturity. In all crops and treatments studied, root dry matter was measured at 150-180cm depth increment except for irrigated corn. Total root dry weight measured was 2.66g, 1.91g, and 4.19g in irrigated; 2.64g, 1.42g, and 2.86g in nonirrigated soybeans, corn, and grain sorghum, respectively. Seed yield differences between treatments were significant only in corn at the 5% probability level.

In the irrigated crops, approximately 71%, 64% and 86% of the root dry matter was in the upper 0-30cm for soybeans, corn, and grain sorghum, respectively. Seasonal water use was 60.7cm, 62.9cm and 49.6cm by soybeans, corn, and grain sorghum, respectively. Hydraulic gradients in the 130-150cm layer during the season were between 0 and -1. In the nonirrigated crops, approximately 67%, 70%, and 79% of the root dry matter was in the upper 0-30cm for soybeans, corn, and grain sorghum, respectively. Seasonal water use was about 38cm for each crop. Hydraulic gradient decreased to -18 during August in soybeans and decreased to -2 in corn and remained there until late in the season.