J Krishi Vigyan 2015, 4(1) : 18-22 DOI: 10.5958/2349-4433.2015.00053.7

Effect of Variability in Climate and Irrigation Regimes on Evapo-transpiration and Water Use in Spring Maize

K B Singh

Department of Soil and Water Engineering
Punjab Agricultural University, Ludhiana 141 004 (Punjab)

ABSTRACT

A simple soil water balance approach was used to estimate actual evapotranspiration of spring maize under variable irrigation regimes for two years on loamy sand soil in a semi arid, subtropical region of north India. Moisture stress to crop was created through three irrigation regimes (irrigation water/open pan evaporation ratio of 1.2 ($I_{1.2}$), 0.9 ($I_{0.9}$) $I_{0.9}$ and 0.6 ($I_{0.6}$)). Depending upon the changes in climate, year 2007 was hot and dry (9.5 cm less rainfall) compared to 2008. During dry season cumulative actual evapotranspiration was greater than the potential evapotranspiration by 14.4 and 6.6 per cent under $I_{1.2}$ and $I_{0.9}$ irrigation regimes, respectively. However under $I_{0.6}$ cumulative actual evapotranspiration was lower than potential evapotranspiration by 3.6 per cent. In wet season cumulative actual evapotranspiration was increased by 14.9, 10.8 and 4.7 per cent under $I_{1.2}$, $I_{0.9}$ and $I_{0.6}$ irrigation regimes, respectively over potential evapotranspiration. During wet season irrigation regime $I_{0.9}$ was at par with $I_{1.2}$ in water use efficiency (WUE) thus, more helpful in saving irrigation water. However during dry season irrigation regime $I_{1.2}$ was beneficial for increasing WUE through increased grain yield. Rainfall favoured the crop growth and grain yield through lowering air temperature and reducing evaporation and recharging soil water storage. Crop coefficients were increased exponentially with leaf area index (LAI) in all treatments and the variability in crop coefficient was more during dry season compared to wet season.

Key Words: Irrigation, Evapotranspiration, Leaf Area Index, Water Use Efficiency, Spring Maize.

INTRODUCTION

In semi-arid sub-tropical regions of Indian Punjab spring maize is gaining popularity among the farmers after potato crop in paddy-potato-spring maize cropping system. Spring maize having high irrigation requirement is sensitive to water stress. Many studies showed that maize grain yields are sensitive to moisture stress at different growth stages (Smith and Ritchie, 1992). Therefore, irrigating the crop with required quantity of water during the moisture sensitive growth stage can produce the optimum yield with maximum water use efficiency and water economy (Norwood, 2000). Water use efficiency of maize was greater with limited irrigation (Trooijen *et al*, 1999) but full irrigation of maize was more profitable than limited irrigation because of increase in crop yield. Hence, determination of crop coefficient under local climatic conditions is the base to improve planning and efficient irrigation management. Accordingly, spring maize producers need to adopt management practices that limit unproductive water losses and increase crop water use efficiency.

In Punjab during spring maize season soil evaporation component of field water balance is high due to high temperature and low rainfall. There is general lack of information with respect to irrigation on evapotranspiration and water use efficiency of spring maize under variable climatic conditions. This paper aims at to ascertain the effects of different irrigation regimes on

Corresponding Author's Email: kbsingh@pau.edu

evapotranspiration and water use efficiency in spring maize with an aim of devising efficient water management practices.

MATERIALS AND METHODS

The field experiment was conducted at the farm of the Department of Soil Science, Punjab Agricultural University, Ludhiana during 2007 and 2008. The experimental soil was deep alluvial loamy sand (mixed hyperthermic, Typic Ustipsamment) having low organic carbon (< 4g kg^{-1}) and consisted of 760, 140 and 100 g kg^{-1} sand, silt (20-2 µm) and clay respectively in top 15 cm. In 1.8 m profile soil retained 44.0 and 14.9 cm water at 33 kPa and 1500 kPa matric suction, respectively. The average weather conditions during study were measured daily at the meteorological station 1.2 km away from the site area. In general, weather conditions were cooler and wetter during 2008 growing season than 2007. The crop received 12.3 and 21.8 cm rain in 2007 and 2008 with corresponding open pan evaporation of 82.0 and 72.2 cm, respectively. In both years crop was sown in the month of February and harvested in the month of June. The month of February is cool and in May temperature rises up to 45 ^{0}C. Generally the rainfall is scanty during spring season. Soil moisture data of replicated 3 irrigation regimes (Irrigation water/ Open pan-evaporation ratio of 1.2 ($I_{1.2}$), 0.9 ($I_{0.9}$) and 0.6($I_{0.6}$)) was used for the estimation of evapotranspiration. Each plot measured 5 m × 9 m. Measured irrigation water was applied using the surface flood method delivered through parshall flume. Soil water content was determined gravimetrically in 0-15, 15-30, 30-60, 60-90, 90-120, 120-150 and 150-180 cm depth increments at seeding, before and after each irrigation and at harvesting time. Soil moisture storage of each layer was calculated by multiplying depth of soil layer with corresponding bulk density and gravimetric moisture content. Actual crop evapotranspiration (ET_a) was estimated under different treatments using the soil water balance equation as:

$$ET_a = I + P - R - D \pm \Delta SW$$

where 'I' represents the irrigation water, 'P' the precipitation or rainfall, 'R' the surface runoff, 'D' the drainage and deep percolation and "SW the change in soil water storage. Drainage was estimated from excess of water beyond field capacity for each irrigation and rainfall event through cascading technique. There was no runoff (R) as sufficient dikes were maintained around each plot. The crop coefficients (Kc) at different growth periods were calculated by dividing actual crop evapotranspiration (ET_a) with reference crop evapotranspiration (ET_0) estimated using the FAO Penman-Monteith equation (Allen *et al*. 1998). Water use efficiency (WUE) for grains was calculated by dividing grain yield with total actual evapotranspiration (ET_a).

RESULTS AND DISCUSSION

Evapotranspiration

Based on evaporation losses from open-pan, 82.5, 67.5 and 45.0 cm irrigation water was applied in $I_{1.2}$, $I_{0.9}$ and $I_{0.6}$ irrigation regimes respectively during 2007. However during 2008 under $I_{1.2}$, $I_{0.9}$ and $I_{0.6}$ irrigation regimes 82.5, 60.0 and 45.0 cm irrigation water was applied. During 2007, total seasonal actual evapotranspiration (ET_a) under $I_{1.2}$, $I_{0.9}$ and $I_{0.6}$ irrigation regimes was 78.4, 73.0 and 66.1 cm (Fig. 1) whereas during 2008, it was 70.2, 67.7 and 64.0 cm under respective irrigation regimes. More variability in soil moisture under $I_{0.6}$ irrigation regime resulted in high variability in crop water stress. Under stress, the behaviour of closer of stomata results low ET losses. Time trend of cumulative actual evapotranspiration (ET_a) showed that during 2007 cumulative potential evapotranspiration (ET_0) was higher than ET_a during early period of crop growth up to 63 and 68 days after sowing (DAS) under $I_{1.2}$ and $I_{0.9}$ irrigation regimes respectively. Thereafter cumulative ET_a was closer to cumulative ET_0 and then became higher after 70 and 76 DAS under $I_{1.2}$ and $I_{0.9}$ treatments, respectively. Similar results have been reported by Tariq and Usman (2009).

Higher magnitude of ET_a than ET_0 was reported under frequently irrigated treatments ($I_{1.2}$ and $I_{0.9}$) due to more available soil moisture and high soil evaporation losses from wet soil. However under $I_{0.6}$ irrigation regimes cumulative ET_a remained lower than ET_0 because of less crop growth due to moisture stress. During 2008, cumulative ET_a was lower than cumulative ET_0 up to 64, 70 and 70 DAS under $I_{1.2}$, $I_{0.9}$ and $I_{0.6}$

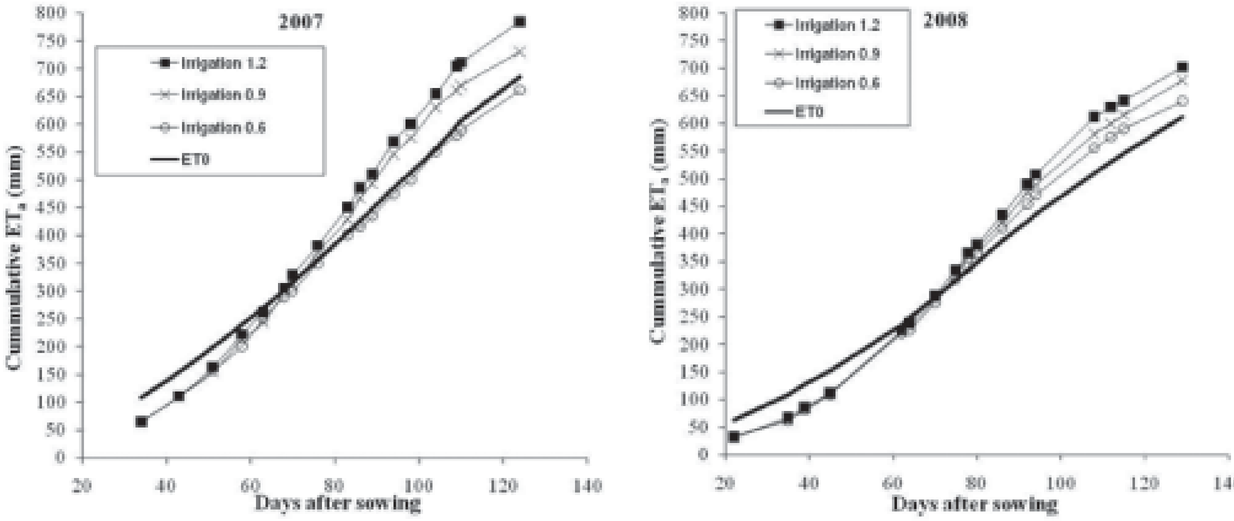

Figure 1. Effect of irrigation on cumulative evapotranspiration (ETa) of spring maize during two years

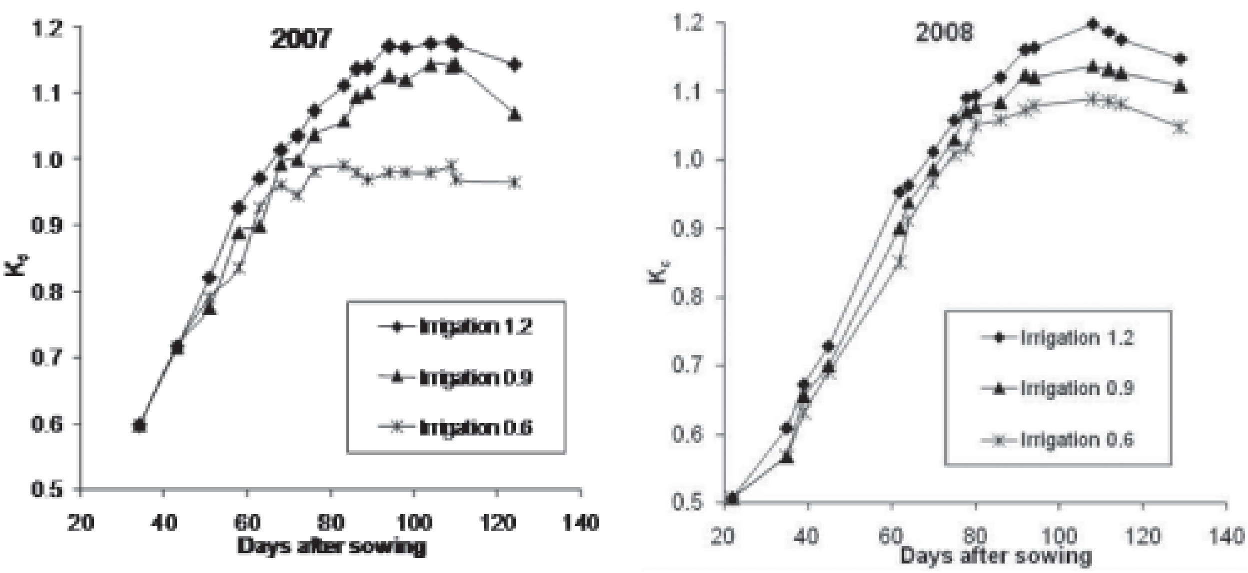

Figure 2. Crop coefficient under different irrigation regimes during two years

irrigation regimes respectively. However, afterwards cumulative ET_a remained higher than cumulative ET_0 up to harvesting because of higher soil moisture loss through soil evaporation and transpiration from high leaf area. This indicates that during the early stages of crop growth because of lower leaf area index and cool weather cumulative ET_a was lower than cumulative ET_0. But as the LAI of the crop reached maximum, cumulative ET_a remained higher than cumulative ET_0. These results were in accordance with earlier studies (Rong, 2013).

Crop Coefficient and relation with leaf area index

During both years crop coefficient (Kc) was <0.6 up to 35 DAS in all irrigation regimes (Fig. 2). Afterwards it increased to 1.0 up to 68 and 76 DAS under $I_{1.2}$ and $I_{0.9,}$ respectively and thereafter remained above unity but under $I_{0.6}$ irrigation regime it was < 1 during the whole season in 2007. During 2008 crop coefficient was 0.6 to 1.0 between 35-64 DAS under $I_{1.2}$ irrigation regime and after wards remained above unity. Due to more moisture stress at different intervals of

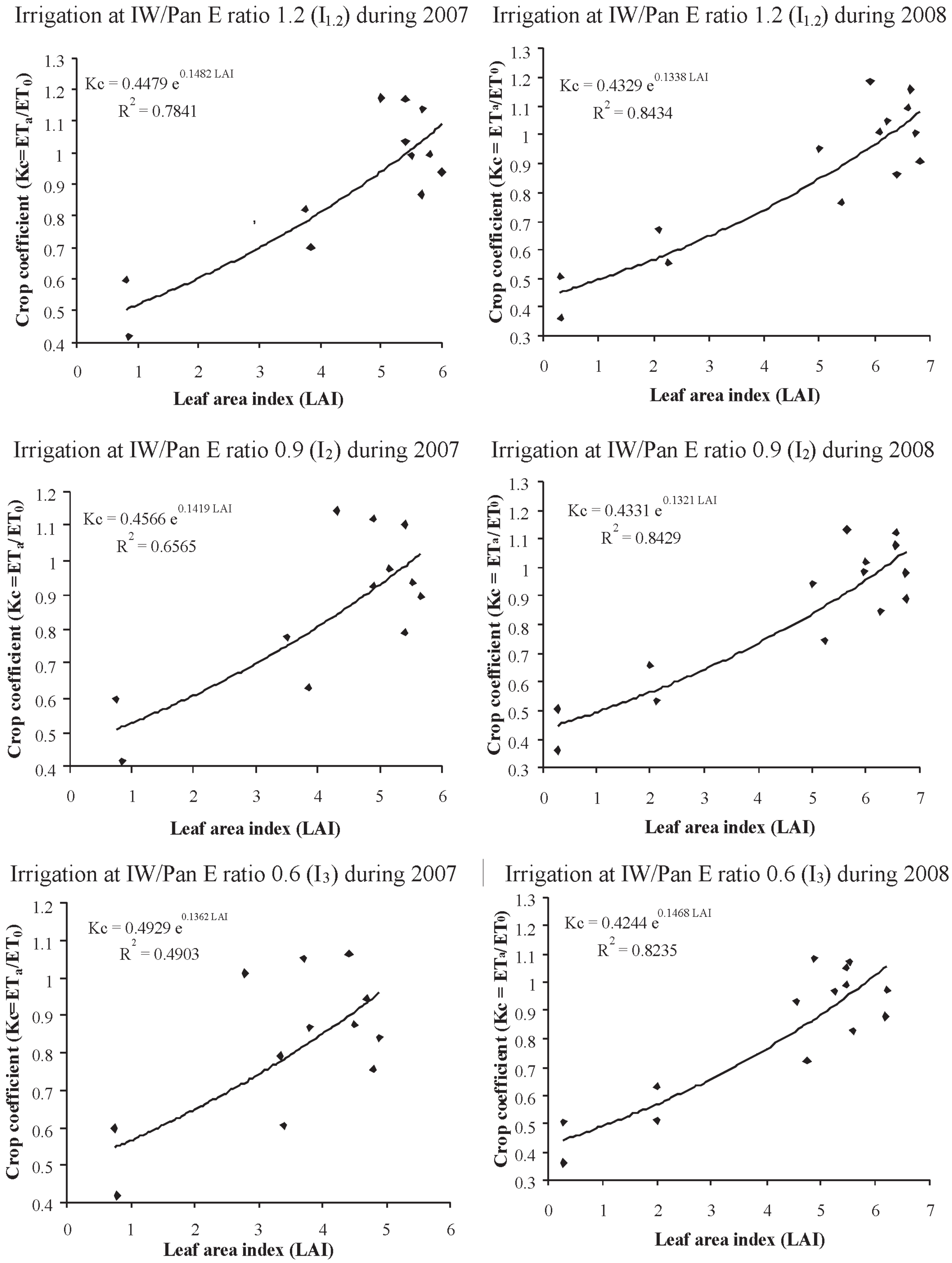

Figure 3. Crop coefficient as a function of leaf area index under different irrigation treatments during two years

irrigation during 2007 under $I_{0.9}$ and $I_{0.6}$ irrigation treatments Kc was < 1 and more variable due to closer of stomata for greater time period which resulted into less growth of crop leading to low LAI compared to frequent irrigation treatment ($I_{1.2}$). Crop coefficient was increased exponentially with leaf area index in all the treatments (Fig. 3). However, the coefficient of determination varies with different treatments. Coefficient of determination between Kc and LAI decreases significantly from 0.78 (under $I_{1.2}$ irrigation) to 0.49 (under $I_{0.6}$ irrigation regime) with decrease in irrigation amount during 2007 irrespective of leaf area index. However, during 2008 the coefficient of determination between Kc and LAI was not varied significantly from frequent irrigations. Variability in Kc was greater during 2007 (lower value of R^2) compared to 2008 (higher value of R^2) because of more variability in temperature and evaporation and less rain fall during 2007.

Crop water use

During 2007, water use efficiency (WUE) of spring maize in $I_{1.2}$ irrigation regime increased by 13.9 and 33.8 percent over $I_{0.9}$ and $I_{0.6}$ irrigation regimes respectively (Table 1). However, during 2008 increase in WUE with $I_{1.2}$ over $I_{0.6}$ irrigation regimes was 17.2 percent and no any difference in WUE was observed between $I_{1.2}$ and $I_{0.9}$. Overall irrigation increased WUE of spring maize due to significant increase in grain yield. Therefore significant increase in WUE with irrigation was because of soil water being used for crop growth and yield rather than in soil evaporation (Todd *et al,* 1991).

Table 1. Grain yield, evapotranspiration and water use efficiency in spring maize.

Years	Treatments	Grain yield (Mg/ha)	ET_a (cm)	Water use efficiency (kg/m^3)
2007	$I_{1.2}$	4.743	78.4	0.605
	$I_{0.9}$	3.882	73.0	0.531
	$I_{0.6}$	2.989	66.1	0.452
2008	$I_{1.2}$	5.008	70.2	0.713
	$I_{0.9}$	4.803	67.7	0.709
	$I_{0.6}$	3.893	64.0	0.608

CONCLUSION

Spring season is very hot and dry in northern India because of which evapotranspiration losses of water are high. Frequent irrigations lead to unproductive water losses through soil evaporation. Therefore actual evapotranspiration exceeds potential evapotranspiration. Medium irrigation regime is helpful in saving irrigation compared to very frequent and delayed irrigation. However, increased frequency of irrigation increased water use efficiency of spring maize by increasing grain yield.

REFERENCES

Allen R G, Pereira L S, Raes D, Smith M (1998). Crop evapotranspiration. In:Guidelines for Computing Crop Water Requirements. FAO Irrigation and Drainage Paper No. 56, FAO, Rome, Italy, *p. 331*.

Norwood C A (2000). Water use and yield of limited irrigated and dry land corn. *Soil Sci Soc Am J* **64**: 365-370.

Prihar S S and Sandhu B S (1987). Irrigation of Field Crops- Principles and Practices. ICAR, New Delhi, India.

Rong Y (2013). Estimation of maize evapotranspiration and yield under different deficit irrigation on a sandy farmland in Northwest China. *African J Agril Res*. **7**: 4698-4707.

Smith D S and Ritchie J T (1992). Short and long term responses of corn to a pre-anthesis soil water deficit. *Agron J* **84**:107-113.

Tariq J A and Usman K (2009) Regulated deficit irrigation scheduling of maize crop. *Sarhad J.Agri.* **25**: 441-450.

Todd R W, Klocke N L, Hergert G W and Parkhurst A M (1991). Evaporation from soil influenced by crop shading, crop residue and wetting regime. *Trans ASAE* **34**: 461-466.

Trooijen T P, Buschman L L, Sloderbeck P, Dhuyvetter K C and Spurgeon W E (1999). Water use efficiency of different maturity corn hybrids and grain sorghum in the Central Great Plains. *J Prod Agri* **12**: 377-382.

Received on 14/5/2015 Accepted on 22/6/2015