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Use of microlysimeters to determine soil water evaporation as a function of drainage

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Abstract. The aim of this study was to test two models and two sizes of microlysimeters to determine soil water evaporation as a function of the removal of water by drainage at the bottom of the units. The experiment was conducted at the experimental field of the State University of Mato Grosso (UNEMAT) in Tangará da Serra, Mato Grosso, Brazil. Soil water evaporation was determined using microlysimeters constructed from rigid PVC tubes, of which two models and two sizes were tested. The four microlysimeter treatments were: 100 mm diameter without drainage (ML100WD), 100 mm diameter with drainage (ML100D), 150 mm diameter without drainage (ML150WD), and 150 mm diameter with drainage (ML150D). The microlysimeters were fitted to an irrigation blade of 60 mm and compared to applications with four irrigation blade sizes (15, 30, 45, and 60 mm). Water evaporation from the soil was obtained from the mass variation of the microlysimeters, and was then compared to the soil water evaporation determined using weighing lysimeters. The obtained data were analyzed using descriptive statistical techniques, tests of means, and regression analysis. The soil water evaporation values present significant differences between the two microlysimeter sizes (100 and 150 mm diameter) and the two models (with and without water drainage). Soil water evaporation is affected by the water drainage that occurs at the bottom of the microlysimeters. There was no difference in soil water evaporation between irrigation rates within the same microlysimeter size and model. The two models and the two microlysimeter sizes tested can be used for the quantification of soil water evaporation, due to the high determination coefficients observed when compared to the evaporation observed with the weighing lysimeters.

Keywords: irrigation, lysimeters, mini-lysimeters, water balance, water management.

1. INTRODUCTION

Soil water evaporation corresponds to a portion of evapotranspiration, which is important in the context of agricultural production, as its impact on the hydrological balance can be considerable, especially in situations of conventional cultivation or those with decreased levels of straw in the soil (Facchi et al., 2017). Thus, understanding and quantifying the process of soil water evaporation assists in providing data for many different agricultural crops, which aids in improving the efficiency of irrigation water use (Facchi et al., 2017; Mansour et al., 2022).

Water evaporation at the soil surface is a physical process whereby water changes from a liquid to a gaseous state, resulting in the transfer of water contained in the soil to the atmosphere (Facchi et al., 2017; Heck et al., 2020), without utilizing the transpiration process in plants that produces the same result (Dalmago and Bergamaschi, 2017).

Soil water evaporation generally affects the first 10–15 cm of the soil, although it varies according to soil characteristics such as texture and structure. It also depends on atmospheric conditions, such as air temperature, relative humidity, wind speed, and solar radiation, and soil factors, such as hydraulic properties and soil water volume (Allen et al., 1998; Facchi et al., 2017).

Studies on the quantification of soil water evaporation provide necessary information for several activities, especially those of irrigation use (Wang et al., 2020), agricultural water use efficiency (Barbieri et al., 2020), evapotranspiration component partitioning (Sánchez et al., 2021; Wang et al., 2021), and water balance (Pereira et al., 2020). In addition, soil water evaporation can account for approximately 20–40% of evapotranspiration in agricultural crops grown in the Cerrado regions (Andrea et al., 2019; Barbieri et al., 2020).

Soil water evaporation was originally quantified using lysimeters (Ritchie, 1972; Waggoner and Turner, 1972; Schneider et al., 2021). However, as the process of installing and maintaining lysimeters is complicated and requires considerable time, cost, and specialized labor, researchers have sought new simpler technologies as alternatives to measure and apply methods of soil water evaporation, considering the varied crops and agricultural sectors.

Water loss through evaporation can be quantified using microlysimeters, which have been developed and tested as research has evolved (Boast and Robertson, 1982; Daamen et al., 1993; Yang et al., 2020). They were initially designed by Boast and Robertson (1982) and have since been used to directly determine soil water evaporation in bare soils or those cultivated with agricultural crops (Andrea et al., 2019; Schneider et al., 2021).

Microlysimeters are small tubes filled with undeformed soil samples that are installed at ground level, and periodically weighed to estimate soil water evaporation by temporal mass differences (Flumignan et al., 2012; Facchi et al., 2017). Microlysimeters are based on the same principle as traditional lysimeters and consist of plastic or steel cylinders with diameters of 50–200 mm and heights ranging between 100 and 300 mm (Daamen et al., 1993; Flumignan et al., 2012; Facchi et al., 2017).

Microlysimeters are inserted into the soil, for filled with soil in an undeformed manner (soil monolith), and then weighed at regular intervals to determine of the amount of water evaporated from the soil based on the mass difference. The small size of the devices dictates that several should be installed in the field (which depends on the size of the area) to extend the behavior of soil water evaporation to a larger scale (Yang et al., 2022).

Studies have demonstrated the accuracy of the measurements obtained using microlysimeters by comparing them with the results of classical lysimeters (Flumignan et al., 2012; Ma et al., 2020), and confirming their applicability in different agricultural situations (Lu et al., 2018; Pereira et al., 2020). Several authors have used microlysimeters to determine soil water evaporation. Dalmago and Bergamaschi (2017) evaluated water evaporation in a soil in response to the amount of straw on the surface and atmospheric evaporative demand, and observed that water evaporation on the soil surface is higher in soils subjected to conventional tillage than those with no-till systems. Vieira et al. (2016) determined the evapotranspiration of wheat crops in the region of Maringá, Paraná, Brazil, using microlysimeters to obtain soil water evaporation. Those researchers calculated the coefficient of soil water evaporation (Ke) and revealed that the microlysimeters proved reliable in measuring soil water evaporation.

The determination of soil water evaporation using microlysimeters is possible because the lower part is sealed and the upper surface is open, allowing for water evaporation, which is the only form of water transfer to the atmosphere in this situation. Daamen et al. (1993) stated that drainage could occur at the bottom of the microlysimeter; however, the drained water can be accounted for, and those authors introduced a model of an effective drainage box to measure the water loss.

Microlysimeters that are sealed at the bottom to prevent outflows that may affect soil water evaporation and its quantification. Therefore, the aim of this study was to test two models and two sizes of microlysimeters to determine soil water evaporation as a function of the drainage of water from the bottom of the units.

2. MATERIALS AND METHODS

2.1 General Description

The experiment was conducted in the experimental field of the Centro Tecnológico de Geoprocessamento e Sensoriamento Remoto (CETEGEO-SR), in the State University of Mato Grosso (UNEMAT), Professor Eugênio Carlos Stieler Campus, Tangará da Serra, Mato Grosso, Brazil. The soil is classified as either dystroferric red latosol with a very clayey texture (Santos et al., 2018) or oxisol (Soil Survey Staff, 2014). The climate is megathermal or tropical with dry winters (Aw), according to the Köppen Climate Classification System (Alvares et al., 2013), with average annual precipitation of 1,830 mm and an average air temperature of 24.4 °C (Dallacort et al., 2011).

An automatic weather station (14°65’00” S, 57°43’15” W, 440 masl) is located near the experimental area and is outfitted with Campbell Scientific Inc. equipment, from which the meteorological data used in this experiment were obtained and the reference evapotranspiration (ETo) was determined, as calculated by the Penman-Monteith method (FAO 56) (Allen et al., 1998).

The evaluated physical and hydraulic characteristics of the soil included texture, soil density, macroporosity, microporosity, total porosity, field capacity, permanent wilting point, soil resistance to penetration, basic infiltration velocity, and available water capacity of the soil (Bernardo et al., 2006; Camargo et al., 2009; Stolf et al., 2012; Teixeira et al., 2017). The dystroferric red latosol of the study site has a very clayey texture, with average values of sand, silt, and clay of 235, 124, and 641 g kg^{-1}, respectively. The soil density averaged 1.172 kg dm^{-3}, which was considered low for the soil studied. The soil moisture at field capacity (θ_{FC}) of the studied area was 0.3490 m^3 m^{-3} and the moisture at the permanent wilting point (θ_{PWP}) was 0.2083 m^3 m^{-3}, with soil presenting an available water capacity (AWC) of 82.45 mm. The average soil resistance to penetration was 1.94 MPa, which is classified as moderate. The basic infiltration velocity (BIV) of the soil was 25.91 mm h^{-1}, which is considered a high value for this soil.

In the previous year of the experiment, some compaction points were found in the studied area, and to homogenize and reduce this compaction, subsoiling was performed in October 2019 with a three-stem subsoiler. Subsequently, an intermediate harrow was used once, followed by a leveling harrow to level and densify the soil. The land was left fallow until July 2020, when the soil was collected for the evaluation and preparation of the microlysimeters.

2.2 Microlysimeter construction process

The process of extracting the undeformed soil (soil monolith) with the microlysimeter is relatively arduous. Therefore, to maintain the soil structure and facilitate the process, the microlysimeter (internal structure) was inserted into the soil with the help of a hydraulic jack with a wedge fixed at the top, and as the jack was activated, the microlysimeter was pushed deeper into the soil. The undeformed samples were then collected, and the soil around the microlysimeter was removed manually and with the aid of a hoe (Fig. 1).

Soil water evaporation was measured using microlysimeters adapted from Boast and Robertson (1982), Flumignan et al. (2012), and Facchi et al. (2017). The microlysimeters were constructed using rigid polyvinyl chloride (PVC) tubes manufactured in two sizes, with the first measuring 100 mm in diameter and 250 mm in height and the second measuring 150 mm in diameter and 250 mm in height. Each microlysimeter size was manufactured both with a drainage system (Fig. 2A) and without drainage (Fig. 2B). For the outer envelope, PVC pipes ranging from 150 to 200 mm in diameter and 320 mm in height were used according to the models described in Fig. 2.

In the model with water drainage, the lower part was not sealed, but covered with a white 80 g TNT fabric (30 × 30 cm) and a 0.1 mm nylon mesh (30 × 30 cm) to prevent the soil from deforming at the bottom of the microlysim-

Fig. 1. Process of inserting the microlysimeter into the soil and collecting the soil to manufacture the microlysimeter with undisturbed soil.

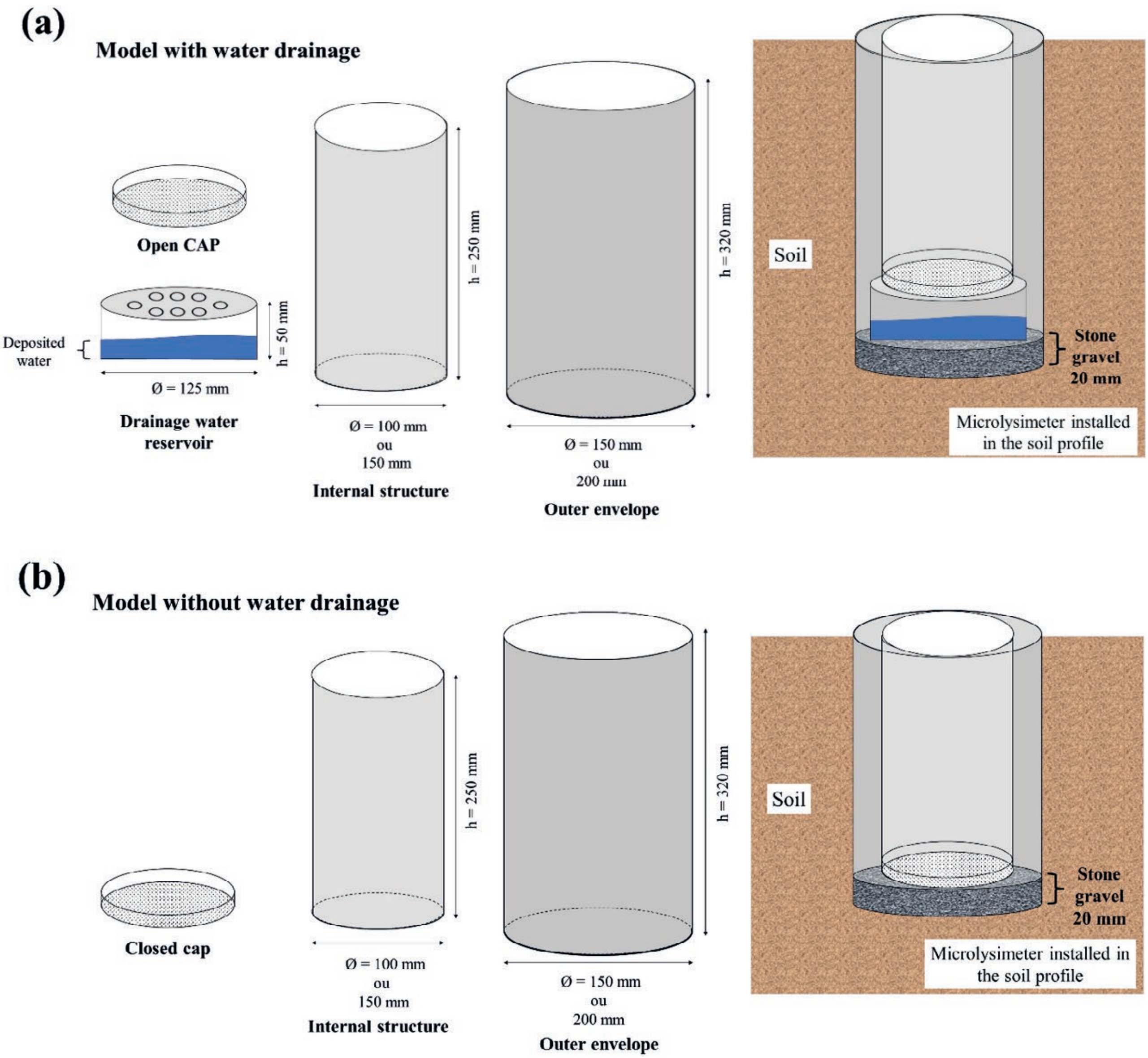

Fig. 2. Microlysimeter models used in the experiment. Microlysimeter with water drainage system at the bottom (A); Microlysimeter without water drainage system at the bottom (B).

eter, while allowing the passage of drainage water (Fig. 3A, 3 B, and 3C). For the model without water drainage, the bottom was sealed using a weldable PVC irrigation CAP (Fig. 3D and 3E). Dalmago et al. (2010) evaluated soil water evaporation by using a similar microlysimeter model to prevent soil loss and facilitate water drainage.

2.3 Tests and data collection methods

Two models and two sizes of the newly manufactured microlysimeters were tested and evaluated with four irrigation blades (15, 30, 45, and 60 mm): 100 mm diameter without drainage (ML100WD), 100 mm diameter with drainage (ML100D), 150 mm diameter without drainage (ML150WD), and 150 mm diameter with drainage (ML150D), with eight repetitions of each.

The collection of soil water evaporation data and that of drained water at the bottom of the microlysimeters was performed during the following periods and days. Test 01 (Single Blade): on Jul 24, 2020, measurements were performed every hour from 06:00 to 18:00, using an irrigation blade of 60 mm with the two models of microlysim-

Fig. 3. Open-bottom microlysimeter model with water drainage (A, B and C); Microlysimeter model with closed bottom without water drainage (D and E). 1 - Internal structure; 2 - Open CAP; 3 - 80 gram white TNT (30 x 30 cm); 4 - 0.1 mm nylon mesh (30 x 30 cm); 5 - Mounting the TNT, the nylon mesh and the CAP on the internal structure; 6 - Bottom of the internal structure of the microlysimeter after it is ready; 7 - PVC closed cap; 8 - Internal structure; 9 - External structure; 10 - Microlysimeter with closed bottom.

eters evaluated. Daily data collection was also performed from Jul 24, 2020 to Jul 30, 2020, at the same times (06:00 and 18:00), to check the variability of evaporation on different days between the microlysimeter models. This irrigation blade was chosen because of the predominance of P75% with less than 60 mm of rainfall in the locality where this study was developed (Fietz et al., 2008; Fietz et al., 2011). Test 02 (Irrigation Blades): On Aug 7, 2020, a second evaluation of evaporation and drainage was conducted with the microlysimeters, performing measurements every hour from 06:00 to 18:00, using four irrigation blades (15, 30, 45, and 60 mm) on the same day. Each treatment consisted of eight microlysimeters, and each irrigation blade was applied to two microlysimeters for each treatment. Daily data collection was performed between Aug 7, 2020 and Aug 13, 2020, at the same times (06:00 and 18:00), to check the variability of evaporation on different days between the models of the microlysimeters with different irrigation blades.

Water drainage was verified in the model of the microlysimeter with drainage (Fig. 2A, 3A, 3 B, and 3C) by collecting water, from the water reservoir where the microlysimeter was placed, in a graduated cylinder with intervals of 1 mL, since it was assumed that 1 mL is equal to 1 g. In the 48 h before the evaluation, all microlysimeters were subjected to a saturation process, whereby they were placed in a 500 L tank, submerged in 1 cm of water at its top, and saturated. Subsequently, they were removed the excess water was drained for 24 h until the field capacity was reached.

The amount of evaporation was obtained from the variation in mass of the microlysimeters, which was determined by manual weighing on a high-precision scale (0.01 g) and noting the values in a spreadsheet. These measurements were used to calculate the variation in mass on a single day and comparing this to the variation on different days. Before weighing, the microlysimeters were cleaned to remove any aggregate material. Soil water evaporation determination using microlysimeters was calculated according to Eq. 1:

$$E_{ML} = \frac{\Delta M_{ML+P+I}}{A_{ML}} \quad \text{(Eq. 1)}$$

where E_{ML} is the microlysimeter evaporation (mm d^{-1}), $\triangle M_{ML}$ is the microlysimeter mass change (kg), A_{ML} is the microlysimeter surface area (A100 = 0.007854 and A150 = 0.017671 m^2), P is the precipitation (mm), and I is the irrigation (mm).

2.4 Experiment installation and irrigation

On the location for mounting the microlysimeters, four repetitions of microlysimeters were installed in each of the evaluated treatments, with eight units for each treatment, totaling 32 microlysimeters. This number of repetitions was considered sufficient to represent total evaporation and drainage. The microlysimeters were randomly arranged in the experimental area, as shown in Fig. 4.

The irrigation used was a sprinkler system composed of eight sprinklers (Eco232 Frabrimar, Brazil) with 4.0 × 2.8 mm nozzles spaced 12 × 12 m apart, with a Christiansen Coefficient of Uniformity higher than 80%, under a pressure of 30 m.c.a., with an applied water blade of 10.38 mm h^{-1}. The irrigation time was determined such that each treatment would receive the desired irrigation blade. Irrigation was started at the calculated times, and at 06:00, it was turned off, and the desired blade was applied for each test.

2.5 Data analysis and statistics

To compare with microlysimeter evaporation, soil water evaporation from weighing lysimeters (EV_L) was determined. The external dimensions of the lysimeter set were 7.2 m in length and 5.3 m in width, with 1.50 × 1.50 m and 1.20 m depth, with a total area of 2.25 m^2 for each lysimeter. The construction, calibration, and validation methodology was that of Fenner et al. (2019). The weighing lysimeters were connected to a data logger (CR1000, Campbell Scientific Inc., Logan, USA) that was programmed to record data every 30 s and store the average every 15 min. The EV_L values were obtained by converting the lysimeter mass variation into mm, as determined by Eq. 2:

$$EV_L = \frac{\Delta M_{L+P+I}}{A_L} \quad \text{(Eq. 2)}$$

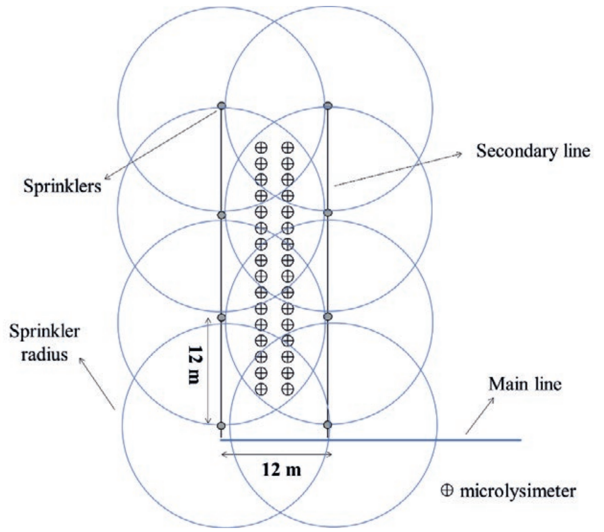

Fig. 4. Sketch of microlysimeters installed in the experimental field and arrangement of the irrigation system.

where EV_L is the soil water evaporation from the lysimeter (mm d^{-1}), $\triangle_{ML}$ is the lysimeter mass variation (kg), A_L is the lysimeter surface area (m^2), P is the precipitation (mm), and I is irrigation (mm).

To calculate the reference evapotranspiration (ETo_{PM}), the Penman-Monteith - FAO 56 methodology was used with Equation 3, as proposed by Allen et al. (1998):

$$ETo_{PM} = \frac{0,408\,\Delta\,(Rn - G) + \gamma \frac{900}{T + 273} U_2\,(e_s - e_a)}{\Delta + \gamma\,(1 + 0,34U_2)} \quad \text{(Eq. 3)}$$

where ETo_{PM} is the reference evapotranspiration (mm d^{-1}), Rn is the net solar radiation of the crop (MJ m^{-2} d^{-1}), G is the soil heat flux density (MJ m^{-2} d^{-1}), T is the air temperature at 2 m above the soil (°C), U_2 is the wind speed at 2 m above the soil (m s^{-1}), e_s is the vapor saturation pressure (kPa) that was estimated through the average of e_s (Tmax) and e_s (Tmin), e_a is the current vapor pressure (kPa), e_s - e_a is the pressure deficit and vapor saturation (kPa $°C^{-1}$), Δ is the vapor pressure curve (kPa $°C^{-1}$), and γ is the psychometric constant (kPa $°C^{-1}$).

Hourly ETo values were accumulated during the same analysis period for both the microlysimeters and lysimeters. A comparison of the drained water from the two microlysimeter sizes and the soil water evaporation between the two sizes and between the models with and without soil water drainage was performed. The data obtained were analyzed by calculating the standard deviation, mean, median, asymmetry coefficient (As), and kurtosis coefficient (Ck).

The mean values of soil water evaporation between treatments were subjected to analysis of variance (ANOVA) using the F test, and the means were compared with the Tukey test at 5% probability. For data analysis, the Sisvar version 5.8 computer program was used (Ferreira, 2011). To evaluate the quality of the microlysimeters for determining soil water evaporation, the averages of the evaporation values of the microlysimeters were compared with those of the lysimeters to observe the correlation between the values, generate a regression equation, and verify the coefficient of determination.

3. RESULTS AND DISCUSSION

3.1 Meteorological elements

The average hourly values of air temperature, relative humidity, precipitation, global solar radiation, and wind speed for the two periods studied (Jul 24, 2020 to Jul 30, 2020 and Aug 7, 2020 to Aug 13, 2020) are shown in Table 1. Solar radiation is the main phenomenon that affects the other climatic variables because the radiant energy that reaches the Earth's surface is used in the convection process, which is related to air heating and heat conduction in the soil, which significantly influences soil water evaporation (Carvalho et al., 2019).

3.2 Water drainage in the microlysimeters

The values of water drainage for the two sizes of microlysimeters with drainage (ML100D and ML150D) were similar on Jul 24, 2020, when the irrigation blade of 60 mm was applied (Test 01) (Fig. 5).

The initial drainage was higher at the beginning of the evaluation and decreased with time. At 07:00, the first drainage evaluation occurred, covering the period from 06:00 to 07:00. At 06:00, when the experiment began, the drainage values were equal to zero and after one hour (07:00), 1.49 and 1.35 mm of drained water were found for the 100- and 150-mm diameter microlysimeters, respectively. Average cumulative drainage values for Jul 24, 2020 were 2.72 mm and 2.44 mm for the 100 mm diameter

Table 1. Daily values of air temperature, relative humidity, precipitation, global solar radiation and wind speed for the two periods studied in Tangará da Serra, Mato Grosso, Brazil.

Test 01 (Single Blade)									
Date	TMean (°C)	TMax (°C)	TMin (°C)	RHMean (%)	RHMax (%)	RHMin (%)	P (mm)	GR (MJ m^{-2} d^{-1})	Wind (m s^{-1})
07/24/2020	26.97	33.69	20.24	55.22	75.57	34.86	0.00	17.89	2.79
07/25/2020	21.05	26.22	15.88	66.30	81.50	51.10	0.00	17.73	4.01
07/26/2020	21.45	31.15	11.74	64.76	93.90	35.62	0.00	19.27	2.26
07/27/2020	24.68	32.90	16.46	55.48	78.53	32.43	0.00	19.75	2.34
07/28/2020	26.53	33.24	19.82	49.40	65.28	33.51	0.00	18.16	2.53
07/29/2020	23.69	29.36	18.01	63.86	81.20	46.52	0.00	18.99	3.48
07/30/2020	20.93	29.04	12.82	65.56	86.10	45.01	0.00	19.55	3.02
Average/Total	23.61	30.80	16.42	60.08	80.30	39.86	0.00	18.76	2.92
Test 02 (Irrigation Blades)									
Date	TMean (°C)	TMax (°C)	TMin (°C)	RHMean (%)	RHMax (%)	RHMin (%)	P (mm)	GR (MJ m^{-2} d^{-1})	Wind (m s^{-1})
08/07/2020	25.33	32.59	18.06	44.67	62.02	27.31	0.00	21.37	3.17
08/08/2020	25.22	32.95	17.49	50.72	73.05	28.39	0.00	21.35	2.95
08/09/2020	25.35	33.36	17.34	45.69	64.51	26.86	0.00	21.36	2.84
08/10/2020	25.93	33.57	18.28	46.85	65.35	28.35	0.00	21.11	2.86
08/11/2020	27.93	35.97	19.88	46.17	63.84	28.50	0.00	19.99	2.56
08/12/2020	28.08	35.88	20.27	48.35	67.16	29.53	0.00	18.94	2.58
08/13/2020	27.38	36.20	18.55	56.38	83.00	29.75	0.00	20.02	2.08
Average/Total	26.46	34.36	18.55	48.40	68.42	28.38	0.00	20.59	2.72

GR = Global solar radiation; TMean = Average air temperature; TMax = Maximum air temperature; TMin = Minimum air temperature; RHMean = Average Relative Humidity; RHMax = Maximum relative humidity; RHMin = Minimum relative humidity; P = Precipitation; Wind = Average wind speed.

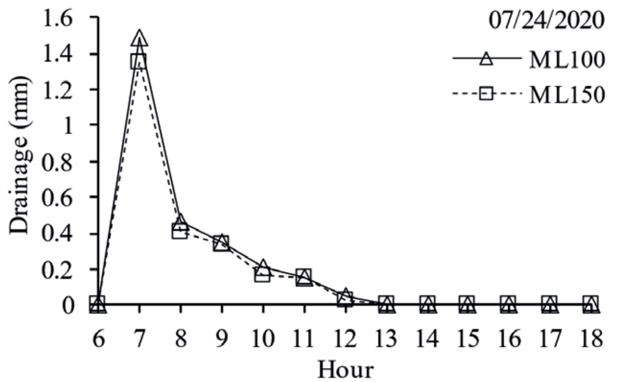

Fig. 5. Water drainage determined in two sizes of microlysimeters (ML100D and ML150D), subjected to an irrigation blade (60 mm) between 6:00 am and 6:00 pm (06:00 to 18:00), observed on Jul 24, 2020. ML100 = 100 mm diameter microlysimeter. ML150 = 150 mm diameter microlysimeter.

and 150 mm diameter microlysimeters, respectively. In this study, we observed that water drainage occurred for a maximum of 7 h, from 06:00 to 13:00, and thereafter, no drainage occurred in either microlysimeter size.

Walker (1983) began to discuss the possible effects of lack of drainage from microlysimeters due to the cap. With the bottom of the microlysimeters remaining sealed, not allowing water to escape, evaporation is the only way to transfer water in this situation to the atmosphere. Thus, a source of error that must be considered when using microlysimeters to quantify soil water evaporation is the possible drainage at the bottom of the soil. However, the measurement of drained water allows this problem to be solved (Daamen et al., 1993).

The values of water drainage for the two sizes of microlysimeters with drainage (ML100D and ML150D) were similar on Aug 7, 2020 (Test 02), when the microlysimeters were subjected to four irrigation blades (15, 30, 45, and 60 mm) (Fig. 6).

Similar to the evaluation performed on Jul 24, 2020, on Aug 7, 2020, the initial drainage was higher at the beginning of the evaluation and decreased with time for all the irrigation blades evaluated. When the experiment began at 06:00, the drainage values were zero and after one hour (at 07:00), 1.27, 1.21, 1.15, and 1.34 mm of drained water was found the 100 mm diameter microlysimeters for the 15, 30, 45, and 60 mm irrigation blades, respectively. For the 150 mm diameter microlysimeters, 1.30, 1.36, 1.22, and 1.41 mm of drained water was observed for the 15, 30, 45, and 60 mm irrigation blades, respectively, at 07:00. For the 60 mm blade, the drainage of water from the soil was greater than that of the other sizes during the day, although not by a large amount. As the microlysimeters were subjected to irrigation at field capacity, there was no marked difference in drainage between the blades.

The average cumulative drainage values on Aug 7, 2020 were 3.12, 3.18, 3.44, and 4.01 mm for the 100 mm diameter microlysimeters with irrigation blades of 15, 30, 45, and 60 mm, respectively. For the microlysimeters with a diameter of 150 mm, the average cumulative drainage values during Aug 7, 2020 were 3.06, 3.48, 3.79, and 4.07 mm for irrigation blades of 15, 30, 45, and 60 mm, respectively Drainage occurred for a maximum of 7 h, from 06:00 to 13:00, similar to that on Jul 24, 2020. Subsequently, no drainage was accounted for in either microlysimeter size (Fig. 6).

3.3 Soil water evaporation

The soil water evaporation values were lower for both sizes of microlysimeters with drainage, with similar evaporation behavior on Jul 24, 2020 (Test 01) (Fig. 7).

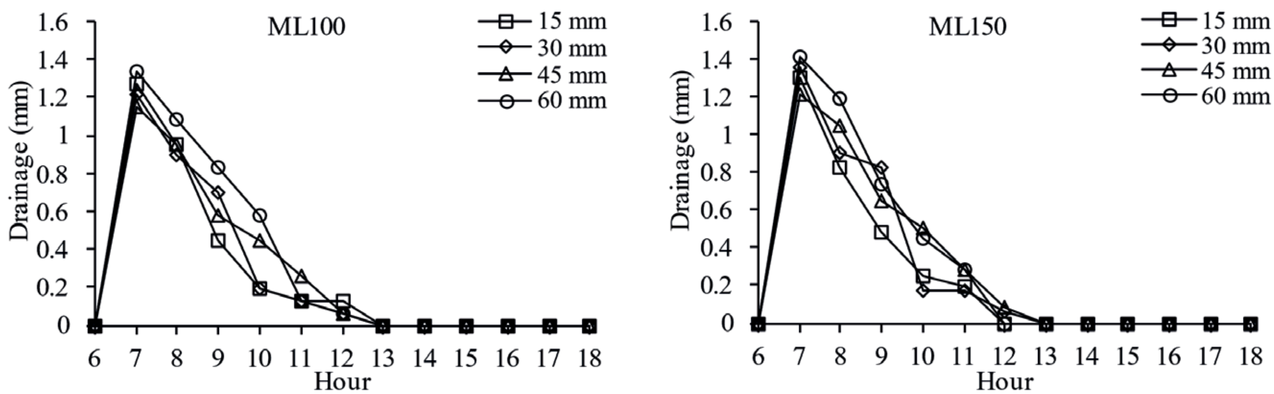

Fig. 6. Water drainage determined in two sizes of microlysimeters subjected to four irrigation blades (15, 30, 45 and 60 mm) between 6:00 am and 6:00 pm (06:00 to 18:00), observed on Aug 7, 2020. ML100 = 100 mm diameter microlysimeter. ML150 = 150 mm diameter microlysimeter.

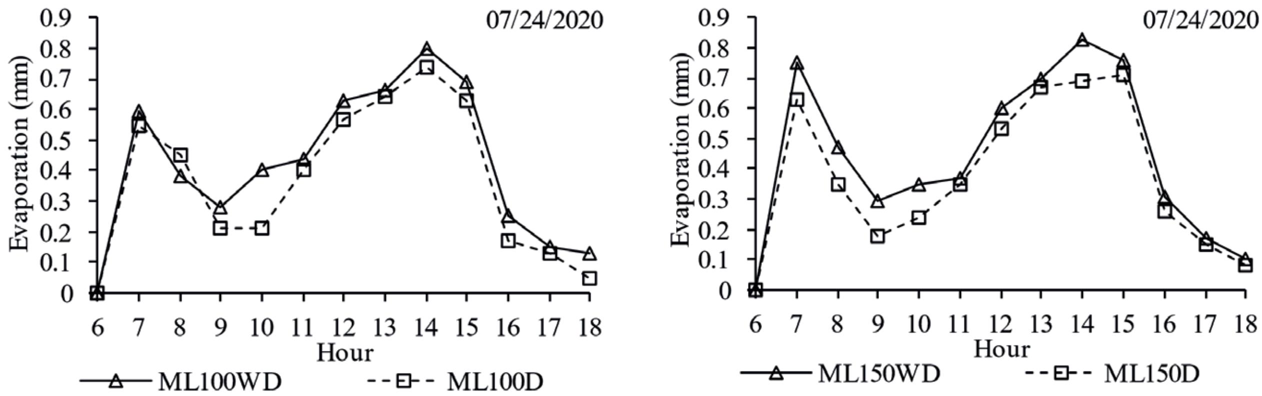

Fig. 7. Hourly soil water evaporation measured by two models and two sizes of microlysimeters between 6:00 am and 6:00 pm (06:00 to 18:00) on Jul 24, 2020. ML100WD = 100 mm microlysimeters without drainage; ML100D = 100 mm microlysimeters with drainage; ML150WD = 100 mm microlysimeters without drainage; ML150D = 100 mm microlysimeters with drainage.

At 07:00, the recorded evaporation was approximately 0.5 to 0.6 mm for the 100 mm diameter microlysimeter and 0.6 to 0.8 mm for the 150 mm diameter unit, with a decrease in values until 09:00. Thereafter, a gradual increase occurred until reaching the peak of evaporation at 14:00 of 0.80 and 0.74 mm for the 100 mm diameter microlysimeters without and with drainage, respectively. The same behavior was observed for the 150 mm diameter microlysimeters without and with drainage, with 0.69 and 0.83 mm of evaporation at 14:00, respectively. Mean cumulative evaporation values during Jul 24, 2020 of 4.75 and 5.40 mm were found for the 100 mm diameter microlysimeter models with and without water drainage, respectively. For the 150 mm diameter microlysimeters, accumulated evaporation during the day was observed to total 4.84 and 5.70 mm for the models with and without water drainage, respectively.

When comparing the soil water evaporation from the two sizes and the two models of microlysimeters subjected to the four blades of irrigation (15, 30, 45, and 60 mm), the same evaporation behavior was observed on Aug 7, 2020 (Test 02) (Fig. 8).

For irrigation blades of 15, 30, and 45 mm, an increase in evaporation was noted from 06:00 until 07:00. The values remained similar until 11:00, when another increase in evaporation occurred with the apex between 13:00 and 14:00 followed by a decrease until 18:00. For the 60 mm blade a gradual increase occurred from 06:00 to 09:00, which remained stable until 14:00, when there was a decrease in soil water evaporation values until 18:00.

Soil water evaporation levels did not vary greatly between the sizes and models of the microlysimeters, or the blade sizes of irrigation. The highest values were observed between 14:00 and 15:00, when they were maintained at approximately 1 mm of evaporation for all irrigation blades, sizes, and microlysimeter models. This apex of soil water evaporation occurred because the solar radiation was at its maximum incidence on the surface (Blight, 2009; Liao et al., 2021), as highlighted in Fig. 8. Thus, the soil reached its maximum evapotranspiration demand.

So far, only a few studies have been carried out to observe the daily or hourly soil water evaporation measured by microlysimeters, highlighting the works of Daamen and Simmonds (1996), Flumignan et al. (2012) and Facchi et al. (2017). The literature does not provide detailed information on how drainage at the bottom of the microlysimeters can affect soil water evaporation and, for this reason, studies such as this one are important to observe the behavior of hourly soil water evaporation.

The evaporation values measured by the lysimeters and by the two models and two sizes of microlysimeters presented the same behavior as the soil water evaporation during the evaluation period in Test 01 (Fig. 9). The soil water evaporation values were generally stable during the evaluation until the fifth day after irrigation, when the measurements decreased both for the lysimeters and microlysimeters due to the drying of the superficial layer of the soil after irrigation. Another factor that influenced the decrease in evaporation values on Jul 29, 2020 and Jul 30, 2020 was the reduction in evapotranspiration demand, which decreased on those days.

During the evaluation period (Jul 24, 2020 to Jul 30, 2020), the average daily reference evapotranspiration observed was 6.56 mm d^{-1}. The average soil water evaporation value between those dates was 3.74 mm d^{-1} for the lysimeters, and 4.03 and 4.31 mm d^{-1} for the 100 mm diameter microlysimeters with and without drain-

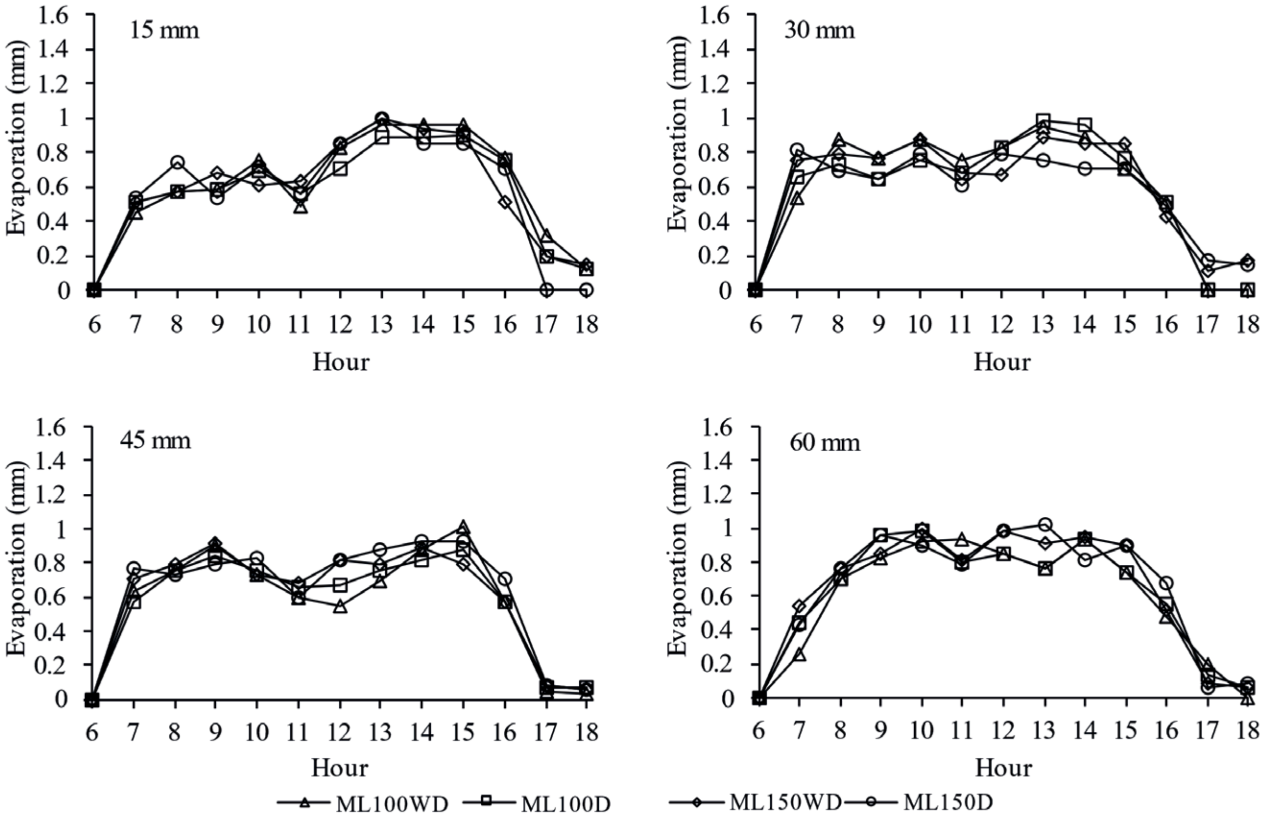

Fig. 8. Hourly soil water evaporation measured by two models and two sizes of microlysimeters subjected to four irrigation blades (15, 30, 45 and 60 mm) between 6:00 am and 6: 00 pm (06:00 to 18:00) on Aug 7, 2020 in Tangará da Serra, Mato Grosso, Brazil.

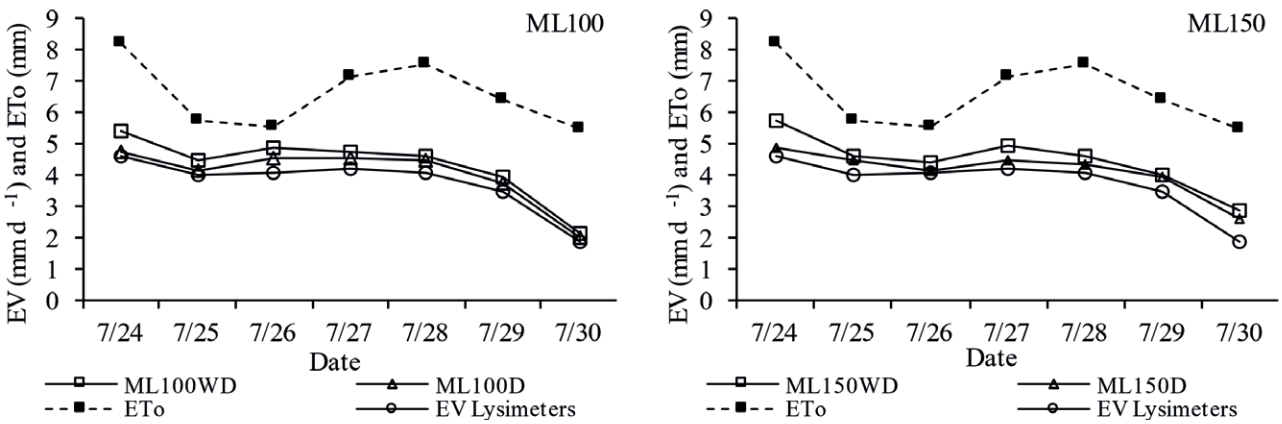

Fig. 9. Reference evapotranspiration (ETo) and daily soil water evaporation (EV) measured by weighing lysimeters (EV Lysimeters) and by two sizes and two models of microlysimeters for the period from Jul 24, 2020 to Jul 30, 2020 in Tangará da Serra, Mato Grosso, Brazil.

age, respectively. For the 150 mm diameter microlysimeters with and without drainage, the average soil water evaporation recorded during those days was 4.11 and 4.43 mm d^{-1}, respectively. The average evaporation of all microlysimeters was 4.22 mm d^{-1}, which was 11.40% higher than the average observed with the lysimeters. The average soil water evaporation for the microlysimeters without drainage was higher than those with water drainage. The values during the period for the 100 mm diameter microlysimeter models with and without water

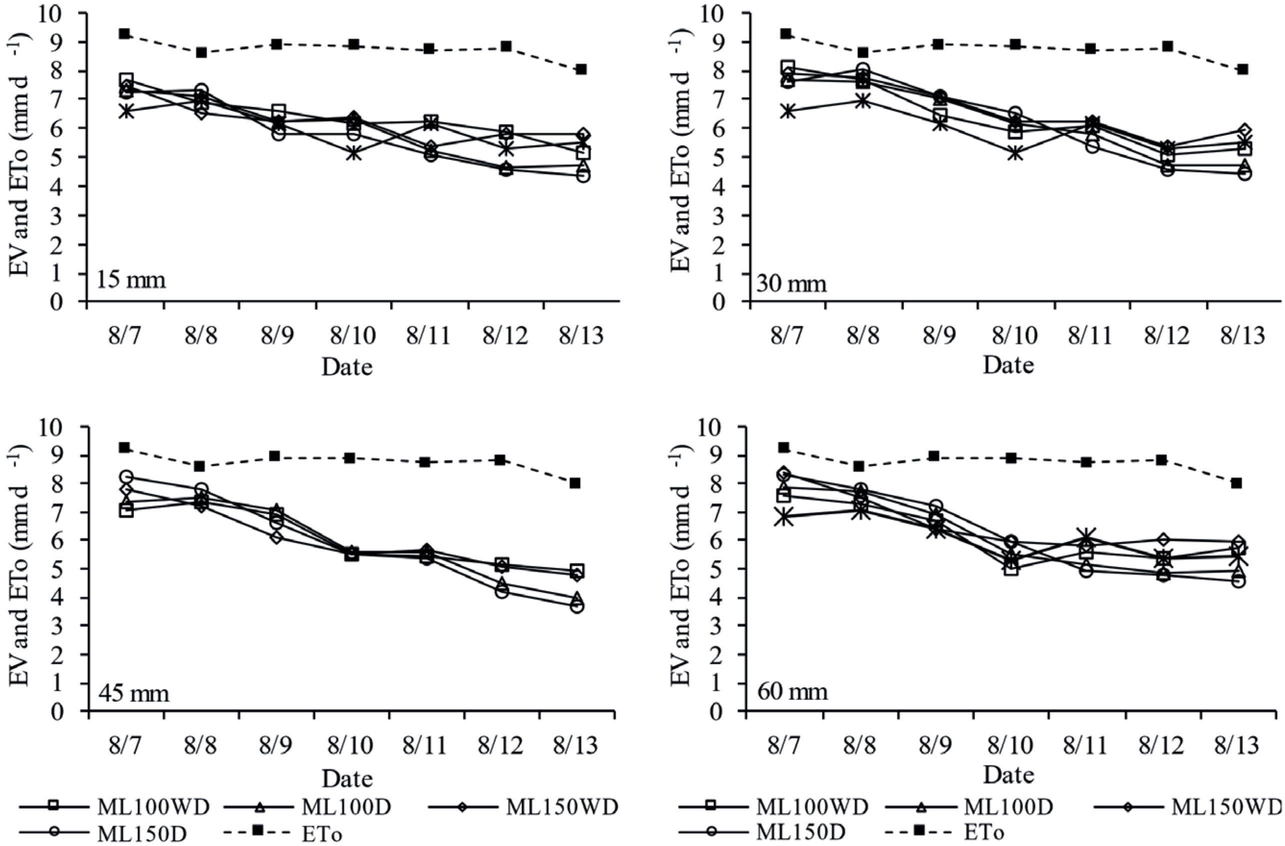

Fig. 10. Reference evapotranspiration (ETo) and daily soil water evaporation (EV) measured by weighing lysimeters (EVL) and two models and two sizes of microlysimeters subjected to 4 irrigation blades (15, 30, 45 and 60 mm) for the period from Aug 7, 2020 to Aug 13, 2020 in Tangará da Serra, Mato Grosso, Brazil.

drainage were 28.19 and 30.15 mm, respectively, while for the 150 mm diameter microlysimeters, the values were 28.79 and 31.04 mm for models with and without water drainage, respectively.

As shown in Fig. 9, soil water evaporation differed between the days evaluated. One explanation is that the response of soil water evaporation to different environmental conditions varies over time, from one locality or region to another (Wei et al., 2015; Wang et al., 2018), and is affected by the evaporative demand of the atmosphere (Tesfuhuney et al., 2015). In addition to these factors influencing soil water evaporation, other authors have reported effects of conditions related to water storage and movement in the soil profile, soil porosity (Gupta et al., 2015; An et al., 2018), and soil cover by straw mulch (Tesfuhuney et al., 2015; Fu et al., 2018; Carvalho et al., 2019).

The soil water evaporation values accounted for by the lysimeters and the two microlysimeter models and sizes, showed the same behavior when subjected to different irrigation blades between Aug 7, 2020 and Aug 13, 2020 (Fig. 10).

The soil water evaporation values showed a slight tendency to decrease over time. The topsoil layer dries, and evaporation moves to Stage 2, according to Lemon (1956), and this stage is less intense because the unsaturated hydraulic conductivity of the soil decreases as the soil dries (Aydin et al., 2005). The process of water evaporation in bare soil is divided into three phases (Ritchie, 1972). The first has a high evaporation potential and is dependent only on the immediate conditions of the atmosphere near the soil. In the second phase, intrinsic soil conditions limit water transport in the profile, and consequently, evaporation. The third phase is characterized by slow water movement toward the surface, due to the low hydraulic conductivity of the soil. Thus, the response over time depends on the phase of the evaporation process.

The high evapotranspiration demand influenced the decrease in evaporation values between Aug 7, 2020 and Aug 13, 2020. During this period, as shown in Table 1, the average air temperature was 26.34 °C and the average solar radiation was 20.59 MJ m^{-2} d^{-1}, and these factors influenced the high values of soil water evaporation and reference evapotranspiration observed. To reduce the variability of soil water evaporation, straw on the soil surface, which is used in no-till management, is an alternative that can delay soil drying and maintain evaporation at Stage 1 for a longer period (Lemon, 1956). Straw also prevents the direct impact of rainwater or irrigation on the soil, which inhibits surface sealing (Liao et al., 2021). This dry layer breaks the continuity of pores with the rest of the soil profile, thereby affecting evaporation (Aydin et al., 2005).

The soil water evaporation values were lower than the observed reference evapotranspiration values during the evaluated period. The average daily reference value observed was 8.72 mm d^{-1}. The average evaporation amounts of all microlysimeters (averages of the two models and the two sizes) for each irrigation blade were 6.07 mm d^{-1} for the 15 mm blade, 6.38 mm d^{-1} for the 30 mm blade, 5.98 mm d^{-1} for the 45 mm blade, and 6.28 mm d^{-1} for the 60 mm blade. These values were 1.48, 6.27, and 4.78%, higher than the average observed in the lysimeters of 5.98 mm d^{-1} for the 15, 30, and 60 mm blades, respectively. For the 45 mm irrigation blade, the evaporation for all microlysimeters equaled that of the weighing lysimeters.

These results are expected since greater water availability with a longer exposure to atmospheric water demand conditions should result in increased evaporation if there is sufficient energy for the process to occur. The variability of soil water evaporation as a function of measurement time as well as irrigation used before the start of the measurement period affects soil water evaporation (Dalmago et al., 2010; Di et al., 2019).

The comparison between evaporation in lysimeters (EV_L) and microlysimeters (E_{ML}) for the period between Jul 24, 2020 and Jul 30, 2020 (Test 01) is presented in Table 2. There was a significant difference between the treatments on the evaluated days. The average soil water evaporation from the two models and two sizes of microlysimeters differ between treatments, with the lowest evaporation values accounted for with the weighing lysimeters.

The findings revealed that the microlysimeters without drainage at the bottom showed higher soil water evaporation values. This effect is possibly related to the non-outflow of water from the bottom of the units, thereby presenting a greater loss of water to the atmosphere. The soil water evaporation ranges for the four models were as follows: ML100WD: 2.12 – 5.40 mm d^{-1} (average 4.31 mm d^{-1}), ML100D: 2.01 – 4.75 mm d^{-1} (average 4.03 mm d^{-1}), ML150WD: 2.85 – 5.70 mm d^{-1} (average 4.43 mm d^{-1}), and ML150D: 2.62 – 4.84 mm d^{-1} (average 4.11 mm d^{-1}).

Certain factors can be identified as responsible for the differences between treatments, and these can significantly interfere with soil water evaporation in experiments with irrigation (Dalmago et al., 2010; Zhang et al., 2019). For example, when using sprinkler irrigation, because it does not present the same homogeneity of water distribution as rainfall, variability of soil moisture inside the microlysimeters can occur, which affects evaporation (Dalmago et al., 2010; Al-Ghobari et al., 2018). Furthermore, Dalmago et al. (2010) reported that the atmospheric water demand after irrigation is different from that after rainfall, which results in altered evaporation responses.

Table 2. Mean values and descriptive statistics for daily soil water evaporation determined in weighing lysimeters and microlysimeters in Tangará da Serra, Mato Grosso, Brazil.

Date	Soil Water Evaporation (mm d^{-1})					SD	$\bar{X}$	Md	As	Ck
	EVL	ML100WD	ML100D	ML150WD	ML150D					
24/07/2020	4.59b	5.40a	4.75b	5.70a	4.84b	0.47	5.06	4.84	0.66	-1.88
25/07/2020	3.96c	4.46ab	4.16bc	4.58a	4.45ab	0.25	4.32	4.45	-0.75	-1.21
26/07/2020	4.03c	4.88a	4.51ab	4.41bc	4.12bc	0.34	4.39	4.41	0.57	-0.36
27/07/2020	4.21b	4.72a	4.52ab	4.90a	4.49ab	0.26	4.57	4.52	-0.17	0.04
28/07/2020	4.06b	4.62a	4.49a	4.59a	4.34ab	0.23	4.42	4.49	-1.19	0.81
29/07/2020	3.46b	3.95a	3.75ab	4.01a	3.93a	0.22	3.82	3.93	-1.37	1.31
30/07/2020	1.86b	2.12b	2.01b	2.85a	2.62a	0.42	2.29	2.12	0.57	-2.09
Average	3.74c	4.31a	4.03b	4.43a	4.11b	0.27	4.12	4.11	-0.48	-0.14

Means followed by the same lowercase letter on the line do not differ statistically by Tukey's test at the 5% probability of error. EVL = Lysimeters evaporation; ML100WD = 100 mm microlysimeters without drainage; ML100D = 100 mm microlysimeters with drainage; ML150WD = 150 mm microlysimeters without drainage; ML150D = 150 mm microlysimeters with drainage; SD = Standard deviation; $\bar{X}$ = Average; Md = Median; As = Asymmetry; Ck = Kurtosis.

The standard deviation of the treatments varied between 0.22 and 0.47 mm d^{-1}, with an average of 0.27 mm d^{-1} among the days evaluated. EV_L varied between 1.86 and 4.59 mm d^{-1}, with an average of 3.74 mm d^{-1}. This variation is due to the different atmospheric demands on the days evaluated as well as the decreasing water loss to the atmosphere. As shown in Table 2, without making any distinction between the soil water evaporation accounted in the lysimeters and microlysimeters studied, the deviations found between the measurements obtained were generally within the range of ±0.35 mm d^{-1} (71.43% of the data).

The evaporation and lifetime of a microlysimeter are influenced by errors intrinsic to this method, such as drainage limitations, capillary rise caused by bottom closure, degree of soil disturbance caused during extraction, and heat conduction inside the microlysimeter (Daamen et al., 1993; Marek et al., 2019). These factors may explain the higher mean evaporation values found in the 100 and 150 mm diameter microlysimeters without drainage compared to those with water drainage (Table 2). It was observed that until the fifth day after irrigation, the evaporation values recorded in the lysimeters remained similar, and on the sixth day, there was a decrease. The symmetrical set and the microlysimeters should be maintained at close to field capacity so that measurements of soil water evaporation are not lower than those that actually occurred on the day because of the smaller amount of water present in the soil.

Allen (1990) reported that soil water evaporation values in the first few days may be overestimated when microlysimeters are installed soon after precipitation or irrigation has occurred. Thus, it is important that when installing the microlysimeters after an irrigation or rainfall event, the aspects of the water sheet applied to the soil and the water distribution capacity of the soil should be considered (Flumignan et al., 2012; Marek et al., 2019).

When comparing the mean with the median, low variation was observed between the values of soil water evaporation, which indicates that they are close to normal; this was also proven by the value of the asymmetry coefficient, showing positive asymmetry for three days and negative asymmetry for four different days, but values close to 0 (symmetry), with an average of -0.48, which is a good parameter for daily assessment of soil water evaporation (Table 2). Regarding the kurtosis coefficient (Ck), the mean values of soil water evaporation for four of the seven days studied presented a platykurtic distribution (Ck < 0), and the other three days presented a leptokurtic distribution (Ck > 0), but soil water evaporation distributions were close to normal for all days (Ck = 0, mesokurtic). According to Carvalho et al. (2002), asymmetry and kurtosis values ranging between -3 < 0 > 3 indicate the normality of the data, which was observed in this study.

The soil water evaporation values from the lysimeters and microlysimeters between Aug 7, 2020 and Aug 13, 2020 (Test 02), where four irrigation blades were applied, are shown in Table 3. The EV_L varied between 5.31 and 6.96 mm d^{-1}, with an average of 5.98 mm d^{-1}.

The soil water evaporation in the ML100WD treatment showed a standard deviation of 0.15 mm d^{-1} between the irrigation blades. The ML100D, ML150WD, and ML150D treatments presented mean deviations of 0.15, 0.29, and 0.24 mm d^{-1} in relation to the irrigation blades, respectively. The mean and median indicated low variation for the soil water evaporation values among the microlysimeter models and sizes and the irrigation blades, indicating that they were close to normal. The trend observed for the low variability of the observed evaporation can be attributed to the short measurement period evaluated and the limited number of days on which evaporation was measured. In addition, irrigation tends to eliminate the differences between treatments and mask the variation in soil water evaporation (Dalmago et al., 2010; Yang et al., 2020).

The average asymmetry for both models and microlysimeter sizes showed negative asymmetry, but the values were close to zero (symmetry). Regarding the kurtosis coefficient (Ck), the mean values of soil water evaporation for the days, microlysimeters, and blades studied mainly showed a leptokurtic distribution (Ck > 0), but some days showed a platykurtic distribution (Ck < 0), with the distribution of soil water evaporation being close to normal for all days.

3.4 Comparison of soil water evaporation between microlysimeters and lysimeters

The average soil water evaporation values obtained for the 100 mm and 150 mm diameter microlysimeters with and without drainage were subjected to regression analysis, using the evaporation values in the weighing lysimeters (EV_L) as a reference (Fig. 11). The adjusted equations indicate that the soil water evaporation data obtained by the microlysimeters and lysimeters were similar, revealing good agreement between the methods based on the high coefficient of determination (R^2) values. The 100 mm diameter microlysimeters showed R^2 values of 0.9834 and 0.9853 for the models with and without water drainage, respectively, while the 150 mm diameter microlysimeters presented R^2 values of 0.974 and 0.9147, respectively.

Table 3. Mean values and descriptive statistics for daily soil water evaporation determined in lysimeters (EV_L) and microlysimeters (E_{ML}) subjected to four irrigation blades (15, 30, 45 and 60 mm) in Tangará da Serra, Mato Grosso, Brazil.

Date	Soil Water Evaporation (mm d^{-1})					SD	$\bar{X}$	Md	As	Ck
	EVL	ML100WD	ML100D	ML150WD	ML150D					
					Irrigation blade - 15 mm					
08/07/2020	6.87	7.70	7.32	7.47	7.27	0.31	7.33	7.32	-0.58	1.17
08/08/2020	7.03	6.88	7.13	6.51	7.36	0.32	6.98	7.03	-0.65	0.78
08/09/2020	6.38	6.62	6.24	6.22	5.80	0.30	6.25	6.24	-0.64	1.48
08/10/2020	5.31	6.18	6.30	6.37	5.80	0.44	5.99	6.18	-1.15	0.28
08/11/2020	6.14	6.24	5.22	5.38	5.09	0.53	5.61	5.38	0.49	-2.89
08/12/2020	5.36	5.86	4.65	5.80	4.56	0.62	5.24	5.36	-0.24	-2.96
08/13/2020	5.41	5.16	4.71	5.80	4.39	0.56	5.09	5.16	-0.05	-1.20
Average	6.07	6.38	5.94	6.22	5.75	0.44	6.07	6.09	-0.40	-0.48
					Irrigation blade - 30 mm					
08/07/2020	6.72	8.09	7.70	7.92	7.64	0.53	7.61	7.70	-1.62	3.02
08/08/2020	7.18	7.70	7.58	7.78	8.06	0.32	7.66	7.70	-0.55	1.21
08/09/2020	6.15	6.47	7.07	7.07	7.07	0.43	6.77	7.07	-0.92	-1.55
08/10/2020	5.39	5.86	6.18	6.22	6.51	0.43	6.03	6.18	-0.81	0.45
08/11/2020	6.01	6.11	5.79	6.22	5.38	0.33	5.90	6.01	-1.16	0.97
08/12/2020	5.15	5.09	4.71	5.38	4.61	0.32	4.99	5.09	-0.14	-2.01
08/13/2020	5.31	5.28	4.71	5.94	4.44	0.58	5.14	5.28	0.24	-0.61
Average	5.99	6.37	6.25	6.65	6.24	0.42	6.30	6.43	-0.71	0.21
					Irrigation blade - 45 mm					
08/07/2020	6.65	7.07	7.38	7.78	8.21	0.61	7.42	7.38	0.08	-0.88
08/08/2020	6.93	7.38	7.51	7.22	7.78	0.32	7.36	7.38	-0.13	0.06
08/09/2020	6.24	6.94	7.07	6.08	6.65	0.43	6.60	6.65	-0.18	-2.47
08/10/2020	5.24	5.54	5.60	5.52	5.52	0.14	5.48	5.52	-1.88	3.96
08/11/2020	6.23	5.41	5.60	5.66	5.38	0.34	5.66	5.60	1.58	2.70
08/12/2020	5.46	5.16	4.46	5.09	4.19	0.53	4.87	5.09	-0.43	-1.96
08/13/2020	5.49	4.90	4.01	4.81	3.65	0.74	4.57	4.81	-0.15	-1.45
Average	6.03	6.06	5.95	6.02	5.91	0.44	5.99	6.06	-0.16	-0.01
					Irrigation blade - 60 mm					
08/07/2020	6.59	7.58	7.89	8.35	8.32	0.72	7.75	7.89	-1.27	1.38
08/08/2020	6.96	7.26	7.70	7.50	7.78	0.34	7.44	7.50	-0.64	-0.92
08/09/2020	6.18	6.68	6.94	6.37	7.19	0.41	6.67	6.68	0.06	-1.68
08/10/2020	5.18	5.03	5.54	5.94	5.97	0.43	5.53	5.54	-0.09	-2.68
08/11/2020	6.14	5.60	5.16	5.80	4.95	0.48	5.53	5.60	0.00	-1.56
08/12/2020	5.31	5.35	4.84	6.03	4.78	0.50	5.26	5.31	0.88	0.49
08/13/2020	5.52	5.72	4.90	5.97	4.56	0.59	5.33	5.52	-0.47	-1.82
Average	5.98	6.17	6.14	6.56	6.22	0.50	6.22	6.29	-0.22	-0.97

EV_L = Lysimeter evaporation; ML100WD = 100 mm microlysimeters without drainage; ML100D = 100 mm microlysimeters with drainage; ML150WD = 150 mm microlysimeters without drainage; ML150D = 150 mm microlysimeters with drainage; SD = Standard deviation; $\bar{X}$ = Average; Md = Median; As = Asymmetry; Ck = Kurtosis.

On a daily basis, the soil water evaporation was on average 15, 8, 18, and 10% higher for ML100WD, ML100D, ML150WD, and ML150D, respectively, when compared to the weighing lysimeter (between ±0.3 and 0.7 mm d^{-1}). Similar results were found by Dalmago et al. (2010), who observed 11% (±0.3 mm d^{-1}) more soil water evaporation from the microlysimeters that had water drainage compared to lysimeters. The high coefficient of determination observed between these measurements demonstrates that the microlysimeter technique

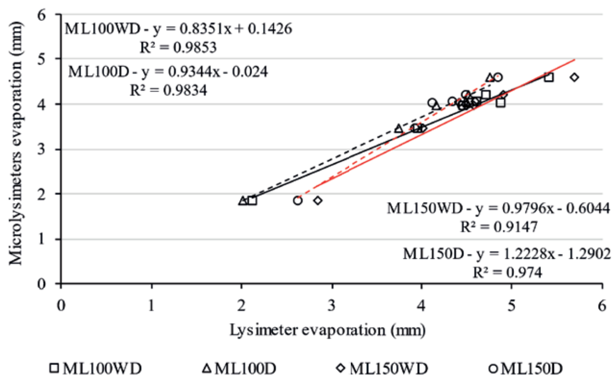

Fig. 11. Linear correlation of soil water evaporation determined by weighing lysimeters and by two sizes of microlysimeters with and without water drainage in Tangará da Serra, Mato Grosso, Brazil.

The field activities that were developed in this study show that the greatest difficulty in the management of microlysimeters is their fabrication and installation because the soil is very clayey and humid; therefore, this procedure requires care to preserve the extracted soil structure. Flumignan et al. (2012) reported that studies with microlysimeters generally require two people to manufacture and install, but once installed, it only requires the daily presence of one person to perform weighing, which takes little time. In this particular study, where 32 microlysimeters were used, two people over approximately six hours were required to perform the installation in the field, and during data collection, two people were required simultaneously for rapid data collection.

used in this study can be adopted for soil water evaporation measurements. The significant adjustment of evaporation measured with the microlysimeters relative to that measured with a weighing lysimeter, both in terms of daily and cumulative evaporation, indicates that microlysimeters are suitable for direct measurements of absolute evaporation values in the field.

Similar results were obtained by Dalmago et al. (2010), who evaluated soil water evaporation in soil management systems (no-till and conventional tillage) using microlysimeters of sizes similar to those used in this study. Flumignan et al. (2012) compared soil water evaporation measurements between lysimeters and microlysimeters, and concluded that the use of microlysimeters is valid for soil water evaporation measurements. Facchi et al. (2017) evaluated the performance of microlysimeters for measuring soil water evaporation in rice crops with intermittent irrigation and stated that microlysimeters are effective tools for measuring soil water evaporation.

Care should be taken when using microlysimeters to quantify soil water evaporation, because measurement failures may occur, which, according to Flumignan et al. (2012), can be associated with several factors, such as days with high rainfall, which may cause unevenness of precipitated water reaching the microlysimeter, inhibition of drainage in the microlysimeters, impacts from falling water drops, and removal of soil particles inside the microlysimeters, as well as differences in the amount and intensity of precipitation. The same authors also mentioned that in cultivated soil conditions, the error and variability in evaporation measurements may be greater because the crop canopy intercepts the precipitated water, which is unevenly distributed in the microlysimeters distributed in the soil profile.

4. CONCLUSIONS

The water drainage at the bottom of the microlysimeters was higher at the beginning of the evaluation and decreased with time. Water drainage occurred for a maximum of 7 h after irrigation, and thereafter, no drainage was observed for the two microlysimeter sizes.

The soil water evaporation values differ significantly between the two microlysimeter sizes (100 and 150 mm diameter) and in the two models (with and without water drainage) and were higher than those observed with the weighing lysimeters. Soil water evaporation is affected by the water drainage that occurs at the bottom of the microlysimeters, with lower evaporation values in the microlysimeter model with drainage compared to those without drainage.

There was no difference between the irrigation blades in terms of soil water evaporation values within the same microlysimeter size and model. The two models and two microlysimeter sizes tested in this experiment can be used for the quantification of soil water evaporation because of the high determination coefficients observed compared to those observed with the weighing lysimeters.

The microlysimeter technique is suitable for measuring soil water evaporation when using irrigation. The high coefficient of determination observed when comparing soil water evaporation between microlysimeters and lysimeters demonstrates that the microlysimeter technique used in this study can be adopted for soil water evaporation measurements.

The study is subject to a specific date and location, needing to assess the effects of drainage on the basis of microlysimeters on soil water evaporation at different locations and assessment times. We emphasize the importance of studying the functioning of microlysimeters in quantifying soil water evaporation in different types of soil, and these need to be investigated further.

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