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# SCHEDULING IRRIGATION USING COMPUTED EVAPOTRANSPIRATION

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**SUMMARY:**

The 1982 results of an irrigation scheduling experiment with corn, grain sorghum and soybeans, conducted at Colby, Kansas, suggest that using calculated ET in a water budget is a reliable method of scheduling irrigation.

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## ABSTRACT

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## INTRODUCTION

Diminishing water supplies and increasing pumping costs have increased the need for efficient use and conservation of water and energy. Production costs have risen sharply over and many farmers are facing a steadily decreasing profit margin. It is well documented that irrigation scheduling saves water and energy but many methods have met little farmer acceptance. Some of the methods are complicated and others are too time consuming.

The Kansas State University Northwest Area Extension Office has been reporting daily evapotranspiration for corn, grain sorghum and soybeans for farmers to use in a water budget for irrigation scheduling. The method is simple and similar to balancing a checkbook. However, the use of this method in Northwest Kansas appears to be minimal. This may be due to misunderstanding the process or to the lack of locally demonstrated results of the method's validity.

In 1982 the KSU Colby Branch Experiment Station and the KSU Northwest Area Extension Office entered into a joint project with the Northwest Kansas Groundwater Management District #4. The objectives of the study were to compare estimated evapotranspiration (ET) to measured water use, and to evaluate heavy, normal and limited irrigation scheduling methods in terms of yields, water use and water use efficiency. An additional objective was to provide a local demonstration of the effectiveness of irrigation scheduling. This report will discuss the 1982 field results.

## PROCEDURE

The project was initiated in 1982 on the Colby Branch Experiment Station at Colby, Kansas, on a deep, well drained, loessial Keith silt loam soil. This medium-textured soil, typical of many western Kansas soils, is described in more detail by Bidwell et al. (1980). The 1.5 m (5-ft.) soil profile will hold approximately 25 cm (10 inches) of available water at field capacity. This corresponds to a volumetric soil moisture content of approximately 0.30 and a profile bulk density of approximately 1.3 $gm/cm.^3$

The climate can be described as semi-arid, with an average annual precipitation of 46.9 cm (18.5 in).

Each crop (corn, soybeans and grain sorghum) was grown in a separate level basin 183 m (600 ft.) by 30 m (100 ft.) with the plots arranged in a complete randomized block design with 6 irrigation treatments and 3 replications. The plots, approximately 30 m (100 ft.) by 5 m (15 ft.), were moldboard plowed and double disked in the fall. In the spring the plots were double disked and firmed before planting. The corn, soybeans and grain sorghum were fertilized preplant incorporated with ammonia nitrate at respective rates of 213 kg/ha, 67 kg/ha, and 112 kg/ha (190 lbs/a, 60 lbs/a, and 100 lbs/a) of actual nitrogen. The corn (Pioneer 3183) was planted on May 4, 1982 with a target population of approximately 53000 plants/ha (21,500 plants/a). Excessive precipitation delayed the planting of the soybeans (Williams) and grain sorghum (Dekalb B-38+) to June 8, and June 18, 1982 respectively with equal target populations of 247,000 plants/ha (100,000 plants/a). A planter malfunction resulted in the soybean plant population being closer to 173,000 plant/ha (70,000 plants/a).

Each replication was instrumented with a neutron access tube to a depth of 150 cm (5-ft.) for soil moisture determinations. Soil moisture was measured on an approximately weekly basis in 30 cm (1-ft.) increments.

Potential ET (PET) was calculated using a modified Penman approach with climatic data obtained at the Experiment Station. The actual ET (AET) was determined by multiplying PET by a crop coefficient (Kco). Crop coefficients were generated by equations developed by Kincaid and Heerman, (1974) based on work by Jensen ( 1969) and Jensen et al. (1970, 1971). The procedure for selecting crop coefficients was to assume 70 days from emergence to full canopy for corn and grain sorghum and 65 days for soybeans. Physiological maturity was assumed to occur at 105 days from emergence for grain sorghum; 130 days for corn and soybeans.

Each plot (replication) was separated by small irrigation borders so that each could be irrigated separately. Irrigation was metered on each replication through gated pipe. To schedule irrigation, an initialization point (IP) for soil moisture depletion was selected, field capacity having a IP of zero. The summation of all ET since the last irrigation (multiplied by a factor of 1.4, 1.2, 1.0, 0.8, 0.6, or 0.4 to give heavy, normal or limited irrigation treatments) was then subtracted from the IP. The summation of all precipitation since the last irrigation was added to the IP. Values of IP greater than field capacity were truncated back to field capacity. Irrigation was initiated when IP reached a range of -7.6 to -12.7 cm (-3 to -5 in.) depletion. This floating depletion range was used strictly to help manage the period between irrigation. This allowed dates for the irrigation treatments to be shifted slightly to accomodate irrigation needs of other studies. In all cases, the irrigation amount was equal to the amount required to bring IP to zero again.

The corn, soybeans, and grain sorghum were hand harvested for yield component analysis on October 5, 10, and 19, 1982, respectively.

## RESULTS AND DISCUSSION

Crop Year 1982

The period from May through the middle of July was characterized by cool wet weather which delayed grain sorghum and soybean plantings until June. There was a 45 day period beginning at the middle of July with less than 8 mm (0.31 in.) of precipitation. Fortunately, temperatures were moderate and evapotranspiration was not excessive. A heavy rainstorm of 79 mm. (3.10 in.) on August 30, 1982 dumped 79 mm (3.10 in.) of rain on the plots. However, the borders around each plot contained the rainfall.

The late planting of the soybeans and grain sorghum probably had an effect on yields, stage of growth, water use and other physiological processes.

Water Use and Irrigation

There were significant differences in water use and irrigation amounts due to irrigation treatments (Table 1). The general trends were for reduced water use as irrigation was decreased. Water use efficiency tended to decrease with increasing irrigation.

Actual water use was estimated by taking differences between successive weekly soil moisture measurements and adding all precipitation and irrigation. This method tends to be an inaccurate measure of crop water use during periods of excessive precipitation and/or following irrigation. It is assumed drainage is the major cause of this inaccuracy, as runoff was contained. Possibly luxurious crop water consumption occurred, but in many cases the measured water use was higher than the potential ET.

Table 2 shows calculated and measured water use for corn during the growing season. It appears calculated ET is a conservative estimate of actual water use; with the exception of periods of irrigation and/or excessive rainfall. Therefore, use of calculated ET to schedule irrigation appears to be a safe and reliable method. It could perhaps be improved with soil moisture measurements but many farmers do not have the time or desire to make these measurements. In some cases an ET-based scheduling method is better than a soil moisture method. The ET method might suggest that irrigation is needed whereas the soil moisture still might be high due to low root development.

Figure 2 shows the seasonal variation of available soil moisture (1.5 m soil profile) of corn for the six irrigation treatments. The treatments 1.4 ET down through 1.0 ET maintained soil moisture at or near field capacity for the entire season. This indicates the normal treatment (1.0 ET) was equal to the heavier irrigated treatments in maintaining good soil moisture for growth. There was some deterioration in soil moisture conditions for the limited irrigation treatments. However, even the 0.4 ET treatment was over 60% of field capacity at season's end.

Calculated water use for grain sorghum was usually greater than the measured water use with the exception of periods of excessive rain and/or irrigation (Table 1). Selection of crop coefficients was poor in 1982 due to the late planting. Fairly high crop coefficients were being used late in the season even though the crop was maturing, thus overestimating ET.

Figure 3 shows the seasonal variation in available soil moisture (1.5 m soil profile) for grain sorghum. Results are somewhat similar to those found for corn. Soil moisture was adequately maintained by all treatments except 0.4 ET, which was never irrigated. After the heavy rainstorm of August 30, 1982 soil moisture in the 0.4 ET treatment was returned to an acceptable level.

Calculated ET overestimated actual water use for soybeans throughout the season (Table 4), probably due to the lateness of planting and inadequate stands. Figure 4 shows seasonal variation in available soil moisture (1.5 soil profile) for soybeans. The long period (June-July) of high soil moisture may have been detrimental to soybeans in terms of root development. Soybeans are sensitive to overirrigation and wet soil conditions may have played a part in the associated yield reductions of the heavily irrigated treatments.

Yields

There were no significant differences (.05 confidence level) in yields as a result of irrigation treatment for any of the three crops but there were some important trends (Table 1). The normal thru heavy irrigation treatments (1.0 ET - 1.4 ET) gave equal corn yields at 12,000 kg/ha (191 bu/a). However, the heaviest irrigation treatment received 6.1 cm (2.4 in.) more irrigation than the normal treatment. It is interesting to note that had the August 30th irrigation for treatment 1.0 ET been delayed one day, the differences would have been over 17 cm (6.8 in.) in irrigation water use. The corn limited irrigation treatments gave equal yields of approximately 10,500 kg/ha (168 bu/a). These are excellent yields especially for the 0.4 ET treatment which received only 7.6 cm (3.0 in.) of irrigation. Looking at Figure 2 again with the yield results in mind, one might hypothesize that the major yield difference between full and limited irrigaton was due to the July 26th irrigation. The corn entered the silk stage around August 1st. Presumably, the delay in irrigation for the limited irrigation treatments caused much of the yield difference. The results from a yield component analysis (Table 5) for corn are somewhat mixed. There were differences in plant population that were not a result of irrigation treatment. The number of seeds/ear and the seed weight was significantly higher for the full irrigation treatments. Corn yields were most sensitive to the number of seeds/ear. This appears to be a logical result but should be taken with caution as plant population was not held constant.

Although there were no significant differences (Table 1) in grain sorghum yields, the trend was toward higher yields for full irrigation than for limited irrigation. Yields were relatively low due to late planting and considerable bird damage. The yield response curve (Figure 5) for grain sorghum was fairly flat as compared to corn. There were no significant differences in the yield component analysis (Table 6) for grain sorghum, but the trend was for increased heads/unit area, seeds/head, and seed weight with heavier irrigation.

Soybeans responded negatively to irrigation (Figure 5) although the response was slight and was not significant (.05 confidence level). Yields were highest for the limited irrigation treatments (Table 7). As stated earlier, yields may have been reduced due to high soil moisture levels throughout the season (Figure 4). A yield component analysis showed seed weight and number of pods/plant were responsible for yield differences.

## CONCLUSIONS

Using calculated ET in a water budget is an acceptable method of irrigation scheduling. More data is needed to determine if the crop coefficient selection technique is acceptable. The normal irrigation treatment yielded as well as the heavier irrigation treatment especially for corn. There was no significant seasonal deterioration in soil moisture when normal irrigation was practiced. Using calculated ET as a reference appears to be beneficial in a limited irrigation scheme also.

The abnormally wet early season probably significantly affected yields, water use and water use efficiencies. However, most trends seem to be logical. More data are needed before any firm conclusions can be drawn.

## ACKNOWLEDGEMENTS

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Table 1. Summary of yields and water use data from an irrigation scheduling study. Colby, Ks. 1982.

| CROP | ET FACTOR | IRRIG #. | IRRIGATION AMOUNT mm | WATER USE mm | YIELD kg/ha | WUE kg/ha-mm |
|---|---|---|---|---|---|---|
| Corn | 1.4 | 3 | 338 | 765 | 11938 | 15.7 |
| | 1.2 | 3 | 282 | 721 | 11926 | 16.5 |
| | 1.0 N | 3 | 277 | 701 | 12045 | 17.3 |
| | 0.8 | 2 | 211 | 691 | 10401 | 15.1 |
| | 0.6 | 1 | 84 | 597 | 10827 | 18.1 |
| | 0.4 | 1 | 76 | 589 | 10463 | 17.8 |
| LSD .05= | | | | 61 | NS | NS |
| Grain sorghum | 1.4 | 2 | 206 | 526 | 6164 | 11.8 |
| | 1.2 | 2 | 173 | 511 | 5881 | 11.6 |
| | 1.0 N | 2 | 173 | 521 | 5988 | 11.5 |
| | 0.8 | 1 | 112 | 450 | 5743 | 12.8 |
| | 0.6 | 1 | 81 | 421 | 5291 | 12.4 |
| | 0.4 | 0 | 0 | 358 | 5335 | 15.0 |
| LSD .05= | | | | 43 | NS | 1.7 |
| Soybean | 1.4 | 2 | 257 | 665 | 2307 | 3.5 |
| | 1.2 | 2 | 216 | 620 | 2643 | 4.3 |
| | 1.0 N | 2 | 178 | 579 | 2569 | 4.4 |
| | 0.8 | 2 | 165 | 587 | 2730 | 4.7 |
| | 0.6 | 1 | 104 | 521 | 2791 | 5.4 |
| | 0.4 | 1 | 79 | 511 | 2757 | 5.4 |
| LSD .05= | | | | 42 | NS | .8 |

Table 2. Corn water use data during the growing season for an irrigation scheduling study. Colby Ks. 1982.

| PERIOD | RAIN | CALCULATED DAILY ET | | MEASURED IRRIGATION AND WATER USE TREATMENT FACTOR | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 1.4 | 1.2 | 1.0 | 0.8 | 0.6 | 0.4 |
| | mm | mm/day | | mm and mm/day | | | | | |
| May 4 - Jun 23 | 189 | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 1.0 | <-> | 2.3 | 2.0 | 2.0 | 2.8 | 2.0 | 2.3 |
| Jun 23 - Jul 16 | 167 | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 4.0 | <-> | 6.9 | 6.4 | 7.1 | 6.9 | 7.4 | 7.1 |
| Jul 16 - Jul 26 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 6.6 | <-> | 5.6 | 7.4 | 6.9 | 5.8 | 5.8 | 6.1 |
| Jul 26 - Aug 2 | 2 | | | 142 | 115 | 88 | 0 | 0 | 0 |
| | | 5.3 | <-> | 13.7 | 11.1 | 7.9 | 3.6 | 2.8 | 3.8 |
| Aug 2 - Aug 9 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 7.1 | <-> | 5.3 | 5.3 | 4.9 | 4.3 | 4.6 | 4.8 |
| Aug 9 - Aug 16 | 3 | | | 111 | 94 | 77 | 122 | 83 | 0 |
| | | 5.0 | <-> | 11.4 | 9.9 | 8.4 | 12.4 | 6.9 | 2.0 |
| Aug 16 - Aug 20 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 6.1 | <-> | 4.0 | 3.8 | 3.6 | 3.3 | 4.0 | 3.0 |
| Aug 20 - Aug 25 | 3 | | | 85 | 72 | 0 | 0 | 0 | 77 |
| | | 5.8 | <-> | 15.0 | 12.7 | 5.0 | 3.8 | 5.0 | 11.1 |
| Aug 25 - Aug 30 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 5.6 | <-> | 3.0 | 2.8 | 3.3 | 2.3 | 5.0 | 1.8 |
| Aug 30 - Sep 7 | 81 | | | 0 | 0 | 112 | 88 | 0 | 0 |
| | | 4.3 | <-> | 6.1 | 7.1 | 11.7 | 12.4 | 5.6 | 5.3 |
| Sep 7 - Sep 21 | 43 | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 3.0 | <-> | 4.8 | 5.0 | 5.1 | 3.8 | 4.0 | 4.0 |
| TOTAL | 487 | | | 338 | 282 | 277 | 211 | 84 | 76 |
| | | 3.6 | <-> | 5.3 | 5.1 | 5.1 | 4.8 | 4.3 | 4.3 |

Table 3. Grain Sorghum water use data during the growing season for an irrigation scheduling study. Colby, Ks. 1982

| PERIOD | RAIN | CALCULATED DAILY ET | | MEASURED IRRIGATION AND WATER USE TREATMENT FACTOR | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 1.4 | 1.2 | 1.0 | 0.8 | 0.6 | 0.4 |
| | mm | mm/day | | mm and mm/day | | | | | |
| Jun 24 - Jul 14 | 156 | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 1.3 | <-> | 6.6 | 6.6 | 6.6 | 6.1 | 6.6 | 6.1 |
| Jul 14 - Jul 28 | 13 | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 2.5 | <-> | 2.8 | 3.6 | 3.6 | 3.6 | 2.8 | 3.6 |
| Jul 28 - Aug 9 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 4.1 | <-> | 3.3 | 2.5 | 3.3 | 3.3 | 2.8 | 3.3 |
| Aug 9 - Aug 16 | 3 | | | 104 | 88 | 72 | 0 | 0 | 0 |
| | | 3.6 | <-> | 11.7 | 10.7 | 8.1 | 2.3 | 2.3 | 2.5 |
| Aug 16 - Aug 25 | 3 | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 5.6 | <-> | 3.0 | 3.3 | 3.3 | 3.6 | 3.3 | 3.6 |
| Aug 25 - Aug 30 | 0 | | | 102 | 86 | 0 | 112 | 81 | 0 |
| | | 6.1 | <-> | 18.0 | 14.7 | 3.3 | 17.3 | 16.0 | 3.8 |
| Aug 30 - Sep 7 | 81 | | | 0 | 0 | 100 | 0 | 0 | 0 |
| | | 5.3 | <-> | 6.9 | 7.6 | 17.5 | 6.9 | 7.9 | 2.3 |
| Sep 7 - Sep 21 | 43 | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 4.8 | <-> | 4.0 | 4.0 | 4.0 | 3.3 | 3.8 | 4.0 |
| TOTAL | 299 | | | 206 | 173 | 173 | 112 | 81 | 0 |
| | | 3.6 | <-> | 5.8 | 5.8 | 5.8 | 5.1 | 4.8 | 4.0 |

Table 4. Soybean water use data during the growing season for an irrigation scheduling study. Colby, Ks. 1982.

| PERIOD | RAIN | CALCULATED DAILY ET | | MEASURED IRRIGATION AND WATER USE TREATMENT FACTOR | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 1.4 | 1.2 | 1.0 | 0.8 | 0.6 | 0.4 |
| | mm | mm/day | | mm and mm/day | | | | | |
| Jun 10 - Jul 6 | 162 | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 1.0 | <-> | 5.1 | 4.3 | 5.0 | 5.0 | 4.8 | 5.1 |
| Jul 6 - Jul 28 | 48 | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 2.8 | <-> | 3.6 | 4.3 | 4.0 | 4.3 | 4.8 | 4.0 |
| Jul 28 - Aug 9 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 5.3 | <-> | 3.8 | 3.8 | 4.0 | 3.8 | 3.8 | 4.0 |
| Aug 9 - Aug 16 | 3 | | | 135 | 115 | 94 | 74 | 0 | 0 |
| | | 4.3 | <-> | 15.2 | 11.9 | 9.1 | 7.9 | 2.5 | 3.3 |
| Aug 16 - Aug 25 | 3 | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 6.9 | <-> | 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.3 |
| Aug 25 - Aug 30 | 0 | | | 121 | 101 | 85 | 0 | 104 | 0 |
| | | 7.9 | <-> | 24.1 | 20.8 | 16.3 | 4.8 | 13.2 | 3.8 |
| Aug 30 - Sep 7 | 81 | | | 0 | 0 | 0 | 92 | 0 | 79 |
| | | 5.6 | <-> | 9.4 | 8.4 | 7.9 | 17.8 | 8.1 | 10.9 |
| Sep 7 - Sep 21 | 43 | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 4.3 | <-> | 4.3 | 4.8 | 5.1 | 4.3 | 4.0 | 5.0 |
| TOTAL | 339 | | | 257 | 216 | 178 | 165 | 104 | 79 |
| | | 3.8 | <-> | 6.4 | 5.8 | 5.6 | 5.6 | 5.1 | 4.8 |

Table 5. Corn yield component analysis for an irrigation scheduling study. Colby, Ks. 1982.

| ET Factor | Plants /Hectare | Ears /Plant | Seeds /Ear | Seed wt. Gm/100 | Yield Kg/Ha |
|---|---|---|---|---|---|
| 1.4 | 55948 | 1.01 | 655 | 32.3 | 11938 |
| 1.2 | 52362 | 1.08 | 640 | 32.9 | 11926 |
| 1.0 Normal | 53080 | 1.03 | 696 | 31.7 | 12045 |
| 0.8 | 57383 | 0.96 | 613 | 30.6 | 10401 |
| 0.6 | 50210 | 1.01 | 682 | 31.2 | 10827 |
| 0.4 | 56664 | 0.99 | 572 | 32.7 | 10463 |
| LSD.05 = | 1576 | NS | 62 | 1.4 | NS |
| Mean Full | 53730 | 1.04 | 664 | 32.3 | 11970 |
| Mean Limited | 54752 | 0.99 | 622 | 31.5 | 10564 |

Table 6. Grain sorghum yield component analysis for an irrigation scheduling study. Colby, Ks. 1982

| ET Factor | Heads /Hectare | Seeds /Head | Seed wt. Gm/100 | Yield Kg/Ha |
|---|---|---|---|---|
| 1.4 | 191516 | 1270 | 2.54 | 6164 |
| 1.2 | 167218 | 1341 | 2.66 | 5881 |
| 1.0 Normal | 178588 | 1285 | 2.64 | 5988 |
| 0.8 | 172154 | 1297 | 2.60 | 5743 |
| 0.6 | 164257 | 1256 | 2.61 | 5291 |
| 0.4 | 180038 | 1182 | 2.54 | 5335 |
| LSD.05 = | NS | NS | NS | NS |
| Mean Full | 179077 | 1298 | 2.61 | 6013 |
| Mean Limited | 172149 | 1245 | 2.58 | 5455 |

Table 7. Soybean yield component analysis for an irrigation scheduling study. Colby, Ks. 1982.

| ET Factor | Plants /Hectare | Pods /Plant | Seeds /Pod | Seed wt. Gm/100 | Yield Kg/Ha |
|---|---|---|---|---|---|
| 1.4 | 147760 | 55.4 | 2.0 | 14.6 | 2307 |
| 1.2 | 164976 | 50.3 | 2.3 | 15.2 | 2643 |
| 1.0 Normal | 160671 | 56.3 | 1.9 | 15.5 | 2569 |
| 0.8 | 149195 | 65.0 | 2.0 | 14.6 | 2730 |
| 0.6 | 145609 | 68.1 | 1.9 | 16.3 | 2791 |
| 0.4 | 172149 | 62.5 | 1.7 | 16.3 | 2757 |
| LSD.05 = | NS | NS | NS | 1.0 | NS |
| Mean Full | 157801 | 54.0 | 2.1 | 15.1 | 2508 |
| Mean Limited | 155650 | 65.2 | 1.9 | 15.7 | 2757 |

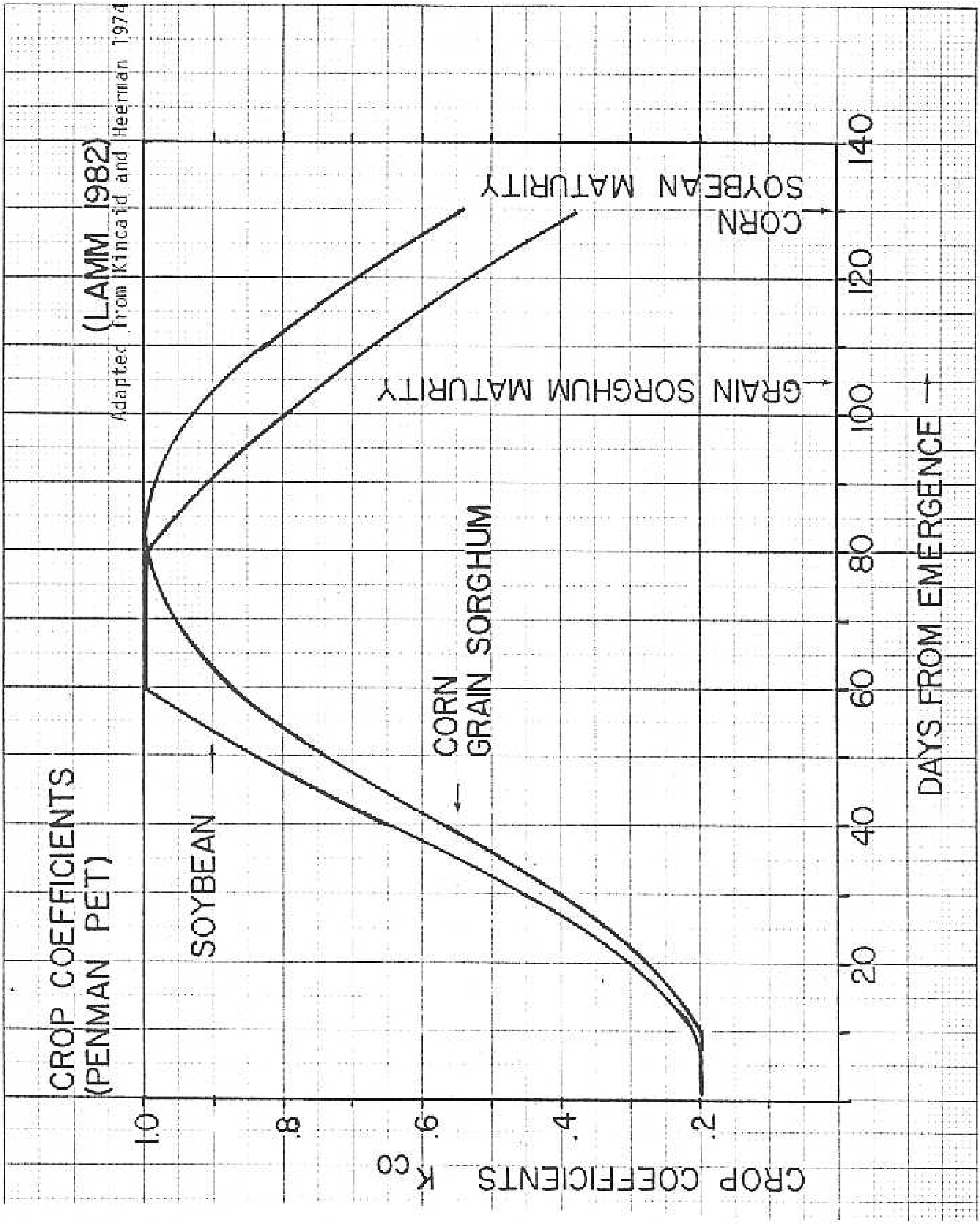


Figure 1. Crop coefficients used in an irrigation scheduling study. Colby, Kansas, 1982.

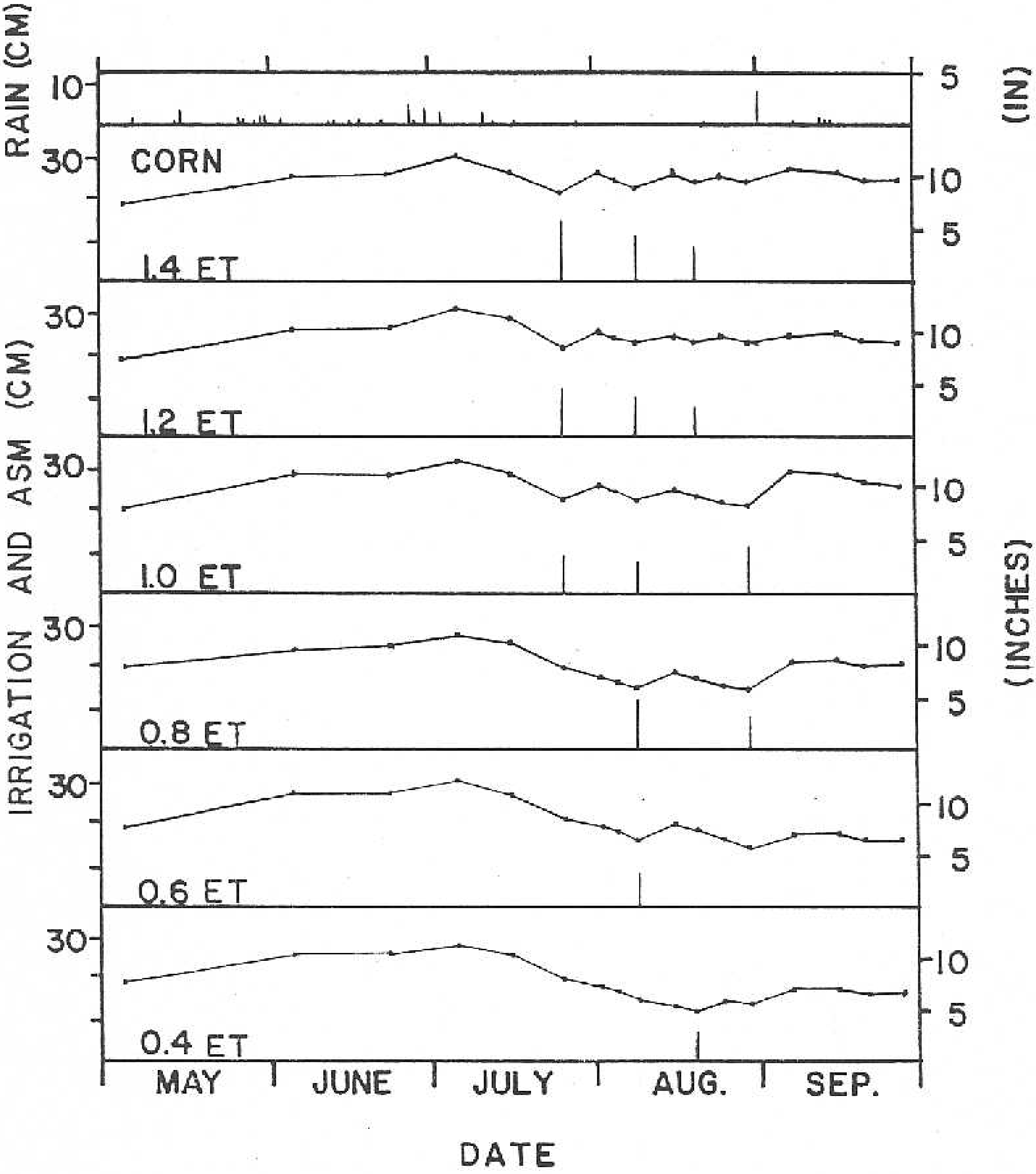


Figure 2. Seasonal variation in available soil moisture for corn in an irrigation scheduling study. Colby, Kansas, 1982.

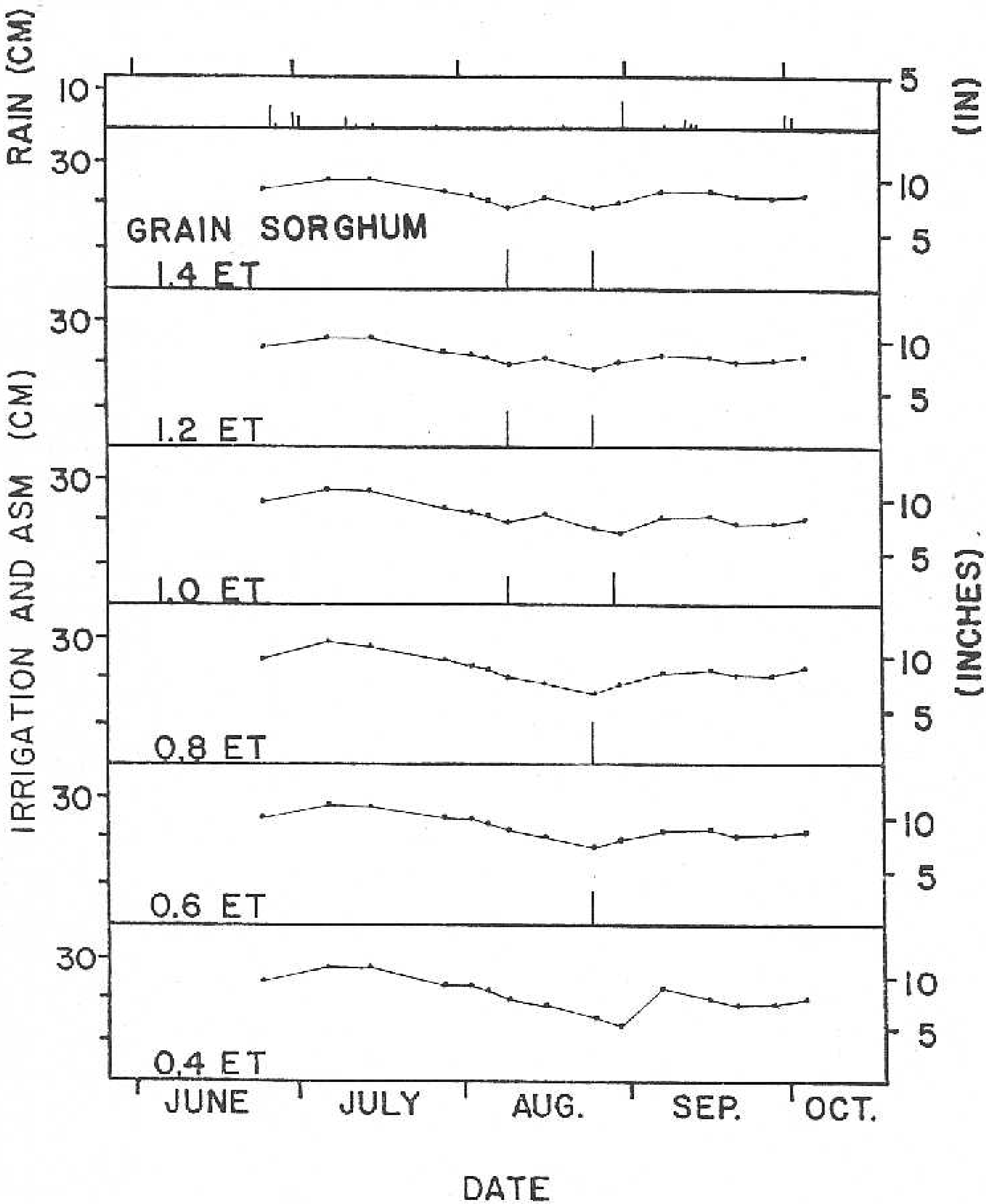


Figure 3. Seasonal variation in available soil moisture for grain sorghum in an irrigation scheduling study. Colby, Kansas, 1982.

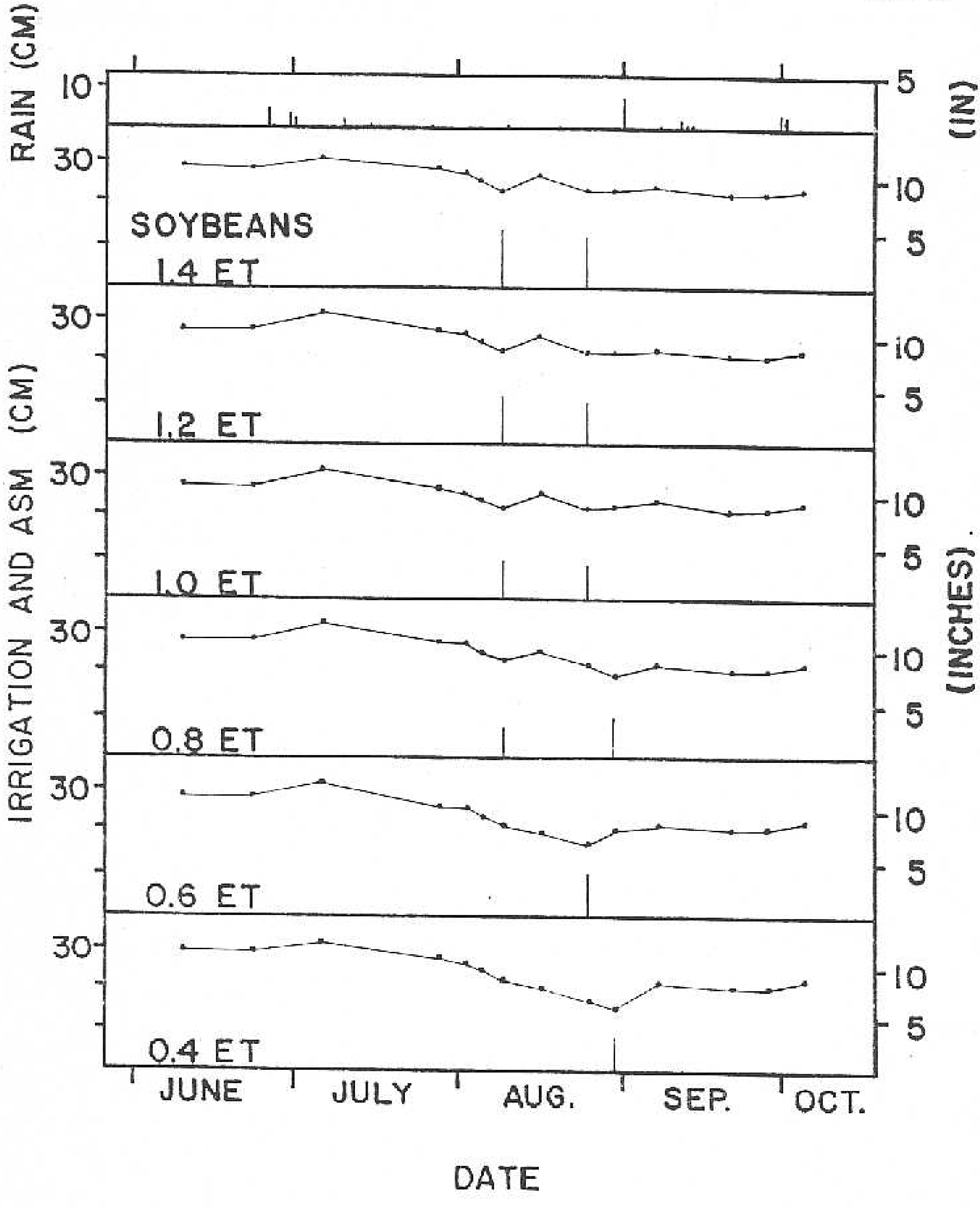


Figure 4. Seasonal variation in available soil moisture for soybeans in an irrigation scheduling study. Colby, Kansas, 1982.

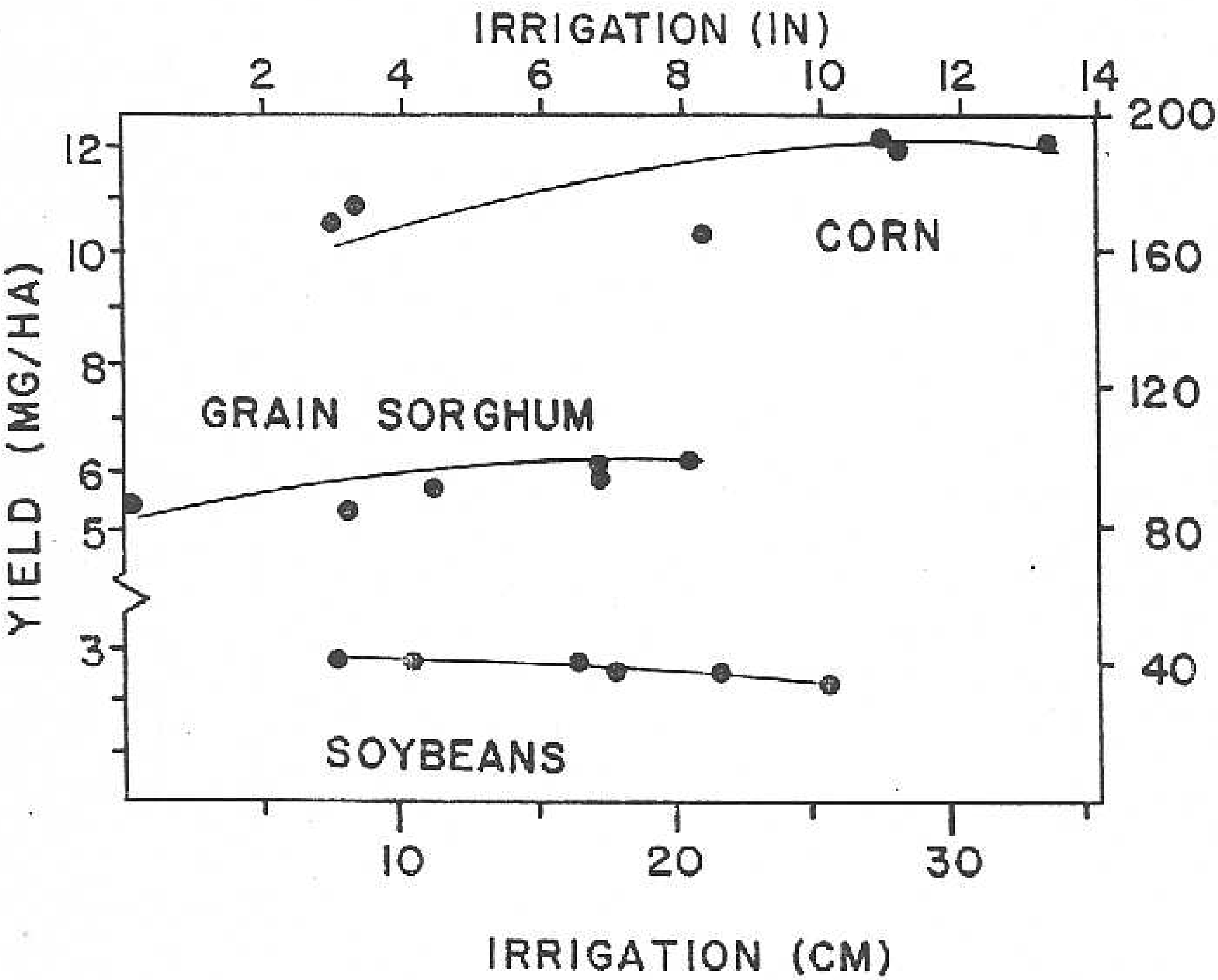


Figure 5. Yield response of corn, grain sorghum and soybeans to irrigation. Colby, Kansas, 1982.