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DETERMINATION OF EVAPORATION AND EVAPOTRANSPIRATION IN WINTER WHEAT USING WEIGHING LYSIMETER

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ABSTRACT

Present investigation was carried out at the research farm of the Rajmata Vijayaraje Scindia Krishi Vishwavidyalaya (RVSKVV), Gwalior during *rabi* 2020-21 to study the evaporation (Et) and evapotranspiration (Eto) of winter wheat using weighing lysimeter. The weighing Lysimeter installed in Environmental Science department having two PANS was used for the study. The wheat crop (cv. HD-2967) was grown by giving N, P_2O_5 and K_2O 120:60:40 kg ha^{-1}(recommended dose of chemical fertilizers) in both the conditions (lysimeter and open field). The various observations of weighing lysimeter *viz.,* tank weight, soil moisture, soil temperature, daily run off and daily water requirement were recorded on daily basis. Similar observations were recorded for the open field conditions.The study revealed that the Eto at crown root initiation (CRI), tillering, jointing, flowering, milking and dough stage was found 2.28 mm day^{-1}, 2.35 mmday^{-1}, 2.35 mm day^{-1}, 3.19 mm day^{-1}, 4.35 mm day^{-1} and 5.30 mm day^{-1}, respectively. Similarly, the Et of winter wheat at CRI, tillering, jointing, flowering, milking and dough stage was recorded as 2.00 mm day^{-1}, 2.30 mm day^{-1}, 2.20 mm day^{-1}, 1.80 mm day^{-1}, 3.00 mm day^{-1} and 6.00 mm day^{-1}, respectively. It is observed that the evaporation was found to be increased with the increase in crop duration. Thus, the use of lysimeter for measurement of evaporation and evapotranspiration was successful approach and need to be explored for various research studies.

(Key words: Evaporation, evapotranspiration, weighing lysimeter, winter wheat)

INTRODUCTION

Globally, water is considered as a precious element for agriculture sector as well as other sectors due to climate change (Saccon, 2018). In increased agricultural production, irrigation plays a vital role in cultivating winter crop and supplementing in *kharif* crop. Also, the water requirement varies from crop to crop according to season. Evapotranspiration is the combined process by which water is transferred from the earth's surface to the atmosphere (Tyagi *et al.,* 2019) and plays an important role in irrigation scheduling for crops (Noreldin and Kasem, 2019). It includes evaporation of liquid or solid water from the soil and plant surface plus transpiration of liquid water through plant tissues. Evapotranspiration (ET) is the sum of evaporation and plant transpiration from the Earth's land and ocean surface to the atmosphere. Evaporation accounts for the movement of water to the air from sources such as the soil, canopy interception, and water bodies. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapor through stomata in its leaves in vascular plants and phyllids in non-vascular plants. Evapotranspiration is an important part of the water cycle. An element (such as a tree) that contributes to evapotranspiration can be called an evapotranspirator. Evapotranspiration and crop coefficients can be estimated by lysimeter study. Lysimeter is a device which is hydrologically separated from the adjacent soil by using a container in which a volume of soil is planted with vegetation (Brown *et al.,* 2021). Water loss and gain can be found easily and crop evapotranspiration can be calculated by using water balance equation. In this study lysimeter is used to calculate crop water requirement (Et_C). Reference evapotranspiration (ET_0) can be estimated by using local atmospheric boundary conditions such as sunshine, temperature, humidity and wind speed. The crop coefficient (K_c) is estimated by the ratio of crop evapotranspiration (ET_c) and grass reference evapotranspiration (ET_0). This value expresses crop exact water need in regional basis which is necessary for the estimation of exact irrigation requirement of various crops for that specific area.

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Winter wheat is the major crops in north and central India (Khamparia *et al.,* 2018; Sahu *et al.,* 2020). Precise calculation of evapotranspiration for different periods of their growth is of great importance for the field water cycle and to determine irrigation requirements that are usually estimated from the penman equation (Tyagi *et al.,* 2019). Large and small scale weighing lysimeter allow daily evapotranspiration to be measured precisely. Generally, the proportion of soil evaporation (E) to crop field evapotranspiration (ET) is also determined by calculation. However, daily rates (E/ET) cannot be obtained from the penman equation. In this study, measurements from large-scale weighing lysimeter were used to determine daily variation in ET and E/ET.Keeping the above facts in view the experiment was conducted to determine the evapotranspiration and evaporation in winter wheat by using weighing lysimeter.

MATERIALS AND METHODS

Study area and climate

The field experiment was conducted at the Research Farm, College of Agriculture, RVSKVV, Gwalior (M.P.) during the *rabi* season of 2020-21. Gwalior is situated in the northern tract of M.P., enjoying subtropical climate with extreme hot about 46° C in summer and minimum temperature 10° C in the winter season. It is located at the latitude of 26°3' N longitude 74°4'E and altitude of 208 m above the sea level.

Meteorological observations

The meteorological observations recorded during the crop growth period are presented in Fig. 1. The minimum and maximum temperature during crop growth period ranged from 5.0-18.4 and 20.8-37.7 °C, respectively. The average maximum and minimum temperature recorded during the crop growing season was recorded 29.1 °C and 11.1 °C, respectively. The minimum and maximum relative humidity during crop growth season ranged from 29.1-78.7% and 72.3-96.5%, respectively. The average maximum and minimum relative humidity recorded during the crop growing season was 86.8% and 51.4% respectively. The total rainfall received during the crop growth period was 62 mm (Fig. 1).

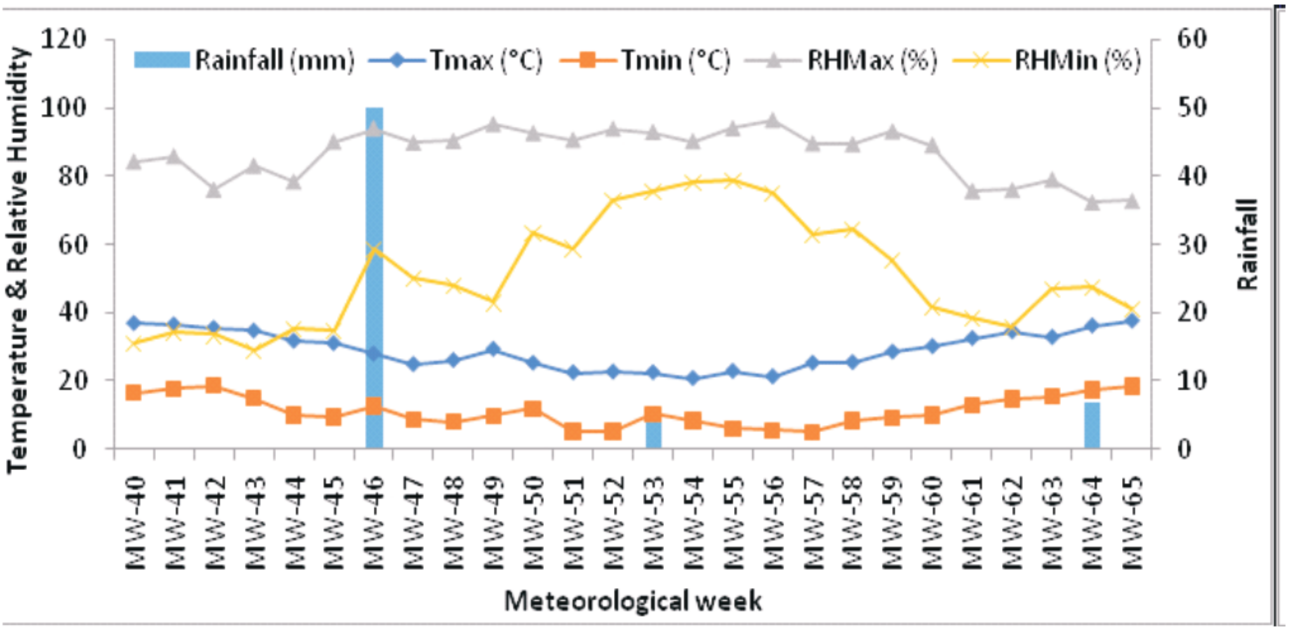

Fig. 1. Meteorological observations during crop growth period (Oct. 2020 to March 2021)

Initial soil properties

The soil samples before commencement of the present investigation were collected from 0-15 cm depth and analyzed for physic-chemical properties. The soil analysis was carried out by following the standard methods (Table 1). The field soil was sandy-loam having soil pH 7.9, electrical conductivity 0.13 dSm^{-1} and organic carbon 4.7 g kg^{-1}. The soil available N, P_2O_5 and K_2O were found 214.3 kg ha^{-1}, 15.3 kg ha^{-1} and 283.8 kg ha^{-1} respectively.

The field experiment

The experiment was laid out in the year 2020-21 in weighing Lysimeter installed in Environmental Science department at college of Agriculture, Gwalior. There are two PANS at a spacing of 76.2 cm. The size of each PAN is 1 m². The details of experiment and cultural operations carried out during the field experiment are given in Table 2. The field was leveled and prepared. The disease free and healthy seeds of wheat (cv. HD-2967) were sown on 18/11/2020 with a row to row spacing of 22.5 cm. The sowing was carried out in both lysimeter as well as open field.

Table 1. Methods adopted for analysis of soil

Parameters	Method adopted for analysis
pH	Glass electrode method (Jackson, 1973)
Electrical conductivity	Conductivity meter (Jackson, 1973)
Soil organic carbon	Di-chromic acid digestion method (Walkley and Black, 1934)
Available N	Alkaline permanganate method (Subbaih and Asija, 1956)
Available P	Ascorbic acid method (Olsen *et al.,* 1954)
Available K	Ammonium acetate method (Hanway and Heidel, 1952)

Table 2. Details of experiment

Crop	Wheat
Variety	HD-2967
Row spacing	22.5 cm
Sowing date	18/11/2020
Fertilizer dose	120:60:40 (N, P and K; kg ha^{-1})
Irrigation applied	04 irrigations each at initial stage, development stage, Mid season stage and Late season stage

Lysimeter observations

The various observations of weighing lysimeter *viz.,* tank weight, soil moisture, soil temperature, daily run off and daily water requirement were recorded on daily basis. These observations were recorded in inbuilt automatic system of weighing lysimeter. Similar observations were recorded for the open field conditions. The daily observations of lysimeter were used for calculating the Et and Eto. The mean field observations used for calculating the Et and Eto are given in Table 3.

Table 3. Mean lysimeter observations at various growth stages of winter wheat

Crop growth stages	Min. Temp (°C)	Max. Temp (°C)	Humidity (%)	Wind Speed (km day^{-1})	Sunshine (hrs)	Radiation (M Jm^{-2} day^{-1})
Crown root initiation	8.1	27.0	61	52	7.0	14.2
Tillering	8.0	25.2	63	55	7.2	15.00
Jointing	8.0	25.5	63	55	7.0	15.00
Flowering	10.5	28.3	62	79	7.8	17.3
Milking	15.5	32.8	54	79	8.6	21.2
Dough	20.2	38.6	40	72	9.4	23.3

Estimation of Reference Evapotranspiration (Eto)

The Reference evapotranspiration (Eto) was determined following the FAO Penman-Monteith Equation (Allen *et al*, 1998) as follows

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where, ET_o - reference evapotranspiration [mm day^{-1}]; R_n - net radiation at the crop surface [MJ m^{-2} day^{-1}]; G - soil heat flux density [MJ m^{-2} day^{-1}]; T - mean daily air temperature at 2 m height [°C]; u_2 - wind speed at 2 m height [m s^{-1}]; e_s - saturation vapour pressure [kPa]; e_a - actual vapour pressure [kPa]; e_s - e_a - saturation vapour pressure deficit [kPa]; Ä - slope vapour pressure curve [kPa °C^{-1}] andã - psychrometric constant [kPa °C^{-1}].

RESULTS AND DISCUSSION

Evaporation and evapotranspiration in winter wheat

The evaporation and evapotranspitaion in winter wheat at various growth stages *viz.,* crown root initiation (CRI), tillering, jointing, flowering, milking and dough stage were recorded. The Eto at crown root initiation (CRI), tillering, jointing, flowering, milking and dough stage were found 2.28 mm day^{-1}, 2.35 mm day^{-1}, 2.35 mm day^{-1}, 3.19 mm day^{-1}, 4.35 mm day^{-1} and 5.30 mm day^{-1}, respectively (Table 4; Fig. 2).

Table 4. The Eto and Et in winter wheat at various growth stages

Crop growth stage	Eto (mm day^{-1})	Et (mm day^{-1})
Crown root initiation	2.28	2.00
Tillering	2.35	2.30
Jointing	2.35	2.20
Flowering	3.19	1.80
Milking	4.35	3.00
Dough	5.30	6.00

The transpiration is predominantly affected by light intensity, vapor concentration gradient between leaf and air, wind speed and soil water supply. Both light duration (sunshine hours) and intensity (photon flux density) over a region affect its temperature. Strong irradiation warms the leaf surface and thus leads to steeper vapor pressure and transpiration (Pallardy, 2008). Rai and Kushwaha (2003) observed Eto varied from 0.8-3.5, 0-6-3.7, 0.5-3.6 and 1.2-2.6 mm day^{-1}. Et was lower upto crown root initiation stage, increased upto dough stage and again decreased upto maturity of the crop with some exceptions. The RMSD between Et estimated and Et observed were 0.22 mm, 0.41 mm. 0.37 mm and 0.28 mm for crop season 1980-81, 81-82, 82-83, 83-84 respectively. The seasonal ETs and ETo during the above respective years were 218.5 and 233.0 mm, 260.4 and 248.4 mm, 308.5 and 292.4 mm, 231.4 and 235.8 mm. The difference between seasonal ETs and ETo ranged between 1.87 to 5.50 per cent. The results of present investigation also showed Eto varied from 2.28 mm day^{-1} to 5.30 mm day^{-1} during various growth stages of wheat crop. The evapotranspiration process is very complex and depends upon various factors such as meteorological parameters, crop, crop duration, soil type, wind speed and direction etc. (Taiz and Zeiger, 2006). Zepel *et al.* (2006) also reported that an evergreen Callitris/Eucalyptus woodland in southeast

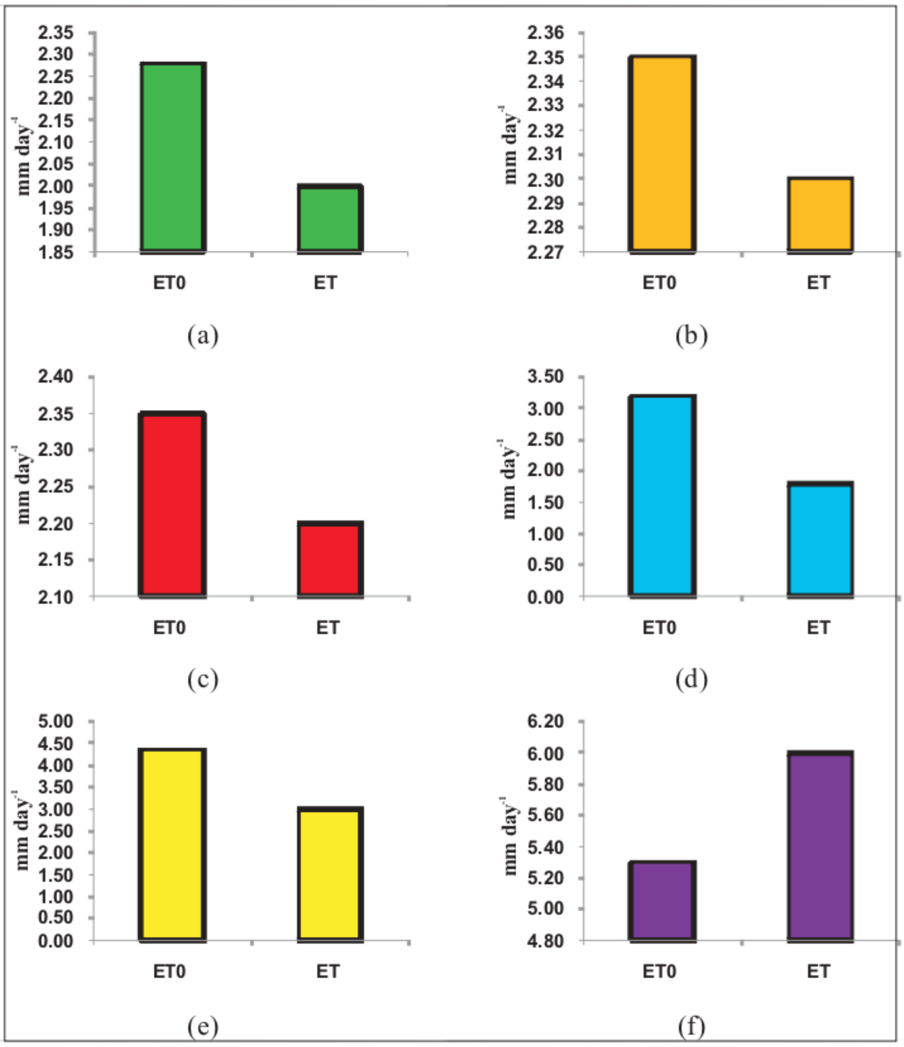

Figure 2.Evapotranspiration (Eto) and evaporation (Et) in winter wheat at various growth stages (a) CRI stage, (b) Tillering stage, (c) Jointing stage, (d) Flowering stage, (e) Milking stage and (f) Dough stage

Australia showed minimal (<1 mm day^{-1}) transpiration rates during winter as compared to very high (>3.5 mm day^{-1}) in summer. The study of Eto measurement using lysimeter conducted by Patil and Manickam (2017) reported highest value of Eto in soybean at flowering stage.Similarly, Lu *et al.* (2018) also conducted evapotranspiration experiment with winter wheat and with summer maize under various water deficit conditions using lysimeter and reported that daily ET values decreased from a maximum value of 4.56 mm to less than 1.5 mm for the wheat and from a maximum value of 6.02 mm to approximately 2 mm for the maize, respectively.

The evaporation (Et) of winter wheat at CRI, tillering, jointing, flowering, milking and dough stage were recorded as 2.00 mm day^{-1}, 2.30 mm day^{-1}, 2.20 mm day^{-1}, 1.80 mm day^{-1}, 3.00 mm day^{-1} and 6.00 mm day^{-1}, respectively (Table 4; Fig. 2). Folegatti *et al.* (2000) demonstrated weighing type lysimeter in greenhouse and reported that the net radiation and mean air temperature better estimated the evapotranspiration in greenhouse. Merta *et al.* (2001) reported that the plant physiology methods are important for the understanding of the complex transpiration process. Rai and Kushwaha (2003) also evaluated the soil-plant water model for simulation of soil water content and evapotranspiration in wheat field. The ET was lower up to crown root initiation stage, increased up to dough stage and again decreased upto maturity of the crop with some exceptions. Further they reported the difference between seasonal ETs and ETo ranged between 1.87 to 5.50 per cent. Xu *et al.* (2018) found Et values of 5.06/ mmyda $^{-1}$ and 4.64 mm day^{-1} for maize crop in large and small canopy size respectively. Liu *et al.* (2020) reported increasing trend of Et from Stage I (sowing to flowering; 0.03–0.35 mm h^{-1}) to Stage II (Flowering to dough; 0.60–1.50 mm h^{-1}) in winter wheat crop in China. The results of present investigation are in conformity with these findings.

The experiment using weighing Lysimeter installed in Environmental Science department at college of Agriculture, Gwalior was carried out successfully. The use of lysimeter for measurement of evaporation and evapotranspiration was successful approach and need to be explored for various scientific studies such as determination of water and fertilizer use efficiency of various crops, assessment of potential of fertilizers to cause ground water pollution through leaching and the dynamics of fertilizers in soil under various crops.

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