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Crop Coefficient (kc) and Water Use Efficiency (WUE) of Soybean as Affected by Soil Moisture Stress and Fertility Levels

[1]U.A. Burriro, [2]H.A. Samoon, [1]F.C. Oad and [1]G.H. Jamro
[1]Sindh Agriculture University Tandojam, [2]Arid Zone Research Institute (PARC)
Umerkot, Pakistan

Abstract: Experiments were conducted to study the crop coefficient (Kc) and Water Use Efficiency (WUE) of soybean as affected by soil moisture stress and fertility levels at Malir Experimental Farm, Sindh Agriculture University, Tandojam, Pakistan on silt loam soil. The results revealed that crop efficient (Kc) increased with an increase in the crop age. The Kc was higher proportionate to higher moisture availability. The peak Kc was at 105-125 days after sowing, corresponding with early stage to complete fill stage of soybean crop. Water use efficiency at 5 bar tensions signified the plants under stress and were more efficient in utilizing water for the production of grain. The higher fertility was exhibited through appropriate fertilizer levels which in-turn increased the water use efficiency and compensated water deficiency. Thus, it is recommended that crop coefficient and fertility levels should be identified for obtaining maximum water use efficiency and yield targets.

Key Words: Soybean, Crop Coefficient, Moisture Stress, Fertility Levels, Yield

Introduction

Soybean *Glycine max* (L.) Merr., combines in one crop both the dominant world supply of edible vegetable oil and the dominant supply of high protein feed supplements for live stock. Other fractions and derivatives of the seed have substantial economic importance in a wide range of industrial, food pharmaceutical and agricultural products (Smith and Huyser, 1987). The United States is the principal world supplier of soybean (Jewell, 1988).

This crop requires frequent irrigations to create micro tropical environment under the prevailing irrigation system in which the farmer gets his share of irrigation supplies on rotational basis, this rotational system naturally lacks concordance between water supply and moisture requirement of the crop. Consequently, the soybean crop under goes moisture stress quite a few times during its growing season. Therefore, it is presumed that one of important reason is improper water management. Shibles *et al.*, (1975); Shaw and Laing (1965); Peters and Johnson (1960) reported that seasonal increase in evapotranspiration in soybean is closely parallel with increase in leaf area index from flowering to maturity. Ritchie (1983) also concluded that transpiration losses of water were closely related to canopy development during vegetative growth and to the water content of the soil surface. Grissom *et al.* (1955) calculated water use rates at 6.47 and 6.03 inches for June, July and August for optimum soybean growth and total water use was 25 inches. Whitt and Bavel (1955) estimated the water requirement in the range of 13 to 23 acre inches and average rate was 0.3 inches per day during July and August at Missourt. While, Cartter and Hartwig (1962) reported that Brag variety of soybean requires about 20-30 acre inches of irrigation water per season. Doss *et al.*, (1974) reported that Brag variety of soybean used 62.7cm of water per season. Heatherly and Russell (1979) pointedout that much lower soil water potential (7.0-1.0 bar) is required for seedling emergence than reported previously for seed germination. Eavis and Taylor (1978) reported that total transpiration increased linearly with leaf area. Considering paramount importance of proper use of irrigation for high yields, the present studies were designed to investigate the effect of soil moisture stress and fertility levels on crop co-efficient and water use efficiency in soybean crop.

Materials and Methods

Experiments on soybean variety Hampton-266A were carried-out at Malir Experimental Farm, Sindh Agriculture University Tandojam on silt loam soil having 23.5% moisture at field capacity. The experimental design was factorial experiments in randomized complete block with four replications. The details of the treatments were as under:

Soil Moisture Stress:

M1= Irrigation at 3 bar corresponding to 12.8% moisture on dry wet basis
M2= Irrigation at 5 bar corresponding to 10.5% moisture on dry wet basis
M3= Irrigation at 8 bar corresponding to 10.2% moisture on dry wet basis

Fertility Levels (NPK kg ha^{-1})

F1= 50-60-30
F2= 50-90-30

All the agronomic operations were carried out in all plots uniformly. The estimates of Kc of the crop during growing season was calculated by using the data of Eta as under:

Kc= Eta/Etp

Where: Kc= Crop coefficient for particular growing stage, using Jensen and Haise (1963) method of Etp.
Eta= Actual crop evapotranspiration for a particular growth stage in mm day.
Etp= Potential evapotranspiration for the same period using Jensen and Haise (1963) method.

$Kc_{(pan)}$ = Eta/Epan

Where, $_{(pan)}$ = Crop coefficient for particular growing stage, using open pan evaporation data.

E_{pan} = Open pan evaporation for the specific period in mm day.

Et_a = Actual crop evapotranspiration for a particular period in mm day,

The evapotranspiration rate of the crop was averaged on weekly basis and a balance sheet of moisture used was prepared according to the growth period. The budget showed the net irrigation amount and effective rainfall during the period. The soil moisture stress was monitored during the entire growth period of the crop. The soil sampling was done before and after each irrigation to determine the soil moisture status. When the moisture dropped to 3, 5 and 8 bar tensions in the upper 60 cm depth, the water was added to makeup the deficit calculated on 150cm root zone depth.

The water use efficiency was calculated by dividing the yield in kg with Et mm used and efficiency in kg mm^{-1} of water was obtained. Yield estimation was made at the time of crop harvest using crops cutting method. For this purpose, 0.5 meter border strip was left and the rest of the area was harvested from each plot and yield per hectare was calculated. The crop from the harvested area was separately threshed, winnowed and weighed for yield estimation.

Results and Discussion

The crop coefficient was calculated as Kc; which increased with the crop age. As the crop developed its vegetative cover by increasing the foliage, the Kc also increased progressively and it reached peak during 90-110 days of crop age. Then it started decreasing as the crop advanced towards maturity. The reduced Kc of the crop during early vegetative phase was noted. When the Kc for M1, M2, and M3 moisture treatments were compared, it was found that with the increase in soil moisture stress the crop coefficient decreased progressively and highest value of 1.09 was obtained when the crop was irrigated at 3 bar soil moisture tension. It was I.04 when the crop was irrigated at 5 bar tension and when irrigation was applied at 8 bar tension the highest Kc recorded was 0.95. All the moisture stress levels produced their peak Kc between 105-125 days after sowing (Fig. 1). The results are in confirmation with those of Shaw and Laing (1965); Peters and Johnson (1960); Shibles *et al.*, (1975); Eavis and Taylor (1978) as they also found that the seasonal increase in evapotranspiration from soybean is closely parallel to the increase in leaf area index from flowering to near maturity, Ritchie (1983) also concluded that transpiration losses of water were closely related to canopy development during vegetative growth and to the water content of the soil moisture.

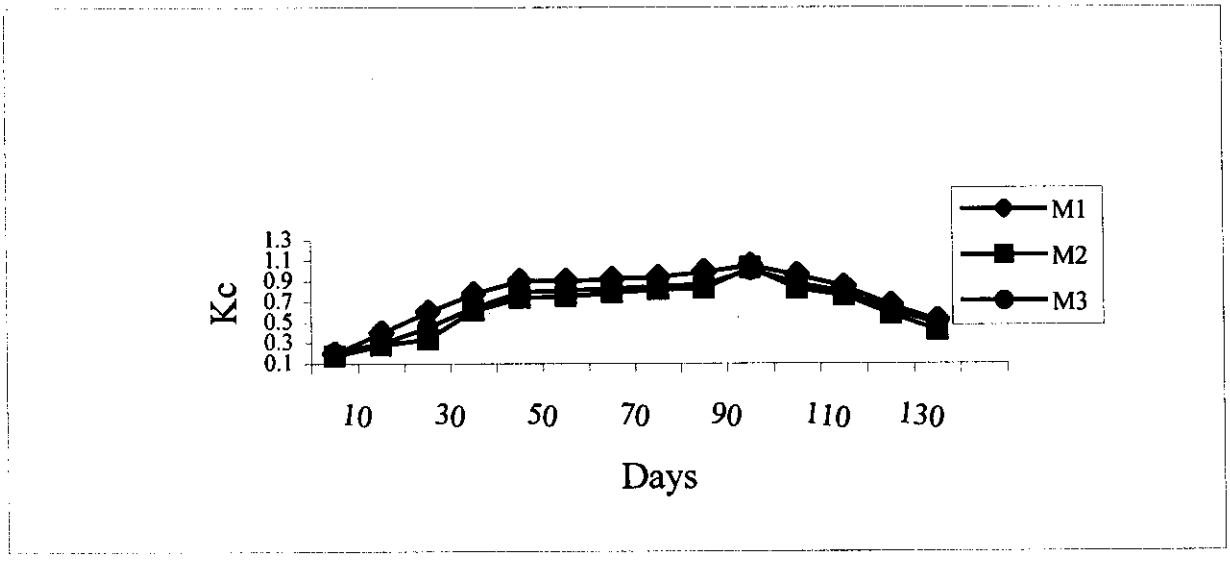

Fig. 1: Effect of Soil Moisture Stress Levels on Crop Coefficient of Soybean

Table 1: Effect of Soil Moisture Stress and Fertility Levels on the Grain Yield (t/ha) and Water use Efficiency

Moisture Levels	Grain yield (t/ha) F1	F2	Average	Eta (mm)	WUE (kg/mm) F1	F2	Average
M1	2.34	2.44	2.39	767	3.05	3.18	3.11
M2	2.13	2.33	2.23	463	3.31	3.62	3.46
M3	1.71	2.01	1.86	535	3.20	3.76	3.48
Average	2.06	2.26	-	-	3.19	3.52	-

The water use efficiency is the rate of soybean grain produced by spending 1mm of water. The results of the water use efficiency as influenced by various soil moisture stress levels from 3-8 bar are presented in Table 1.

The water use was affected by water stress. The highest water use efficiency of 3.76 Kg $mm^{-1}$of water was recorded when the crop received 50-90-30 NPK kg ha^{-1}. The lowest water use efficiency (3.05 kg mm^{-1}) was recorded when the crop was irrigated in response to 3 bar tension and fertilize rate was 50-60-30 kg NPK ha^{-1}. It was observed that the water use efficiency increased with the increase in the soil moisture stress. However, the rate of increase from 3 bar to 5 bar was more pronounced than from 5 to 8 bar tension. This signifies that optimum water use efficiency is attained by irrigating the crop slightly above 5 bar tension.

The fertility levels had also a very distinct effect on the water use efficiency of soybean grain production. The higher fertilizer obviously produced more grain per mm of water than the lower level. It is evident from the results that the water use efficiency increased sharply from 3 to 5 bar tension under both the fertility levels thought the initial as well as final increase rate was more pronounced under higher than lower fertilizer dose. But at lower fertility, the increase in water stress from 5 to 8 bar tension decreased water use efficiency, whereas it increased in case of higher fertilizer dose. This signifies that the higher fertility level compensates for the moisture deficit, dispelling the earlier action of the fertilizer application is not beneficial under drought conditions.

The water use efficiency results obtained in the present studies are in confirmation with the findings of Ambak and Hammond (1983). The rates of water use efficiency were quite low in this study as computed to the results obtained by the above mentioned workers. The higher grain yields ha^{-1} and lesser amount of water used during the crop season. That might had been due to humid temperate climate prevailing during crop hot climatic conditions of lower Sindh, Pakistan.

Conclusion

It is concluded that crop coefficient (Kc) increased with an increase in the crop age and was higher at higher moisture available and peak attained at 90-110 days after sowing. The water use efficiency increased with increase in the soil moisture up to 3 bar tension and higher fertilizer increased the water use efficiency and also compensated for water deficit.

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