Evapotranspiration of Dry Beans With Drip Irrigation

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ABSTRACT

Information about the effect of irrigation on dry bean production in the Southwestern Colorado is very limited. The primary objective of this study is to establish a crop water use (ET) data base for evaluating dry bean response to different rates of irrigation.

Soil water content at various depths in the root zone was measured by neutron attenuation. A randomized Complete Block Design (RCBD) was used in assigning five irrigation treatments: 0 ET, 0.33 ET, 0.67 ET, 1.0 ET, and 1.33 ET. Water use was estimated by using the water balance approach and the Penman equation.

The results obtained agree strongly with the ET estimated by using crop coefficients developed in Nebraska. Statistical analysis revealed a significant increase in bean seed yield at 1.0 ET and 1.33 ET while dry matter production showed no significant differences at those rates.

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INTRODUCTION

In many areas, irrigation provides the means to optimize plant water use and increase crop production. Irrigation scheduling systems are necessary to overcome excessive irrigation and to eliminate many associated problems. Thus, a knowledge of crop water use will help establish a better understanding of irrigation requirements. In Southwestern Colorado, irrigation is the dominant agricultural practice; therefore, water use studies are of vital importance.

The relationship between yield and water use has been investigated by many researchers. Spurgeon and Makens (1991) found that yield of soybeans continued to increase under low energy precision application (LEPA) with five levels of irrigation. In another study by Weis et al., (1991), it was found that the corn yield under drip irrigation was highest for 100% ET.

Water applied directly to the root zone minimizes water loss due to runoff and deep percolation. Accurate irrigation is necessary to produce the numerous water levels required to generate desired production and efficient water use. Bauder et al., (1975) used drip irrigation systems to obtain the high degree of water control needed.

The objectives of this study were to determine the affect of five different levels of irrigation on yield, dry matter, and to develop a crop coefficient that is related to regional conditions.

MATERIALS AND METHODS

The study was conducted during the summer of 1992 at the Colorado State University Southwestern Colorado Research Center at Yellow Jacket, Colorado. The soil on the site is Witt silty clay loam (fine-silty, mixed, mesic Ustollic Haplargids). The experiment consisted of five plots, each with dimensions of 6.1x3.1 m (20x10 ft). Five levels of irrigation were used. The treatments were: 0%, 33%, 67% 100%, and 133% of predicted ET. Predicted ET was calculated by using USDA-ARS Program SCHED developed by Buchleiter et al., (1988) using crop coefficients developed in Nebraska (K_{Ncb}) and alfalfa reference evapotranspiration (E_{tr}) from the local weather station data using a Penman equation (1963). Irrigation was provided through a drip system.

The irrigation system consisted of a 5 cm (2 in) I.D. polyethylene tube connected to the main irrigation line. A filter system was installed in the main line to prevent sediment from blocking the emitters. Four 1 cm

(0.5 inch) I.D., 60 m (120 ft) long lateral tubes were connected perpendicular to the main line.

The drip irrigation system was designed to deliver four different rates of water with emitters spaced at 76 cm for all treatments: 0.33, 0.65, 0.95, and 1.28 cm h^{-1} at 10.4×10^4 Pa which corresponded to irrigation treatments. Dry beans 'RNK354' (*Phaseolus vulgaris L.*) were planted on June 6, 1992, in 76 cm (30 in) rows at a density of 172,840 plants ha^{-1} (70,000 plant per acre). A randomized complete block design with four replicates was used. Irrigation treatments constituted the main plots. Each plot was separated by a buffer zone 3.1 m (10 ft) wide. To eliminate the possibility of runoff, the plots were diked to contain the water. In the center of each plot, between the rows, a 1.5 m (5 ft) access tube was installed. A neutron probe was used to measure soil moisture content at five different depths twice a week. Samples for dry matter production were taken at different growth stages. Four rows were used to estimate dry matter and bean seed yields. The middle two rows were used for bean seed yield assessment. The outer two rows were used for dry matter measurements. Plant shoots for dry matter production were cut at the ground level.

The following water balance relationship was used to calculate ET from soil moisture and irrigation data:

$$I+P=R+SW+DP+ET$$

where:

I = irrigation water, depth
P = precipitation, depth
R = surface runoff, depth
SW = change in soil water content, depth
DP = deep percolation from root zone, depth
ET = evapotranspiration, depth

Surface runoff (R) was assumed to be zero. Deep percolation was measured after each irrigation event. When excess water accumulated in the bottom of the access tube, it was removed with a pump and measured.

RESULTS AND DISCUSSION

Daily average predicted evapotranspiration (ET) was calculated by using a SCHED Program that was mentioned above. Figure 1(A, B, and C) summarizes the daily average of predicted ET, actual ETa by water balance approach, and seasonal irrigation. The results show that water use increased with irrigation for all treatments. However, both 1.0 ET and 1.33 ET showed a significant increase in water use. This can be attributed to high rates of growth and corresponding ET as compared

Table 1. Water use and dry matter of dry beans

Treatment	Irrigation(cm)	Seasonal Moisture change(cm)	Actual Total ET(cm)	Dry Matter(Kg/ha)	Kg/ha/cm IWUE	Kg/ha/cm TWUE
0ET	0.0	4.7	7.4	1900 A	0	257
0.33ET	11.4	3.3	17.4	3281 B	287	188
0.67ET	23.1	2.4	28.2	4815 C	208	171
1.0ET	33.7	2.0	38.3	6324 D	188	165
1.33ET	47.2	1.8	51.6	6365 D	135	123

Means with the same letter are not significantly different (at 0.05).

Table 2. Water use and seed yield of dry beans

Treatment	Irrigation(cm)	Seasonal Moisture change(cm)	Actual Total ET(cm)	Seed Yield(Kg/ha)	Kg/ha/cm IWUE	Kg/ha/cm TWUE
0ET	0.0	4.7	7.4	1043 A	0	141
0.33ET	11.4	3.3	17.4	1837 B	161	105
0.67ET	23.1	2.4	28.2	2757 C	119	98
1.0ET	33.7	2.0	38.3	3344 CD	99	87
1.33ET	47.2	1.8	51.6	3912 D	83	76

Means with the same letter are not significantly different (at 0.05).

to other treatments. Dry matter and seed yield showed a significant increase under those two rates (Tables 1 and 2).

Water use by dry beans showed an increase as the rate of irrigation was increased Fig.1 (A and B). Seasonal average predicted ET was 0.13, 0.25, 0.38, and 0.50 cm day^{-1} for the irrigation treatments 0.33 ET, 0.67 ET, 1.0 ET, and 1.33 ET, respectively. The water balance approach actual ET was 0.13, 0.28, 0.33, and 0.50 cm day^{-1} for the same irrigation treatments. The estimated ET by both methods showed no significant differences at the 0.05 level. High ET under a high rate of irrigation has been confirmed by other studies (Al-Nakshabandi and Ismail, 1979).

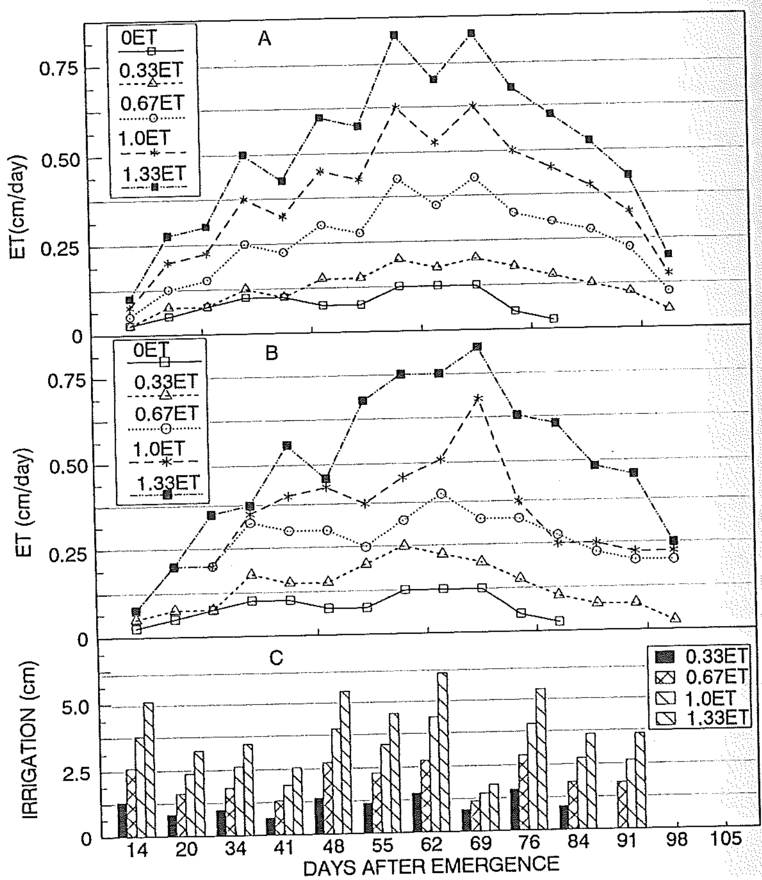

Fig.1. (A) Predicted ET. (B) Actual ETa calculated using water balance approach. (C) Irrigation during growing season.

Nebraska crop coefficients (K_{Neb}) and crop coefficients developed from water balance approach (K_{WB}) actual ETa and Penman equation E_{tr}, are summarized in Fig. 2 (A and B). Crop coefficients are the ratio of ET to reference E_{tr} of the Penman equation. The peak values of Nebraska crop coefficients (K_{Neb}) were 0.32, 0.65, 0.96, and 1.27, versus (K_{WB}) 0.55, 0.73, 1.0, and 1.36 calculated by the water balance approach, for 0.33 ET, 0.67 ET, 1.0 ET, and 1.33 ET, respectively.

The results reveal that crop coefficients estimated

from the water balance approach (K_{WB}) were higher than those from Nebraska (K_{Neb}). The increase in crop coefficient value under the high irrigation treatments may be due to high wind speed at the experiment site. Also, it may be due to advected sensible heat from the uncultivated area around the experiment site. However, the lowest values were associated with the lowest levels of irrigation. This can be attributed to a limited soil moisture supply under low irrigation levels which limits soil evaporation, (Ritchie, 1971) and transpiration (Ritchie and Burnett, 1971).

Figure 3 (A, B, and C) shows the dry matter, soil moisture content, and irrigation amount of the different treatments. Figure 3B shows the average soil moisture

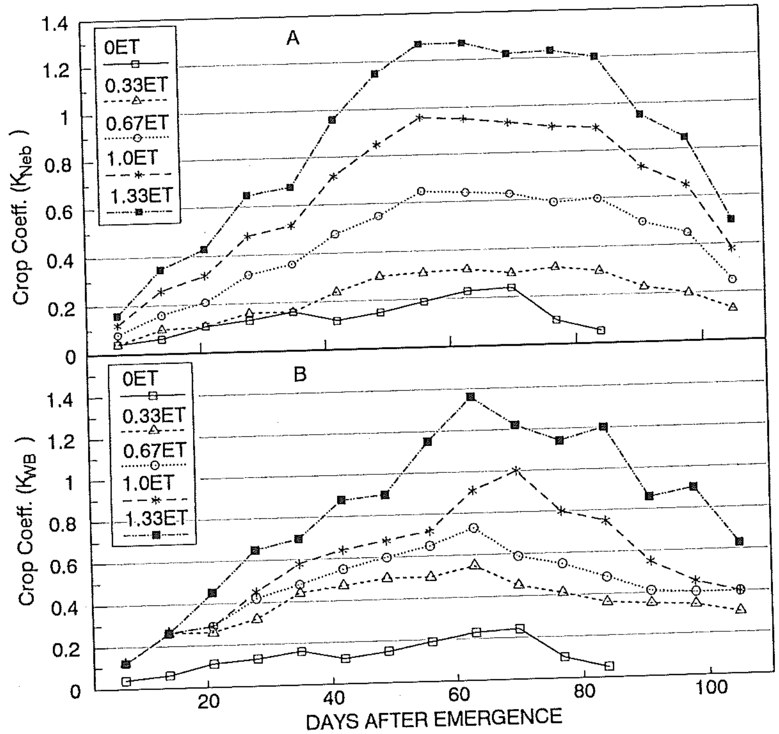

Fig. 2. (A) Nebraska Crop coefficient (K_{Neb}). (B) Crop coefficient from water balance ET (K_{WB}).

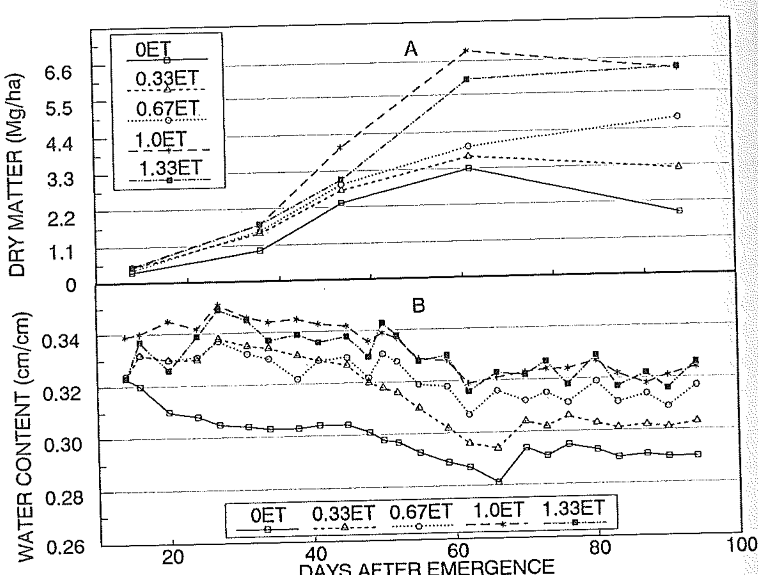

Fig. 3. (A) Dry matter. (B) Soil water content average for the top 1.5 m.

content in the top 1.5 m (3 ft). The effect of different levels of irrigation on dry matter production shows the greatest production at 1.0 ET treatment. Dry matter production at harvest also showed significant differences, except between the 1.0 ET and 1.33 ET levels (Fig. 3A). Dry bean seed yield was significantly different between treatments (Table 2). These differences in yield were strongly related to soil moisture depletion (Fig. 3B).

Total water use efficiency (TWUE) and irrigation water use efficiency (IWUE) for both dry matter production and dry bean seed yield showed a lower water use efficiency as the level of irrigation increased. This was also reported by Viets (1962) and Al-Nakshabandi and Ismail (1972). Moreover, in irrigation studies using similar ranges of irrigation by Spurgeon and Makens (1991) and Weis et al., (1991) applied by LEPA and drip irrigation, no significant difference in corn yield was found between the 1.0 ET and 1.33 ET treatments.

CONCLUSION

The use of controlled drip irrigation offers a reliable method of evaluating yield response to different levels of irrigation. By applying different rates, we can evaluate existing irrigation schedules. In addition, using precise water application leads to a reduction in deep percolation and runoff. Evaluating the current irrigation program reveals a significant yield increase at 1.33 ET. This raises the concern of testing ET levels higher than 1.33 ET in order to establish an optimum yield and irrigation level.

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