Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.4, No.7, 2014

Variation in Crop Co-Efficient of Maize Varieties under Irrigated Condition

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Abstract
A field study was conducted on clay loam soil at the research farm of The University of Agriculture Peshawar during Kharif 2012 to determine the crop co-efficient of maize using two traditional (V_1=Azam and V_2=Jalal) and two hybrid (V_3=3025W and V_4=30K08) varieties having four replicates. Soil moisture was determined by gravimetric method, actual evapotranspiration (ETa) was worked out by field water balance taking into account soil moisture, rainfall, and irrigation water applied. The Potential evapotranspiration (ETo) was estimated by Pan Evaporation method. Crop coefficient (Kc) was determined by dividing ETa over ETo for all growth stages. ETa of traditional maize variety V_1 was found lowest and highest for hybrid maize variety V_4. Comparison of seasonal ETa of selected maize varieties showed that V_2, V_3 and V_4 had 3, 24 and 34 % higher values compared to V_1. ETa of V_1 varied between 2.7 to 4.8 mm d^{-1}, for V_2 between 2.6 to 5.2 mm d^{-1}, for V_3 between 3.3 to 6.2 mm d^{-1} and for V_4 between 3.4 to 6.5 mm d^{-1}. The seasonal ETa of selected varieties V_1, V_2, V_3 and V_4 was found 411, 422, 512 and 550 mm, respectively. Results showed that ETa of hybrid varieties was higher as compared to traditional varieties. Kc values of variety V_1 ranged from 0.38 to 0.87, for V_2 it ranged from 0.38 to 0.91, for V_3 ranged from 0.43 to 1.13 and for V_4 ranged from 0.47 to 1.19. It was concluded that FAO reported Kc values of a crop are generalized one for a wide range of climate therefore,Kc value of each crop variety should be investigated and used.
Keywords: Crop coefficient, Actual crop co-efficient, Reference crop co-efficient and Crop water requirement.

INTRODUCTION

Maize being the highest yielding cereal crop in the world is of significant importance for countries like Pakistan. Maize has its origin inasemi-aridand isnot a dependable crop for growing under dry land situation, withlimited or variable rainfall (Arnon, 1972). In Pakistan, it is planted on about 43% cropped area with the production of 461,000 tons and average grain yield of 3671 kg ha^{-1} and 37% in Khyber Pakhtunkhwa, produce 101,515 tons and average grain yield of 2984 kg ha^{-1} (Govt. of Pakistan, 2010).

It is normally cultivated under smallholder continuation farming systems, both under rainfed and irrigated conditions in the major and minor seasons that keep up a correspondence to the Monsoons. For maximum production a medium matured maize crop requires between 500 to 800 mm of water depending on environment (FAO, 2012).The effect of limited water on maize grain yield is significant and cautious control of frequency and depth of irrigation is required to optimize yields under circumstances of water scarcity (FAO, 2000).However, crop growth and seed yields are generally lower in the drier seasons due to low water availability to crop need, as a result crop goes under moisture stress condition whichis the significant cause for yield loss in maize after low soil fertility (Edmeades et al, 1992).

Maize crop is a C_4 plant, which is more capable to use CO_2, solar radiation, water and N in photosynthesis as compared to C_3 crops. Crop water productivity (CWP) of maize is about twice than C_3 crops grown at the similar places. Its transpiration ratio (molecules of water lost per molecule of CO_2 fixed) is 388, corresponding to 0.0026 in CWP (Jensen, 1973). Different maize cultivars have varying water requirement and crop water use efficiencies (Asare et al, 2011). The yields and crop water productivity are different for different maize hybrids. Also irrigation water requirement differ statistically among all the hybrids (Maria, 2009). To a careful estimate, only low water availability to crop demand results 50% or more declines in average yields internationally (Wang et al,2003). Maize has a high water and nutrient demand with the flowering stage being the most sensitive to water stress during which grain yield may be decreased by declining grain number and kernel weight (Pandey et al, 2000). For normal growth and development of maize, its maximumand even yields and high class, it is essential to keep optimal soil moisture during the growing period. Only optimal situation allow the plants to use water as their needs.

Objectives

To find crop coefficient for various growth stages of selected maize varieties;

To find crop water requirement of selected maize varieties under irrigated condition in Peshawar valley.

MATERIALS AND METHODS

Field Preparation

The experimental field having size of 95 m × 19 m was ploughed and properly levelled before crop sowing to make surethe uniform application of water. A pre-irrigation was applied to the field for easy tillage operation and plots preparation. A field ditch of one meter width was constructed along with each sub-plot from the main irrigation channel for the easy entrance of water. The experimental field was divided into 16 subplots of 4 m x 20 m, where plant to plant and row to row distance was kept 0.2 and 0.70 m, respectively.

Actual Evapotranspiration (ETa)

Actual evapotranspiration (ETa) of maize was determined by water balance equation. The difference in moisture content was added to the rainfall, the depth of irrigation applied and dividing this by the number of days between successive samplings. The following equation was used to determineETa:

$$ETa = \frac{I + P - Drz(\theta f - \theta i)}{\Delta t}$$

Where,

ETa	=	Actual evapotranspiration between two successive samplings (mm d^{-1})
I	=	Depth of irrigation (mm)
P	=	Precipitation between the sampling periods (mm)
Drz	=	Depth of root zone (mm)
θf	=	Soil moisture content at the time of second sampling (% by vol.)
θi	=	Soil moisture content at the time of first sampling (% by vol.)
Δt	=	Time interval between samplings (days).

Runoff and deep percolation was assumed to be negligible throughout the growing season, because field is bunded and irrigation was applied according to crop requirement.

Determination of Soil Moisture Content

The moisture content of the soil was determined by gravimetric method. The first soil sampling for moisture estimation was done at the time of crop sowing. Subsequent soil moisture samplings were carried out at an interval of 7 to 10 days until harvest of the crop. Soil moisture samples were also collected in between irrigation periods to check depletion of moisture in the soil. Similarly, after each substantial rain, a moisture sample was taken. Final moisture sampling was taken at the time of crop harvest.

A soil sample was taken at 0-100 cm depth from each treatment of the block. Soil moisture samples were dried in oven at 105^{0}C for 24 hrs. Percentsoil moisture content was calculated on a dry weight basis by using the following formula:

$$\theta m = \frac{Ww - Wd}{Wd} \times 100$$

Where,

θm	=	Soil moisture content (% by wt.)
Ww	=	Wet weight of soil (g); and
Wd	=	Oven dry weight of soil (g).

The percent soil moisture content on a volume basis was calculated by using the following relationships:

$$\theta v = \rho b \times \frac{\theta m}{\rho w}$$

Where,

θv	=	Soil moisture content (% by vol.)
ρw	=	Density of water (g cm^{-3}); and
ρb	=	Bulk density of the soil (g cm^{-3}).

Irrigation

Flow rate of the watercoursewas measured with the help of cut-throat flume, which was installed at the inlet of the researchfield. Discharge readings and the time of irrigationwas noted periodically until the flow cut off. Each plot was irrigated separately by applying the measured amount of irrigation water.

The irrigation was applied at 55% depletion of available water (FAO, 2012). Subsequent irrigations were applied to the respective plots, when soil moisture reached to critical moisture level. The critical moisture level on volume basis was computed as follows:

$$\Theta c = \frac{FC - (MAD \times AW)}{Drz} \times 100$$

The depth of irrigation to be applied to each plot was calculated as follow:

$$Dw = \frac{Drz(FC - \Theta i)}{100}$$

Where,

dw	=	Depth of water to be applied (cm)
Drz	=	Depth of root zone (cm)
FC	=	Field capacity (%); and

θi = Soil moisture content before irrigation (% by vol.).

Gross irrigation requirement (mm) for maize was calculated from the following equations:

$$GIR = \frac{dw}{Ea}$$

Where,

dw = Depth of water to be applied (mm)
GIR = Gross irrigation requirement (mm); and
Ea = Application efficiency (%).

The field application efficiency was taken 80%, to overcome the losses of water due to non-uniform infiltrations of experimental field. The time of irrigation required to get the required depth of water for each plot was calculated as follow(Jensen, 1998).

$$t = \frac{A \times dw}{Q}$$

Where,

t = Time required to irrigate (s)
A = Area of subplot (m^2)
dw = Depth of water to be applied (mm); and
Q = Discharge from the watercourse ($l\ s^{-1}$).

Crop Coefficient (Kc)

Crop coefficient is the ratio of the actual evapotranspiration to the potential crop evapotranspiration occurring during the same time period. It was determined by using the following equation.

$$Kc = \frac{ETa}{ETo}$$

Where,

Kc = Crop coefficient for a specific crop and for particular growth stage.
ETa = Actual evapotranspiration in (mm d^{-1})
Eto = Potential evapotranspiration (mm d^{-1})

Calculating ET_O

For the determining evaporation United States Weather Bureau (USWB) Class A open pan method is most simple and common method inirrigation scheduling for vegetables, fruit and fields. Evaporation data from U.S. Class A pan installed at Pakistan Forest InstitutePeshawar, was used for determination of Potential evapotranspiration (ET_0).Pan evaporation method process evaporation from the surface of open water, considering thecollective effect of temperature, radiation, humidity and wind. The relationship between ET_O and pan evaporation is as follow (Linarce, 1993):

$$ETo = Kp \times Epan$$

Where,

ET_O = Potential evapotranspiration (mm d^{-1})
Kp = Pan Coefficient; and
Epan = Pan evaporation (mm d^{-1}).

For the US Class A evaporation pan, the Kp varies between 0.35 and 0.85, with an average of 0.70.

RESULTS AND DISCUSSIONS

Actual Evapotranspiration (ETa)

Statistical analysis showed that there was significant difference in ETa between selected maize varieties (Table 3). ETa of traditional maize variety V_1 was found to be lowest and hybrid variety V_4 was found to be highest. Comparison of seasonal ETa of selected maize varieties showed that V_2, V_3 and V_4 had 3, 24 and 34 % higher values compared to V_1.Similar results were found by Piccinni et al. (2009) who reported that seasonal ETa of maize ranged from 441 to 641 mm. Similarly, Tariq et al. (2003) reported that ETa of maize was 451 mm during the study period. According to Ruzsanyi (1987),ETa of medium maturity maize hybrids ranged from 430 to 545 mm for the whole growing season.Similarly, length of growing season also increases the ETa as hybrid varieties take relatively greater number of days to harvesting than traditional maize varieties. The stage wise comparison showed gradual increase in ETa from crop initial stage to mid stage and then started decline till crop harvest.

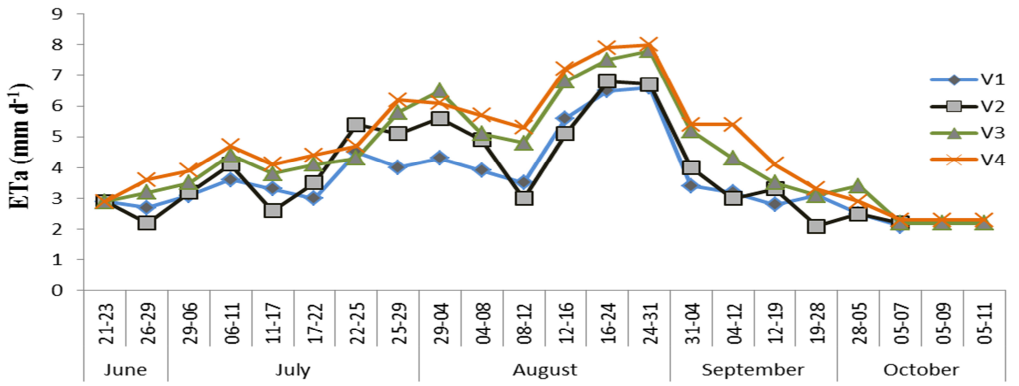

Figure 1 Actual evapotranspiration (ETa) of selected maize varieties

The FAO reported values for ETa were different than present study. The reason might be the differences in the climatic conditions of the research areas.

Table1 Stage wise actual evapotranspiration (ETa) of selected maize varieties

Varieties/Stages	Initial	Developmental	Mid-Season	Late Season
V_1	3.1	3.7	4.8	2.7
V_2	3.1	4.2	5.2	2.6
V_3	3.5	4.5	6.2	3.3
V_4	3.8	4.9	6.5	3.4

Potential Evapotranspiration (ETo)

Results of potential evapotranspiration (ETo) estimated using Pan Evaporation method are presented in Figure 2. There was high variability in ETo during the growing period (June to October) of maize crop. Highest ETo (9.7 mm d^{-1}) was found during the second week of July and lowest (3 mm d^{-1}) in the second week of October. The fluctuation in ETo during the month of August and September was due to intermittent rainfall events which resulted in lowering of atmospheric temperature. The total ETo during the growing period of maize crop was 738 mm.

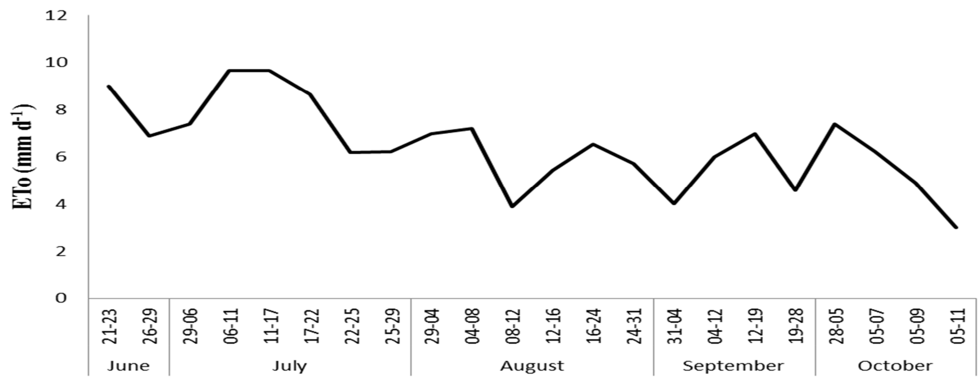

Figure 2 Potential evapotranspiration (ETo) for growing season of maize

Crop Coefficient (Kc)

The Kc of selected maize varieties showed almost the similar trend with some minor variation as shown in the Figure 3. It was observed that hybrid V_3 and V_4 varieties had higher Kc values as compared to traditional varieties V_1 and V_2. Traditional maize varieties Kc was almost similar to each other, whileKc of hybrid maize varieties during all the growth stages was found higher than traditional varieties. The maximum Kc values for V_1, V_2 were 0.87 and 0.91, while maximum Kc values for V_3, V_4 were 1.19 and 1.13, respectively. These results are in agreement with Islam and Hossain (2010) who reported that Kc of hybrid maize during initial, development, mid-season, and late season were 0.38, 0.87, 1.36, and 0.75, respectively. It was seen that Kc of maize variety V_4 was consistently higher during all growth stages, and Kc of maize variety V_1 was lowest among all the varieties. Kc during crop initial stages of all varieties was quite similar, as the crop canopy increased towards middle stage, evapotranspiration increased which in turn increased the Kc values of all varieties. During themid-season stages Kcvalues of traditional varieties was similar to each other but were observed different from hybrid varieties. In the third week of August Kc of V_3 and V_4 showed sudden decline, and then increase in the last week of August, the reason of abrupt increase and decrease might be due to change in atmospheric temperature or the genetic characteristics of the individual variety. The sharp decline after middle stage may be due to low water requirement of the crop during late stage. Other reason could be heavy rainfall that occurred during late stage of the crop, which directly decreased the actual evapotranspiration and resulted decline in Kc values.

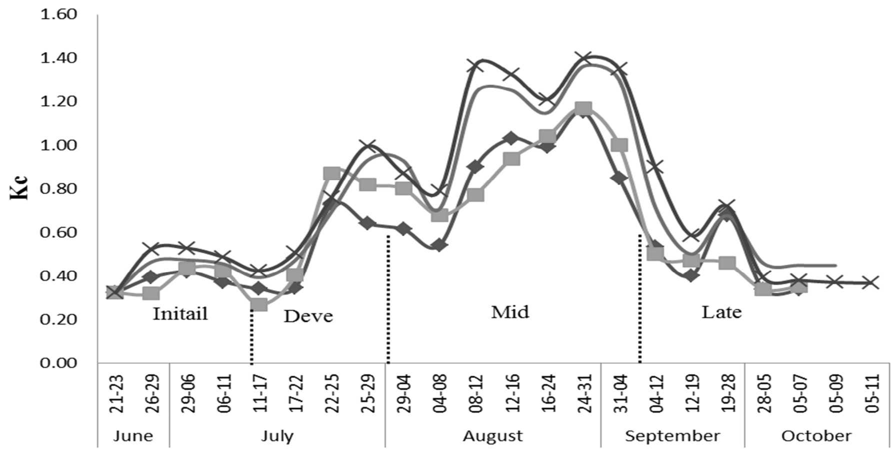

Figure 3 Crop co-efficient (Kc) of selected maize varieties

Similarly, variations in wind speed, solar radiation, temprature and relative humidity alter the aerodynamic resistance of the crops and hence their crop coefficients (Kc) will be greater, especially when leaf area and roughness heights are greater and for those crops which are substantially taller than the hypothetical grass reference and also varies with the climatic conditions and crop height.

TheKc values were different upto some extent from FAO reported values, the reason might be that FAO Kc values are generalized ones and recommended for a wide range of climatic conditions (Table 2). Other reasons might be that different maize varieties have different crop water use pattern and evapotranspiration.

The total numbers of days taken by traditional varieties sowing till crop harvest were 96, while hybrid varieties took 106 days. A reason of greater Kc value of hybrid may be due to length of growing season, as length of growing season increases the Actual Evapotranspiration increases due to which Kc increases.The duration of each stage depends on the length of growing season of a particular crop and climate (Doorenbos and Pruitt, 1977).

Table 2Comparison of observed Kc values of selected maize varieties with FAO reported values

Stages/Var.	**Initial**	**Developmental**	**Mid-Season**	**Late Season**
FAO (Kc)	**0.3-0.5**	**0.7-0.85**	**1.05-1.20**	**0.6-0.55**
V_1	0.38	0.51	0.87	0.46
V_2	0.38	0.59	0.91	0.42
V_3	0.43	0.62	1.13	0.56
V_4	0.47	0.67	1.19	0.59

Grain Yield

Significant difference was found in grain yield among all the varieties (Table 3). The mean grain yield obtained for traditional varieties ranged from 3046 to 3499 kg ha^{-1}, whereas for hybrid varieties it ranged from 5452 to 5832 kg ha^{-1}. These results are the contrast with those of Shah et al. (2007) and Hussain et al. (2006) who stated that 30K08 can produce the highest grain yield 9551 kg ha^{-1} among all the varieties, these might be due to variation in genotype among the varieties (Qamar et al., 2007).Similarly, Aziz et al. (1992) reported that potential yield of a hybrid is greater than the synthetic variety.

Table 3 Analysis of variance for Crop Water Requirement and Grain Yield

Varieties	**Grain yield (kg ha^{-1})**	**Crop water requirement (mm)**
V_1	3046d	410.75c
V_2	3499c	421.50c
V_3	5452b	512.25b
V_4	5832a	549.75a
Significance	**	*
LSD 5%	79.18	9.60

Mean value of same category followed by different lettersare significantly different fromeach other at $P \leq 0.5$ using LSD test.

ns = Non significant, * = Significant, ** = Highly significant

Conclusions

Some of the conclusions of the study are as follows:

- Actual evapotranspiration (ETa) for V_1, V_2, V_3, and V_4 were 411, 422, 512 and 550 mm when all the varieties were irrigated according to recommended MAD (55%). Comparison of ETa showed significant difference between all the varieties.
- The average seasonal crop coefficient (Kc) for V_1, V_2, V_3, and V_4 were 0.6, 0.62, 0.75 and 0.79, respectively.
- The highest grain yield (5832 kg ha^{-1}) was obtained for V_4, while lowest grain yield (3046 kg ha^{-1}) was found forV_1.

Recommendation/ Suggestions

- FAO reported Kc values of a crop are generalized one for a wide range of climate therefore,Kc value of each crop variety should be investigated and used.

REFERENCES

Arnon, I. 1972. Economic Importance of Maize.Crop production in dry regions.Leonard Hill Londo. 2:146-156.

Asare, D.K., J.O. Frimpong, E.O. Ayeh and H.M. Amoatey. 2011. Water use efficiencies of maize cultivars grown under rainfed conditions. Agric. Sci. 2:125 -130.

Aziz, A., M. Saleem, H. Rahman and M. Fida. 1992. Performance of maize hybrids under irrigated condition. Sarhad J. Agric. 8(5): 509-111.

Doorenbos, J. and W.O. Pruitt. 1977. Guidelines for predicting crop water requirement. FAO Irr.& Drain. 24:144–145.

Edmeades, G.O., J. Bolans and R.A. Lafitte. 1992. Progress in breeding for drought tolerance in maize in Wilkinson D. (Ed.). Proceedings of 47th Corn and Sorghum Research Conference State transactions.USA.93–111.

FAO. 2012. Crop Evapotranspiration (Guidelines for computing crop water requirement). Irr.& Drain.56:163.

FAO. 2000. Agriculture, food and water, a contribution to the world. Water Rep. 5:236-240.

Goverment of Pakistan. 2010. Economic Survey of Pakistan. Ministry of Finance, Govt. Pak. Isl. p.22.

Hussain, N., M.S. Baloch, Q. Zaman, A. Aziz and G.Sadozai. 2006. Adaptability and genetic variation in some maize hybrids. J. Agric. Res. 48(4): 437-443.

Islam, M.S. and M. A. Hossain. 2010. Determination of crop co-efficient of Hybrid maize by lysimeter study. Bangladesh J. Agric. Res. 35(1): 77-82.

Jensen, M.E. 1973. Consumptive use of water and irrigation water requirements. American Soc. Civil Eng. 23(81):225-231.

Linacre, E.T. 1993. Data sparse estimation of lake evaporation using a simplified Penman equation. Agric. & Forestry Meteor. 64:237-56.

Maria, B.I. 2009. Researches concerning the hybrid influence on water use efficiency in maize from north-western Romania. University of Oradea, Faculty of Environmental Protection, 26 Gen. Magheru St., 410048 Oradea, Romania. (14).

Pandey, R.K., J.W. Maranville and A. Admou. 2000. Deficit irrigation and nitrogen effects on maize grain yield and yield components, in a Sahelian environment. Agric. Water Mgt. 46:1-13.

Piccinni, G., K. Jonghan, T. Marek and T. Howell. 2009. Determination of growth stage specific crop coefficients (Kc) of maizeand sorghum. Agric. Water Mgt. 96:1698-1704.

Qamar, M., A.G. Zulfiqar, H.N. Malik and S.K. Tanveer. 2007. Evaluation of maize hybrid under double cropping zone of northern areas of Pakistan. Sarhad J. Agric. 23(4): 1009-1012.

Razsanyi, L. 1987. Main results of the maize production research conducted at the crop production department of the University of Agronomy, Debrecen. InformattionnylByalleten PO-Kukuruze. 6:49-57.

Shah, Z., Z. Shah, M.Tariq and M. Afzal. 2007. Response of maize to integrated use of compost and urea fertilizers. Sarhad J. Agric. 23(3): 667-673.

Tariq, J.A., M.J. Khan and K. Usman. 2003. Irrigation scheduling of maize crop by pan evaporation method. Pak. J. Water Res. 7(2):1-50.

Wang, W., B. Vinocur and A. Altman, 2003. Plant responses to drought, salinity and extreme temperature: towards genetic engineering for stress tolerance. Planta. 218:1-14.