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Estimation of seasonal evapotranspiration and crop coefficient of wheat (*Triticum aestivum* L.) under drip irrigation and N-fertigation scheduling at Jalgaon, Maharashtra

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ABSTRACT

An attempt was made to determine the seasonal evapotranspiration and crop coefficient of wheat during various growth stages under drip irrigation and N-fertigation scheduling in Jalgaon, Maharashtra during 2012-13 and 2013-14. The results revealed that grain and straw yield of wheat increased significantly at each higher levels of drip irrigation up to 1.0 Epan and fertigation of 120 kg N ha^{-1} in both the years. The mean daily ETc of wheat during its initial stage was found to be lower and almost constant and it increased continuously during vegetative stage, flowering and grain filling stage (4.75 mm day^{-1}) and decreased during the maturity stage. The measured seasonal ETc of wheat was ranged from 294.5 to 453.5 mm. The highest seasonal ETc and ETc was recorded in surface check basin irrigation at IW/CPE 1 and lowest in deficit irrigation schedule i.e. drip irrigation at 0.6 Epan. Each higher level of nitrogen from N_0 to N_{160} slightly increased the seasonal ETc of wheat. Estimated crop coefficient values (0.71, 1.31, 1.34 and 0.76 at initial, crop development, mid season and late season stage) at 1.0 Epan through drip were slightly higher over the FAO Kc values.

Keywords: Crop coefficient, crop evapotranspiration, drip irrigation, wheat, yield

Wheat is the one of the major food grain crop in India cultivated in an area of around 30.61 m ha with a production of 95.91 million tons. It is grown under different soil and climatic conditions. Appropriate water management and fertilization is key component and critical issues for wheat production system in semi-arid tropics of India. Off late due to erratic behavior of monsoon and uncontrolled exploitation of ground water caused scarcity of water resources (Perveen *et al.,* 2012). The scarce water resources in the country necessitate its economic use which will be possible only by efficient water management practices by adopting advanced technology of irrigation like micro-irrigation. Since wheat is grown mostly in irrigated conditions, comprehensive knowledge of actual water requirement (ETc) of the wheat crop is necessary for appropriate irrigation scheduling under drip irrigation.

Crop evapotranspiration (ETc) is used to determine the water requirement of the crop and developing irrigation schedules. Measurement of seasonal ETc being difficult, the same is commonly estimated using the meteorological data. Several measurement researches on farmland ET was tested for different crops in different climatic conditions (Khandelwal *et al.,* 1999; Pandey *et al*., 2008; Mehta and Pandey, 2015). For estimating ET_0, Penman- Monteith method is most preferred as it suits a wide variety of climatic conditions. Although crop co-efficient values for different crops grown under different climatic conditions as suggested by Doorenbos and Pruitt (1977) are used where locally measured data are not available. Allen *et al.* (1998) have suggested that these values need to be derived empirically for each crop based on the local conditions to determine the water requirement. Mehta and Pandey (2015) developed crop coefficients for wheat and maize from ETc measurements and local weather data.

MATERIALS AND METHODS

A field experiment was carried out during winter (*rabi*) season of 2012-13 and 2013-14 at Jain Hi-Tech Agri. Institute, Jalgaon, Maharashtra (21° 01' 52'' N-Latitude, 75° 56' 38'' E-Longitude at 292 m above mean sea level). The soil of the experimental plot was sandy clay loam texture in surface layer with increased sand percentage towards lower depth, neutral in reaction and non-saline. The available nitrogen content was lower throughout the profile ranging from 164.6 to 276.6 kg N ha^{-1}. The available phosphorous content was higher in second layer (68.97 kg P_2O_5 ha^{-1}), medium in 0-15 cm depth and lower in 30-45 cm and 45-60 cm depth. The available potassium content was medium in all layers ranging from 222.7 to 297.9 kg K_2O ha^{-1}. The soil moisture retention capacity at field capacity and at permanent wilting point of 0-60 cm depth was 22.4% and 10.3% respectively. The total plant available soil water was amounted to 89.8 mm with moderate hydraulic conductivity (1.34 to 2.50 cm h^{-1}) and bulk density (1.475 g cm^{-3}) of 0-60 cm soil depth. The climate of Jalgaon is described as dry tropical and semi-arid with dry winter (Nov-Feb). During both years of experiment, there was no rainfall in crop growing period. With respect to pan evaporation, mean pan evaporation ranged from 4.07 to 6.71 mm day^{-1} and 3.44 to 4.72 mm day^{-1} in 2012-13 and 2013-14, respectively. The seasonal pan evaporation during the crop period was 511 mm in 2012-13 and 406 mm in 2013-14, respectively.

LOK-1 wheat variety with seed rate of 125 kg ha^{-1} was sown on 6th November in 2012-13 and 1st November in 2013-14. The experiment was laid out in a split plot design with twenty treatment combinations in four replication. The main treatment comprised five irrigation levels involving four irrigation through drip (DI - 0.6, 0.8, 1.0, 1.2) Epan and one control [SI- surface check basin irrigation at IW/CPE 1] as main treatments along with four N-fertigation schedule *viz*., control, 80, 120 and 160 kg ha^{-1} through drip. Drip irrigation was scheduled once in two days and N-fertigation scheduled once in a week up to 65 days. Full dose of phosphorus was applied as basal dose and potassium applied through fertigation at weekly intervals up to 65 days. For providing irrigation, inline dripper line laid out on the ground surface along the crop rows at 0.90 m apart with emitters spaced at 0.30 m apart delivering 4 L h^{-1}. Both the drip and surface irrigation treatment plots were separated by buffer channels of 1.0 m width to avoid seepage into the adjoining drip irrigated plots. Drip Irrigation scheduled on daily evaporation and irrigation for 0.6 to 1.2 pan evaporation replenishment (Epan) treatments were fixed for alternate day in surface check basin irrigation. Irrigation was scheduled on climatological approach and it was given at IW/CPE 1 with 50 mm depth throughout the experiment. First irrigation was given immediately after sowing.

The daily reference evapotranspiration was calculated following FAO56- Penman -Monteith equation and seasonal crop evapotranspiration (ETc) was estimated based on water balance equation using soil water measured by gravimetric sampling method (FAO) at weekly intervals. Crop coefficient (K_c) was calculated following Doorenbos and Pruitt (1977). For estimation of Kc values, the crop life was divided into germination and establishment (0-15 DAS), vegetative stage (16-40 DAS), flowering stage (41-60 DAS), grain filling stage (61-80 DAS) and maturity stage (81- 90 DAS).

The data obtained on grain and straw yield were analyzed statistically by the method of analysis of variance as per the procedure outlined for split plot design. Statistical significance was tested by P–value at 0.05 level of probability and critical difference was worked out where ever the effects were significant.

RESULTS AND DISCUSSION

Grain and straw yield

Average grain and straw yield was found to be higher (4761 and 5425 kg ha^{-1} respectively) when irrigation was scheduled by DI - 1.2 Epan but it was statistically at par with DI - 1.0 Epan and significantly superior to DI - 0.6 and 0.8 Epan on polled basis. However, harvest index showed no response in relation to irrigation levels (drip and surface check basin). On an average the crop in DI - 1.0 Epan treatment registered 44.28% and 10.26% more yield over DI - 0.6 and 0.8 Epan (Table 1). Wheat grain yield under surface check basin irrigation at IW/CPE 1 (3590 kg ha^{-1}) was also statistically inferior in comparison to drip irrigation treatments (DI - 0.8, 1.0 and 1.2 Epan) except DI - 0.6 Epan. The above trends in grain and straw yield registered under DI - 1.0 and 1.2 pan evaporation (Epan) in comparison to other treatments could be traced to the favourable soil water balance near to field capacity (applied water) as observed by variation in soil moisture during the crop growing season. Thus, favourable soil water balance under DI - 1.0 and 1.2 Epan aided the plants to put forth improved performance over other treatments, since water plays a vital role in carbohydrate metabolism, protein synthesis, cell wall synthesis, cell enlargement and partitioning of photosynthates to sink for improved development of growth traits (Gardner *et al.*,1985). Therefore, crop plants in DI - 1.0 and 1.2 Epan treatments had the crop growth, development and yield contributing characters resulting in higher yields.

In case of nitrogen levels, fertigation of N_{120} recorded significantly higher grain and straw yield of wheat over N_0 and N_{80} and it was at par with N_{160} on polled basis (Table 1). However, harvest index showed inverse relationship with each higher level of N. Greater grain yield of wheat under

Table 1: Grain yield, straw yield, harvest index and total seasonal crop evapotranpiration of wheat as influenced by irrigation (drip and surface check basin) and nitrogen levels (mean of 2012-13 and 2013-14).

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)	Total seasonal crop evapotranspiration (mm)
Irrigation scheduling (I)				
DI - 0.6 Epan	3207	3486	47.96	294.5
DI - 0.8 Epan	4196	4610	47.83	341.0
DI - 1.0 Epan	4627	5195	47.23	378.1
DI - 1.2 Epan	4761	5425	46.83	414.1
IW/CPE=1	3590	3926	47.76	453.5
SEm±	111.6	98.1	0.66	-
CD (0.05)	343.9	302.2	N.S.	-
Nitrogen levels ($N_{0,}$ kg ha^{-1})				
N_0 - 0	2937	3126	48.43	347
N_{80} - 80	4205	4594	47.85	350
N_{120} -120	4520	5109	47.00	354
N_{160} -160	4642	5284	46.83	358
SEm±	85.8	90.76	0.44	-
CD (0.05)	244.7	258.5	1.31	-
Interaction (I x N)				
Nitrogen at same level of irrigation				
SEm±	223.2	196.2	1.33	-
CD (0.05)	N.S.	N.S.	N.S.	-
Irrigation at same or different levels of nitrogen				
SEm±	200.8	201.6	1.07	-
CD (0.05)	N.S.	N.S.	N.S.	-

Table 2: Crop evapotranpiration (ETc), evapotranspiration rate and crop coefficient (Kc) of wheat as influenced by irrigation (drip and surface check basin) (mean of 2012-13 and 2013-14).

Crop growth stages	DI-0.6 Epan		DI-0.8 Epan		DI-1.0 Epan		DI-1.2 Epan		IW/CPE 1		
	ETc (mm)	Kc	ETc (mm)	Kc	ETc (mm)	Kc	ETc (mm)	Kc	ETc (mm)	Kc	ETc (mm)
0-15 (Germination & establishment)	34.4	0.75	34.4	0.75	34.4	0.75	34.4	0.75	41.0	0.89	46.35
16-40 (Vegetative)	82.3	0.96	98.4	1.13	113.3	1.31	126.5	1.45	130.4	1.50	87.00
41-60 (Flowering)	70.0	0.98	84.9	1.18	96.8	1.34	107.3	1.48	114.7	1.59	72.30
61-80 (Grain filling)	78.2	0.99	93.6	1.18	105.6	1.33	117.6	1.49	128.1	1.62	79.30
81-90 (Maturity)	29.4	0.80	29.5	0.80	27.7	0.76	28.2	0.77	39.4	1.07	36.70
Total growing season	294.5		341.0		378.1		414.1		453.5		321.60

higher N levels (N_{120}) could be traced to adequately N fertilized crop benefited from higher rates of nitrogen nutrition that might have resulted into a more vigorous and extensive root system of crop leading to increased vegetative growth means for more efficient sink formation and greater sink size, greater carbohydrate translocation from vegetative growth.

Table 3: Crop evapotranpiration (ETc), evapotranspiration rate and crop coefficient (Kc) of wheat as influenced by nitrogen levels (mean of 2012-13 and 2013-14).

Crop growth stages	N-0 kg ha^{-1}		N-80 kg ha^{-1}		N-120 kg ha^{-1}		N-160 kg ha^{-1}	
	ETc (mm)	Kc	ETc (mm)	Kc	ETc (mm)	Kc	ETc (mm)	Kc
0-15 (Germination & establishment)	36.3	0.78	36.3	0.78	36.3	0.78	36.3	0.78
16-40 (Vegetative)	97.8	1.13	98.8	1.14	99.8	1.15	100.8	1.17
41-60 (Flowering)	86.2	1.20	87.2	1.21	88.7	1.23	89.7	1.25
61-80 (Grain filling)	98.6	1.25	99.1	1.25	100.4	1.27	102.2	1.29
81-90 (Maturity)	27.8	0.77	28.3	0.79	28.5	0.79	28.7	0.79
Total growing season	346.8		349.8		353.8		357.8	

Wheat crop fertilized with N_{120} (120 kg N ha^{-1}) had more plant height, which in turn helped the plants to put forth more number of tillers contributing to higher leaf area index, as leaves continued to grow and persist (LAD) until an optimal leaf area index (leaf area index = >4.0) is achieved, that maximizes canopy photosynthesis with higher photosynthetic efficiency i.e., net assimilation rate (NAR) resulting in greater crop growth rates contributing to higher dry matter production.

Crop evapotranspiration (ETc)

The crop ETc at various crop growth periods i.e. establishment to vegetative period was linear in all the treatments in on polled year data (Table 2). However during establishment period, the difference in crop ETc was not varied much among treatments and recorded average ETc of 34.4 mm, owing to uniform water application during this period. From vegetative period until maturity due to variations in the water application levels as per the treatments a large difference in ETc was observed. At maturity period due to withholding of irrigations after crop reaching physiological maturity, large reductions in crop ETc was observed in all the treatments. The lower ETc values observed in the wheat with drip irrigation at 0.6 and 0.8 Epan from 15 DAS to maturity in comparison to 1.0 and 1.2 Epan treatments were due to less water application in this treatment. Lowest seasonal ETc of 294.5 mm was associated with 0.6 Epan and highest seasonal ETc (453.5 mm in on polled basis) were observed with surface check basin irrigation at IW/CPE 1 (Table 2). In the present experiment, reduction in seasonal ETc with decreasing irrigation level was observed in the order of surface check basin irrigation > 1.2 Epan> 1.0 Epan> 0.8 Epan> 0.6 Epan on pooled basis.

The seasonal crop ETc of wheat where irrigations were scheduled at ETc/ETm$\geq$1 throughout the crop growing season was more than that registered in lower treatments. Reduction in irrigation levels (ETc/ETm<1) caused appreciable reduction in ETc in comparison to drip irrigation at 1.0 and 1.2 Epan. The crop ETc is a physical process taking place continuously from a periodically replenished source of water and variable potential *viz.,* soil moisture reservoir to a sink of virtually unlimited capacity i.e. the atmosphere. As long as the water availability matches the rate of water loss through transpiration by the crop canopy and evaporation from soil surface the ETc continues at potential rates as determined by the evaporative demand of the atmosphere as witnessed in drip irrigation at 1.0 and 1.2 Epan (Table 2). However, as the crop removes the water from the soil, the soil moisture content and soil water potential decreases leading to low soil water conductivity thereby resistance to water movement in the soil increases. This tend to decrease water flow in to the plant system causing marked reduction in ETc as could be observed in deficit irrigation levels i.e. 0.6 Epan.

Crop coefficient

In initial period of crop growth i.e. germination and establishment stage (15 DAS) the estimated Kc values were same in all irrigation treatment owing to uniform water application during this period. From vegetative period until maturity due to variations in the water application levels as per the treatments a large difference in Kc was observed. Such variations in Kc values with crop growth stages wise was also reported by Pal *et al.* (2001) and Kingra *et al.* (2004). During the flowering, grain filling and maturity phase, estimated Kc values at drip irrigation 1.0 Epan which produced significantly higher grain yield recorded showed little more Kc values over FAO Kc values 0.70, 1.0, 1.25 and

0.70 at initial, crop development, mid and late season; Allen *et al.,* 1998) which clearly indicate the calculated Kc values differ from the average Kc values of FAO and suggesting the optimum Kc values at this treatment for the semi-arid tropics of India. These results are in corroborating with the values obtained by, Mehta and Pandey (2015) and Bandyopadhy and Mallick (2003) who developed crop coefficient for wheat from ETc measurement and local weather data.

In case of nitrogen fertigation, each unit increase in nitrogen level from 0 to 160 kg ha^{-1}, Kc values increased slightly over its lower levels at all crop growth stages (Table 3). In initial stage, Kc value of wheat was low (0.78) and it increased continuously toward development stage (1.13 to 1.17) and during the mid season stage (1.22 to 1.27) and decreased during late season stage (0.77 to 0.79). Fertigation of N120 kg ha^{-1} producing significantly higher grain yield had the crop coefficients values of 0.78, 1.15, 1.23 and 0.79 at initial, crop development, mid season and late season in on pooled year basis respectively.

CONCLUSION

Drip irrigation with N-fertigation is an advantageous technique for getting higher yield of wheat in semi-arid tropics of India. The study established precise information on ETc at different crop stage wise for wheat. The ETc values were found to be vary with different irrigation levels and vary with stage of crop. The calculated Kc values for wheat were higher than FAO values which will be useful to estimate crop water requirements and further developing optimum irrigation schedules for achieving higher water productivity. The outcome of such research is useful to draft guidelines on the regional drip irrigation scheduling for scientist, farmers, stakeholders and policy makers under different models for profit maximization and resource conservation.

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