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Research Article

Effect of Different Conservation Tillage Practices on Evapotranspiration and Water Use Efficiency in Maize Crop (*Zea mays* L.)

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ABSTRACT

The field experiment was undertaken in maize crop at research farm of IARI, New Delhi to study the evapotranspiration and water use efficiency (WUE) under different conservation tillage treatments. The experiment was carried out with seven treatments i.e. conventional tillage (CT), permanent narrow-bed without residue (PNB), permanent narrow-bed with residue (PNB+R), permanent broad- bed without residue (PBB), permanent broad-bed with residue (PBB+R), zero tilled flat bed without residue (ZT), zero tilled flat bed with residue (ZT+R). The evapotranspiration was measured by single and dual crop coefficient method. For maize crop, reference evapotranspiration (ET_0) range was between 1.8 to 7.6 mm day^{-1} during crop growing period. All the conservation treatments had lower evapotranspiration as compared to CT treatment. Results showed that crop coefficient methods are useful for determining water stress in crop and daily evapotranspiration losses which are helpful in estimation of water need of crop and irrigation scheduling. Among all the treatments, PBB+R treatment was superior with respect to water use efficiency. PBB+R treatment had 25-30% higher water use efficiency (WUE) as compared to CT treatment.

Key words: Conservation treatment, single crop coefficient, dual crop coefficient, evapotranspiration, water use efficiency

Introduction

Agriculture cannot sustain the growing human population on the current damaging rate of natural resources and climate change. Traditional animal-based tillage systems used in agriculture are costly as feed, fodder and maintenance round the year is expensive affaire for the farmers. Greenhouse gases emitted by animals mostly methane is potentially 21 times more dangerous than carbon dioxide (Grace *et al.,* 2003). Large quantities of fossil fuels is consumed by tractors when used for ploughing which adds more cost as well as greenhouse gases emissions (mostly CO_2) thus playing major role in global warming (Grace *et al.,* 2003). Conservation agriculture practices can suppress these emissions and costs. Farmers in Pakistan and India were surveyed and it was found out that zero-till of wheat preceding rice reduces costs of cultivation up to US$60 ha^{-1} commonly due to lesser fuel (60–80 L ha^{-1}) and labour (Hobbs and Gupta, 2004). Conservation agriculture includes reduced tillage, crop rotation, and residue retention as its main components. Zero-tillage reduces time for establishment of a crop. The practice of zero-tillage (minimum soil disturbance) means leaving 30% crop residue or stubble on the field even after the harvest of crop (instead of throwing away) or incorporation of residues into the soil from external sources.

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This organic mulch lessens runoff, facilitates infiltration, and declines the evaporation of the soil's water (Arshad *et al*., 1999; Rasmussen, 1999). The benefits of tillage decisions may comprise of improved crop establishment, better infiltration, and lesser runoff (Cogle *et al*., 1997). Crop residue mulch aids to decrease soil water evaporation and enhances soil moisture storage (Huang *et al*., 2005; He *et al*., 2011; Singh *et al*., 2011). Conventional agriculture leads to soil organic matter reduction, increased water runoff, soil erosion, and degradation of soil physical, chemical, and biological properties (Thierfelder and Wall, 2009). On the other side, conservation tillage practices like sub- soiling, tied ridging, and ripping have the potential to mitigate intra-seasonal dry spells and increase soil moisture retention (Manyatsi *et al.,* 2011). Conservation tillage can conserve rainwater which is otherwise lost as surface runoff, evaporation, and through deep percolation in the magnitude of 70 to 85% of rainfall in Sub Saharan Africa, hence makes it beneficial to the crops (Cornelis *et al.,* 2013). Keeping the above point in view, the present study was aimed to study the effect of different conservation tillage practices on evapotranspiration and water productivity in maize crop by using single and dual crop coefficient.

Material and Methods

Experiment site description

The present study was carried out in the experimental field of ICAR-Indian Agricultural Research Institute (IARI), New Delhi, India which is stretching from 28°35' N latitude to 77°12' E longitude at an altitude of 228.16 m above mean sea level. The field had a fairly leveled topography. The climate of New Delhi is sub-tropical and semi-arid with warm and dry summer and cold winters come under the 'Trans-Gangetic Plains' agro-climatic zone. Weather detail during the crop growing period is given in Fig. 1. Long-term conservation agriculture (CA) experiments were initiated in May 2010 at the research farm of the IARI, New Delhi on an alluvial sandy clay loam soil (fine loamy, illitic, Typic Haplustept). The surface (0-15 cm) soil of the experimental site had pH 7.7, Walkley-Black organic C 5.2 g kg^{-1}, $KMnO_4$ oxidizable N 182.3 kg ha^{-1}, 0.5 M $NaHCO_3$ extractable P 23.3 kg ha^{-1} and 1 N NH_4OAc extractable K 250.5 kg ha^{-1}. Maize (*Zea mays* L.) variety BIO 9637 was sown on 5th July during *Kharif* season.

Treatments detail

The field experiment was carried out with seven treatments i.e. conventional tillage (CT), permanent narrow-bed without residue (PNB), permanent narrow-bed with residue (PNB+R), permanent broad-bed without residue (PBB), permanent broad-bed with residue (PBB+R), zero tilled flatbed without residue (ZT), zero tilled flatbed with residue (ZT+R). Detail of different treatments is given in Table 1. The

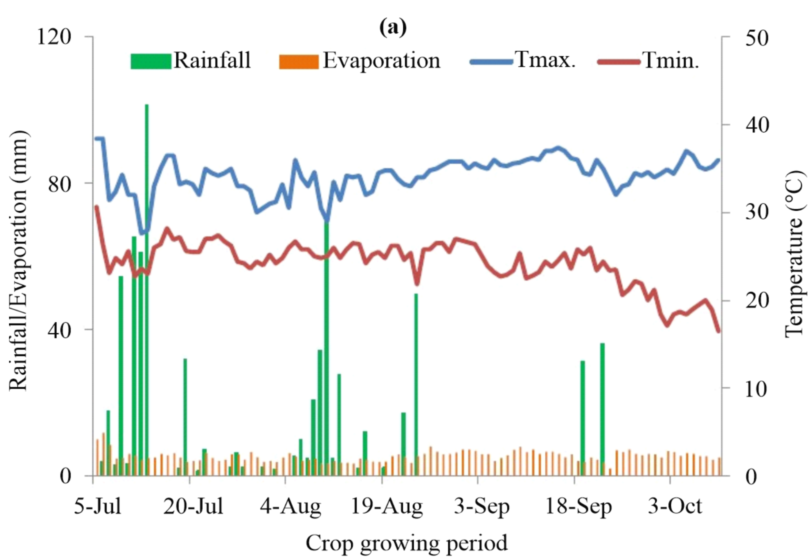

Fig.1. Daily weather data during crop growing period

Table 1. Details of the different tillage treatments used during the crop growing period in maize crop

Treatment	Tillage	Type of bed	Residue retention
CT	Conventional tillage	Flat beds	No
PNB	Zero tillage	Permanent narrow bed (PNB; 40cm bed and 30 cm furrow)	No
PNB+R	Zero tillage	Permanent narrow bed (PNB; 40cm bed and 30 cm furrow)	Yes
PBB	Zero tillage	Permanent broad bed (PBB; 110cm bed and 30 cm furrow)	No
PBB+R	Zero tillage	Permanent broad bed (PBB; 110cm bed and 30 cm furrow)	Yes
ZT	Zero tillage	Flat beds	No
ZT +R	Zero tillage	Flat beds	Yes

layout of field experiment was randomized block design (RBD) with three replications. In the CT and ZT plots, irrigation was applied using the flooding method (water applied during the first irrigation, measured with a water meter, was in the range of 0.065 m and 0.056 m in CT and ZT, respectively) always resulted in more water application than that in the plots under PNB and PBB (where irrigation water was applied in furrows). The irrigation water amount applied in both bed planting schemes was slightly different. The ratio of amount of water applied per ha in PNB to PBB plots was 1:0.9. Recommended doses of fertilizer i.e. 120 kg N + 60 kg P_2O_5 + 40 kg K_2O ha^{-1} were applied in maize crop.

Reference evapotranspiration

The FAO Penman-Montieth equation (Allen *et al.*, 1998) was used to calculate reference evapotranspiration, ET_0.

$$ET_0 = \frac{0.408\,\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2\,(es - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad \ldots(1)$$

where ET_0 expressed in (mm day^1); R_n net radiation at crop surface (MJ m^{-2} hr^{-1}); G soil heat flux density (MJ m^{-2} day^{-1}); T air temperature at 2 m height (°C); u_2 wind speed at 2m height (m s^{-1}); e_s saturation vapour pressure (kPa); e_a actual vapour pressure (kPa); Δ the slope of the vapour pressure curve (kPa°C^{-1}) and γ is the psychrometric constant in (kPa °C^{-1}).

Net radiation calculation

The net radiation, the difference between the incoming net shortwave radiation and the outgoing net longwave radiation, is the fundamental variable for calculation of evapotranspiration.

$$R_n = (1-r)\,(0.25 + 0.5\,n/N)R_o - (0.9n/N + 0.1)(0.34 - 0.14\,\sqrt{e_a})\,\sigma T^4 \quad \ldots(2)$$

where, R_o extraterrestrial radiation (MJ m^{-2} day^{-1}), ea actual vapor pressure (kPa), σ Stefan-Boltzmann constant (4.903×10^{-9} MJ m^{-2} K^{-4} day^{-1}), T air temperature (K), r reflection coefficient (observed mean value, 0.24), n number of hours of bright sunshine per day (h) and N is the total day length

Actual evapotranspiration (ETa)

A detailed description of procedures for applying the single-K_c and dual-K_c methods to estimate ET_a is given in FAO-56. K_c and K_{cb} methods were estimates ET_a using the equations:

$$ET_a = K_s K_c ET_0 \quad \ldots(3)$$

$$ET_a = (K_s K_{cb} + K_e)\,ET_0 \quad \ldots(4)$$

where ET_c crop evapotranspiration, K_c single crop coefficient, K_{cb} basal crop coefficient (K_{cb}) and K_s is soil stress coefficient.

FAO approach for evapotranspiration calculation

Single crop coefficient (Kc)

Kc value for the initial period was calculated by

$$Kc_{ini} = f_w \times Kc_{ini}\,(Tab) \quad \ldots(5)$$

Where, f_w is the fraction of surface wetted by irrigation or rain (0-1), for flood irrigation in CT and ZT treatments, f_w was 1, for PBB treatment, f_w was 0.5 and for PNB treatment, f_w was 0.7 taken and Kc_{ini}

(Tab) for maize crop was 0.3. All the values were taken from FAO-56.

Crop coefficient for the mid-stage season ($K_{c\ mid}$)

$$K_{c\ mid} = K_{c\ mid}\ (Tab) + [0.04(u_2\text{-}2)\text{-}0.004(RH_{min}\text{-}45)](h/3)^{0.3} \quad \ldots(6)$$

where, $K_{c\ mid}$ (Tab) value for $K_{c\ mid}$ was 1.20 for maize crop (FAO-56).

Crop coefficient for the end of the late-season stage ($K_{c\ end}$)

$$K_{c\ end} = K_{c\ end}(Tab) + [0.04(u_2\text{-}2)\text{-}0.004(RH_{min}\text{-}45)](h/3)^{0.3} \quad \ldots(7)$$

where $K_{c\ end}$(Tab) value for $K_{c\ end}$ was 0.35 for maize crop (FAO-56). u_2 mean value for daily wind speed at 2m height over grass during the late-season growth stage [m s^{-1}], for 1 m $s^{-1} \le u_2 \le 6$ m s^{-1}, RH_{min} mean value for daily minimum relative humidity during the late-season growth stage [%], for 20% $\le RH_{min} \le$ 80%, h mean plant height during the late-season stage [m] for 0.1m $\le$ h $\le$ 10m.

Dual crop coefficient (Kcb)

The dual crop coefficient (K_{cb}) is the ratio of the crop evapotranspiration over the reference evapotranspiration (ET_c/ET_0) when the soil surface is dry but transpiration is occurring at a potential rate, i.e., water is not limiting transpiration. The adjustment was done according to prevalent conditions-

$$K_{cb} = K_{cb}(Tab) + [0.04(u_2\text{-}2)\text{-}0.004(RH_{min}\text{-}45)](h/3)^{0.3} \quad \ldots(8)$$

where, K_{cb}(Tab) the value for $K_{cb\ mid}$ or $K_{c\ end}$ (if $\ge$ 0.45) given by FAO-56, u_2 mean value for daily wind speed at 2m height over grass during the mid or late season growth stage [m s^{-1}], for 1 m $s^{-1} \le u_2 \le 6$ m s^{-1}, RHmin mean value for daily minimum relative humidity during the mid or late season growth stage [%], for 20% $\le RH_{min} \le$ 80%, h mean plant height during the mid or late season stage [m], $K_{cb(ini)}$ was 0.15 used for maize crop, it was < 0.45 so no adjustment needed, $K_{cb\ mid}$ was 1.15 used for maize, it was > 0.45 so no adjustment needed, $K_{c\ end}$ was 0.50 used for maize crop, which >0.45 so adjustment according to climatic conditions.

Soil evaporation coefficient (Ke)

$$K_e = K_r \times (K_{c\ max}\text{-}K_{cb}) \le f_{ew} \times K_{c\ max} \quad \ldots(9)$$

Where, K_e soil evaporation coefficient, K_{cb}=basal crop coefficient, $K_{c\ max}$= maximum value of K_c following rain or irrigation, K_r= dimensionless evaporation reduction coefficient dependent on the cumulative depth of water depleted (evaporated) from the topsoil, f_{ew}= fraction of the soil that is both exposed and wetted, i.e., the fraction of soils surface from which most evaporation occurs.

Water stress coefficient (Ks)

$$K_s = \frac{TAW - Dr}{TAW - RAW} = \frac{TAW - Dr}{(1-p)\,TAW} \quad \ldots(10)$$

Where water stress coefficient (K_s) is dimensionless transpiration reduction factor dependent on available soil water (0-1), Dr is root zone depletion (mm), TAW is total available soil water in the root zone (mm), RAW is the readily available water and p is the average fraction of TAW that can be depleted from the root zone before moisture stress (reduction in ET) occurs.

Water use efficiency

Amount of water used is the actual evapotranspiration (ET_a) which was calculated from single and dual crop coefficient respectively. Water use efficiency of the crop was calculated as:

$$\text{Water use efficiency (WUE)} = \frac{\text{Biomass or yield produced (g m}^{-2})}{\text{Amount of water used (cm)}} \quad \ldots(11)$$

Statistical analysis

The data were analyzed using SPSS (version 10.0), Excel package (version 7.0). Analysis of variance as applicable for randomized block design was used to test the least significant differences among the various treatment means and their interactions using statistical analysis. MS Excel software package was used to draw the required graphs. The means of all the treatments were separated by DMRT at 5% level of significance and as per standard ANOVA. Pearson's correlation matrix was also computed.

Results

Net radiation and reference evapotranspiration (ET_0)

The values of net radiation and estimated reference evapotranspiration for maize are given in Fig. 2. Estimated reference crop evapotranspiration was validated by pan evaporation by multiplying the pan evaporation data with correction factor. Fig. 3 shows the relationship between estimated reference evapotranspiration and calculated by pan evaporation had good correlation at R^2 of 0.87 for maize crop. ET_0 ranged between 1.8 to 7.6 mm day^{-1} during the crop growing period.

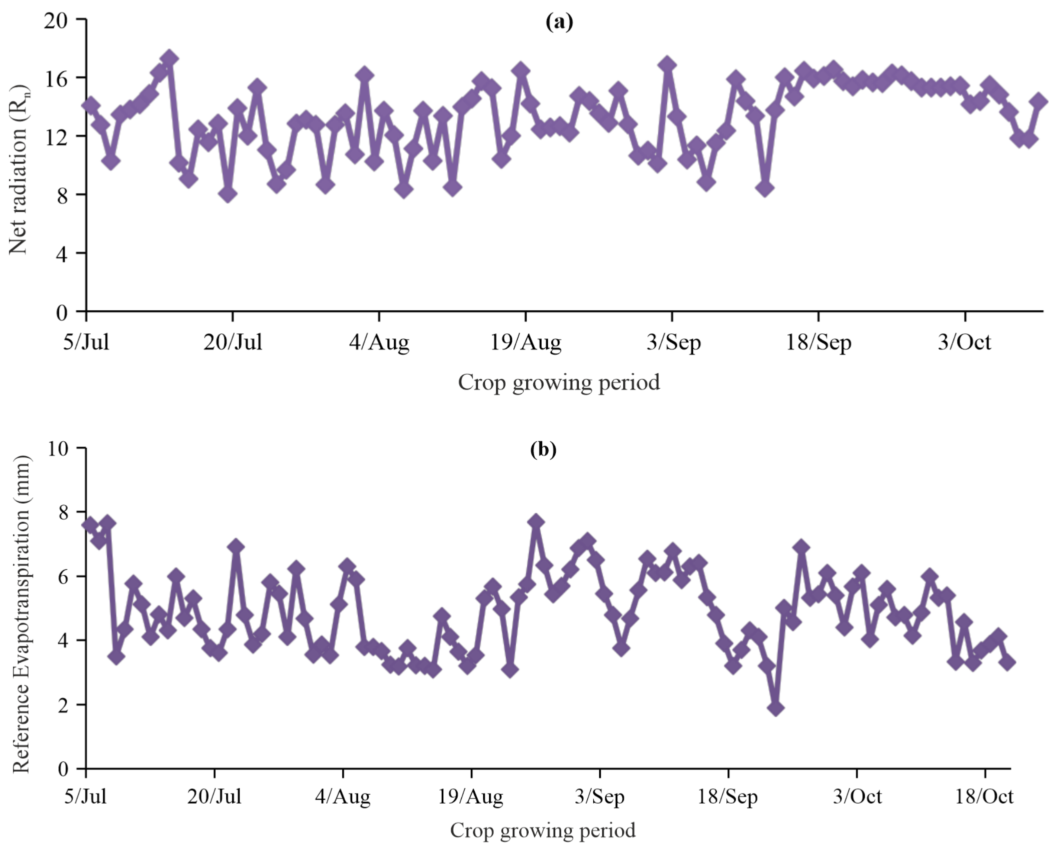

Fig. 2. (a) Net radiation (Rn) and (b) reference evapotranspiration (mm/day) calculated in maize crop

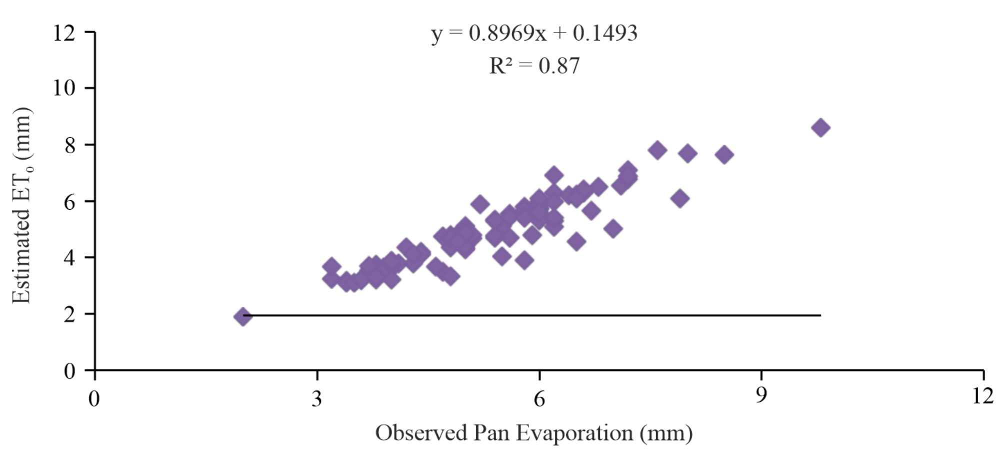

Fig. 3. Relation between reference evapotranspiration calculated through Penman-Monteith equation and pan evaporation in maize crop

Table 2. Adjusted single and basal crop coefficient (K_{cb}) of maize crop during the growing period

Treatment	Adjusted single crop coefficient (K_c)			Adjusted basal crop coefficient (K_{cb})		
	Initial stage	Mid season stage	Late season stage	Initial stage	Mid season stage	Late season stage
CT	0.30	1.339	0.421	0.15	1.227	0.614
PNB	0.21	1.347	0.422	0.15	1.229	0.621
PNB+R	0.21	1.348	0.424	0.15	1.230	0.622
PBB	0.15	1.354	0.428	0.15	1.235	0.625
PBB+R	0.15	1.355	0.430	0.15	1.237	0.627
ZT	0.30	1.350	0.425	0.15	1.232	0.624
ZT +R	0.30	1.352	0.427	0.15	1.233	0.626

Adjusted single and basal crop coefficient

Single crop coefficient (K_c) values suggested by FAO-56 are 0.30, 1.20, and 0.35 for the initial, mid-season, and late-season stages in maize crop, respectively. They are adjusted for the semi- arid climatic conditions as FAO-56. Adjusted crop coefficients for the initial stage, midseason stage, and late-season stage for maize crop under different treatment are shown in Table 2. Similarly, basal crop coefficient (K_{cb}) values suggested by FAO-56 are 0.15, 1.15, and 0.50 for the initial, mid-season, and late-season stages in maize crop, respectively. After adjustment, the K_{cb} of maize in the initial stage is 0.15 for all tillage treatments under different weather conditions but the K_{cb} values in the mid and late season stage are different for different treatments (Table 2).

Soil evaporation coefficient (K_e)

Soil evaporation coefficient (K_e), as a function of the growth period is affected by the soil water characteristics, exposed and wetted soil fraction, and soil water balance. In the initial stage, the effective fraction of soil surface covered by crop plants is small and thus, soil evaporation losses are considered during this period. After irrigation, K_e reached its maximum values of 1.04-1.11 in the maize crop. The cumulative depth of evaporation from the topsoil layer is small because of the low water retention capacity. K_e had a sharp fall when the soil evaporation switched from the initial to developing stage. In the development stage, the effective fraction of soil surface covered by crop plants gradually increased, and the K_e value decreased step by step. In the mid-season stage, the effective fraction of soil surface covered by crop plants reached above 0.9. Once the crop canopy is completely covering the soil, the influence of water evaporation on determining the evapotranspiration is reduced because of a reduction in soil water evaporation (Allen *et al*., 2006). The small exposed soil fraction resulted in a small K_e value. The K_e values ranged between 0.25-0.33 during the mid-season stage. In the late-season stage, the K_e value was greater than that in the midseason stage because of the drooping of the main leaves. Liu and Fernando (1998) have shown that soil evaporation decreases with the increases of leaf area index (LAI) and that, for a given range of LAI values, it increases with soil water availability.

Crop evapotranspiration (ET_c) using single and dual crop coefficient

During the initial stage of maize crop growth, which is the period from sowing to 20 days of crop growth, the ETc values were very low except during irrigation events. The ET_c values increased during the crop development stage (20-45 days) of crop growth and reached their peak during the midseason stage (45-85 days) due to maximum canopy cover and leaf area index. The ETc values decline rapidly during the late stage, the period from 85 to 105 days of crop growth because leaves were dried and senescence. The Sum of daily values of ETc for maize crop in initial, development, mid, and late-stage using single and dual crop coefficient are given in Tables 3 and 4 respectively. Maximum ETc values were found under CT treatment in all stages of crop growth followed by ZT, ZT+R, PNB, PNB+R, PBB, and

Table 3. Crop evapotranspiration (ETc) (mm) using single crop coefficient in maize crop

Treatment	Initial stage ETc	Development stage ETc	Mid season stage ETc	Late season stage ETc	Total Etc
CT	53.1[a]	104.5[a]	269.7[a]	55.4[a]	483[a]
PNB	48.7[c]	99.4[bc]	257.1[c]	53.4[a]	459[c]
PNB+R	48.2[cd]	98.9[c]	254.7[cd]	52.9[ab]	455[cd]
PBB	47.8[cd]	97.7[c]	252.2[de]	52.4[ab]	450[de]
PBB+R	47.6[d]	96.6[c]	249.3[e]	52.1 [b]	446[e]
ZT	50.3[b]	102.7[a]	264.5[b]	55.1[a]	473[b]
ZT+R	48.9[cd]	101.8[ab]	262.1[b]	54.8[a]	467[b]

Mean values marked with same alphabet within a column are non-significantly different ($p<0.05$, Tukey's HSD)

Table 4. Crop evapotranspiration (ETc) (mm) using dual crop coefficient in maize crop

Treatment	Initial stage ETc	Development stage ETc	Mid season stage ETc	Late season stage ETc	Total ETc
CT	58.8[a]	124.7[a]	268.4[a]	47.7[a]	500[a]
PNB	57.2[abc]	118.5[d]	260.9[d]	45.6[ab]	482[b]
PNB+R	56.3[bc]	115.3[e]	259.4[e]	45.3[ab]	476[c]
PBB	56.1[bc]	114.3[e]	255.8[f]	45.3[ab]	472[cd]
PBB+R	55.3[c]	112.8[f]	253.7[g]	44.7[b]	467[d]
ZT	58.1[ab]	122.8[b]	266.7[b]	47.3[a]	495[a]
ZT+R	57.8[ab]	120.0[c]	262.8[c]	46.7[ab]	487[b]

Mean values marked with same alphabet within a column are non-significantly different ($p<0.05$, Tukey's HSD)

PBB+R treatment. Statistical analysis for comparing crop evapotranspiration (ETc) calculated by single and dual crop coefficient methods using paired t test are shown in Table 7. According to Kjaersgaard *et al*. (2008) awareness about crop water requirements is necessary for irrigation scheduling and agricultural water management in hydrological research and field management. Crop water requirement is directly related to an accurate estimation of crop evapotranspiration (ET_c) which depends on crop characteristics and its developmental stages, environmental conditions, weather parameters, and management practices.

Actual evapotranspiration (ETa)

When rainfall or irrigation was low, water stress-induced, and the evapotranspiration dropped below the standard crop evapotranspiration (ET_c). Due to water stress, actual evapotranspiration (ET_a) was decreased below the crop evapotranspiration (ET_c). ET_a from single crop coefficient (SCC) was found maximum under CT (438 mm) followed by ZT (429 mm), ZT+R (423 mm), PNB (419 mm), PNB+R (414 mm), PBB (411 mm), and PBB+R (404 mm) treatment. Similarly from dual crop coefficient (DCC), ET_a was found maximum under CT (449 mm) followed by ZT (441 mm), ZT+R (434 mm), PNB (431 mm), PNB+R (428 mm), PBB (422 mm) and PBB+R (415 mm) treatment. Results (Table 5) showed that crop coefficient methods are useful for determining water stress in crops and daily evapotranspiration losses, water need of crop, and irrigation scheduling. Statistical analysis for comparing actual evapotranspiration (ET_a) calculated by single and dual crop coefficient methods using paired t test are shown in Table 7. Vidhana Arachchi and Liyanage (2003) also revealed that additional build-up of leaf litter conserved the soil moisture by reducing the evapotranspiration from the compact soil layer. Aggarwal and Goswami (2003) and Gupta *et al.* (2007) reported that the practice of raising seedling in a raised bed- furrow seeding system in

Table 5. Actual evapotranspiration (ETa) (mm) in maize crop by single and dual crop coefficient

Treatment	ETc by single crop coefficient	ETa by single crop coefficient	ETc by dual crop coefficient	ETa by dual crop coefficient
CT	483[a]	438[a]	500[a]	449[a]
PNB	459[c]	419[cd]	482[b]	431[d]
PNB+R	455[cd]	414[de]	476[c]	428[d]
PBB	450[de]	411[e]	472[cd]	422[e]
PBB+R	446[e]	404[f]	467[d]	415[f]
ZT	473[b]	429[b]	495[s]	441[b]
ZT+R	467[b]	423[bc]	487[b]	434[c]
LSD (0.05)	9.2	11.8	10.4	9.1

Mean values marked with same alphabet within a column are non-significantly different (p<0.05, Tukey's HSD)

northwest India gave a significant reduction of water utilization and obtaining higher yields for a range of crops, in comparison with the flatbed with flood irrigation traditional system followed by the farmers.

Table 6. Water use efficiency (WUE) (Kg/ha/mm) by single and dual crop coefficient in maize crop

Treatment	WUE by single crop coefficient	WUE by dual crop coefficient
CT	9.70[f]	9.45[f]
PNB	11.75[e]	11.43[e]
PNB+R	12.78[d]	12.37[d]
PBB	13.69[b]	13.34[b]
PBB+R	14.22[a]	13.81[a]
ZT	12.61[d]	12.26[d]
ZT+R	13.23[c]	12.90[c]
LSD (0.05)	0.46	0.57

Mean values marked with same alphabet within a column are non-significantly different (p<0.05, Tukey's HSD)

Water use efficiency (WUE)

WUE in maize crop was found lowest under CT treatment by single crop coefficient and dual crop coefficient method. WUE from single crop coefficient was 9.70 kg/ha/mm under CT treatment followed by PNB (11.75 kg/ha/mm), PNB+R (12.78 kg/ha/mm), ZT (12.61 kg/ha/mm), ZT+R (13.23 kg/ha/mm), PBB (13.69 kg/ha/mm) and PBB+R (14.22 kg/ha/mm) treatment. WUE calculated from dual crop coefficient was 9.45 kg/ha/mm under CT treatment followed by PNB (11.43 kg/ha/mm), PNB+R (12.37 kg/ha/mm), ZT (12.26 kg/ha/mm), ZT+R (12.90 kg/ha/mm), PBB (13.34 kg/ha/mm) and PBB+R (13.81 kg/ha/mm) treatment (Table 6). PBB+R treatment had 30-33% higher WUE as compared to the corresponding value in conventional treatment under maize crop. Statistical analysis for comparing water use efficiency (WUE) calculated by single and dual crop coefficient methods using paired t test are shown in Table 7. WUE of crops and availability of water depends on soil management practices (Hatfield *et al*., 2001). Du *et al*. (2000)

Table 7. Paired t-test for crop evapotranspiration (ETc), actual evapotranspiration (ETa) and water use efficiency (WUE) calculated by single crop coefficient (SCC) and dual crop coefficient (DCC) method

	Paired differences					t	df	Sig. (2-tailed)
	Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
				Lower	Upper			
ETc by SCC and DCC	-20.88	2.06	0.45	-21.82	-19.94	-46.50	20	.000
ETa by SCC and DCC	-12.00	1.56	0.34	-12.71	-11.29	-35.26	20	.000
WUE by SCC and DCC	.32	.37	0.08	0.16	0.49	4.03	20	.001

reported a similar finding that compared to conventional tillage, in conservation tillage, the WUE was 13% higher for the winter wheat.

Conclusion

The crop evapotranspiration (ET_c) and actual evapotranspiration (ET_a) values calculated by single and dual crop coefficient were found higher values under CT, ZT, and ZT+R treatments because they had flood irrigation. PNB, PNB+R, PBB, and PBB+R had less value due to furrow irrigation. Residue treatment had lower water loss by residue and improved water holding capacity. Water requirement in crops can be estimated more accurately by dual crop coefficient approach as compared to single crop coefficient as it includes both soil and crop coefficient. Water use efficiency by single crop coefficient and dual crop coefficient had maximum values under PBB+R treatment and lowest value under conventional tillage treatment. So, PPB+R treatment can use in the north-western region to improve water use efficiency as compared to conventional treatment.

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