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LYSIMETRIC QUANTIFICATION OF BIODRAINAGE POTENTIAL OF SOME TREE SPECIES

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ABSTRACT

Cylindrical plastic drums of 2.84 m^3 capacity filled with field soil and with a water table observation well were used as a single lysimeter. The overall layout comprised of 24 lysimeters with six treatments *i.e.* i) *Casuarina equisetifolia,* ii) *Eucalyptus tereticornis* clone-10, iii) *Melia azedarach*, iv) *Prosopis juliflora* v) *Terminalia arjuna* and vi) blank lysimeter (control). Tree-to-tree spacing was 5m and edges of the lysimeter drums were 3.60 m apart. Results showed that in trees like *Casuarina equisetifolia, Eucalyptus tereticornis* and *Prosopis juliflora* which displayed large leaf area over extended period of time, consumptive water use was maximum as 16.7, 16.3 and 14.0 kL $year^{-1}$, respectively. Conversely, trees like *Melia azedarach and Terminalia arjuna,* which were deciduous, the water biodrained was 6.8 and 5.9 kL $year^{-1}$, respectively. On a seasonal scale ambient temperature (r = 0.750** to 0.902**), pan evaporation (r = 0.557** to 0.906**) and vapor pressure deficit (r= 0.434** to 0.797**) in different tree species were the most influential factors determining quantity of water biodrained. Present findings report a new lysimetric design for the rapid quantification of the biodrainage potential of tree species.

Abbreviations: LA: leaf area, DBH: diameter at breast height, VPD: vapor pressure deficit, WS: wind speed, Rad: radiation, Ep: potential evaporation, Wb: water biodrained, RCC: reinforced cement concrete, PVC: polyvinyl chloride

INTRODUCTION

Trees are known to act as biological pumps that can transpire copious amount of soil water into the atmosphere and the phenomenon is also referred to as biodrainage (Heuperman *et al.,* 2002). When the surface soil water gets depleted, trees continue to thrive by drawing water from the aquifers 5 to 20 m deep. It has been demonstrated that under ideal conditions, a tree canopy may lower water tables by 1-2 m over a time period of 3-5 years. Comparative information on the consumptive water use potential or 'biodrainage potential' of different tree species is imperative for control of ground water. However, the field experimentation has its limitations in exact measurement of the tree biodrainage potential (Heuperman *et al*., 2002, Kapoor 2002, Angrish *et al*., 2006, Nolz *et al*., 2016).

Lysimeters are devices where several cubic meters of soil is encapsulated in a container with arrangement to monitor water flux into the atmosphere or to the water table formed at the container floor. The common feature of all lysimetric designs is that the root-soil zone of the experimental vegetation is completely cut off from the ambient soil with regard to any water or nutrient flux. At the same time, the atmospheric conditions and soil surface are almost comparable with natural conditions (Unlu *et al.,* 2010, Meissner *et al*., 2010). Recently several workers have used lysimeters for biodrainage and related physiological issues involving tree species (Chhabra and Thakur 1998, Boman *et al*., 2007, Gafni and Zohar 2008).

However, the major constraints of lysimetric studies are: i) the limited soil volume of the lysimeter container becomes a constraint for unimpeded growth of the tree root system and ii) huge expenditure involved in the construction and maintenance of the lysimetric set up. It is with this background in mind, the present studies were conducted to fabricate desirable type and quantity of lysimeters for tree water use and to quantify the biodrainage potential of five tree species.

MATERIALS AND METHODS

Fabrication of lysimeters

A suitable lysimetric set up was established modifying the design of Chhabra and Thakur (1998). This design is described in the Results and discussion section (Fig 9**)**. Lysemeters were set up at research farm area adjacent to Ludas road of CCS Haryana Agricultural University, Hisar. A 35 × 45 m^2 plot from a field hitherto under pearlmillet-wheat rotation was earmarked for this purpose. For each lysimeter commercially available plastic overhead water storage tanks of 3,000 L capacity were utilized after cutting their top lid. The left over cylindrical drum 1.25 m in height and 1.45 m in diameter (2.84 m^3) was used as the mainframe of the lysimeter. A schematic diagram of the lysimeter design is given in Fig. 1. Cylindrical pits were dug in the soil (Fig. 2a) and the bottom of each pit compacted flat with a mixture of sand, gravel, and cement. The drums were lowered and placed on the flat platform with 10 cm of the drum projecting above the original soil surface, suitably filled up with the field soil (loamy sand Typic Haplustepts). An 'observation well' was also installed in each lysimeter (Fig. 2b). For this a 1.30 m long and 8 cm diameter pipe was inserted vertically downwards up to the bottom of each lysimeter at a distance of 15 cm from the lysimeter wall.

The lower 20 cm portion of the well pipe was drilled with 10 mm diameter perforations at a distance of 2 × 2 cm and tightly wrapped by two layers of a nylon mesh. The observed wells formed an excellent system to readily observe water table in each lysimeter correct by upto 1 mm. For this a sufficiently long thin disposable strip of non glossy brown paper clipped to a 75 g plumbline iron weight was used. The strip was gradually lowered into the well. When the plumb line just dipped in water the paper strip acquired a clear and distinct water mark line. The upper end of the strip at the level of well pipe was also marked with a pencil. The strip was taken out of the well and the water table depth measured as the distance (mm) between the pencil mark and water mark with the help of a flexible measuring tape. Further the well also served as conduit to add or drain out water directly to the water table of the lysimeter as per experimental requirements.

Edge to edge distance of the lysimeters was 3.60 m and centre to centre (plant to plant) distance was 5.0 m. The overall layout comprised of 24 lysimeters in 6 rows of 4 lysimeters each in east to west direction. A boundary of 24 *Tamarix aphylla* trees, each planted at a distance of 3.6 m from each lysimeter, was also established. This served as a wind break and moderator of the microclimate for the lysimetric area.

Establishment of trees in lysimeters

Seedlings of five different tree species were procured from different sources and maintained in a screen house of the Department of Botany and Plant Physiology, CCS Haryana Agricultural University. These are: *Casuarina equisetifolia* L. (Casuarina), (ii) *Eucalyptus tereticornis* clone-10 Sm. (Eucalyptus/safeda), (iii) *Melia azedarach* L. (Bakain), (iv) *Prosopis juliflora* (Sw.) DC. (Mestique/vilayati kikar), (v) *Terminalia arjuna* (Roxb.) (Arjun). The seedlings were initially sown/established in thick perforated polyethylene bags of suitable size containing loamy soil, Balsamand dune sand and farm yard manure in the ratio of 2:1:1. These were allowed to grow under ambient conditions for about 1½ years.

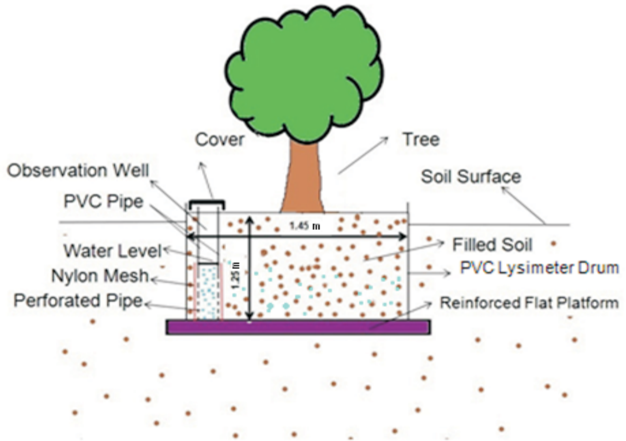

Figure 1: A schematic diagram of the lysimeter setup

Figure 2(a): A cylindrical pit being dug for the fixation of lysimeter drum at the lysimeter site and (b) A freshly installed lysimeter filled up with field soil. Note the upper end of the observation well (arrow)

In mid July 2006, the one and half year old saplings were transplanted to lysimeters. Four saplings (replicates) of each of the five species were planted in completely randomized design (CRD) in 20 lysimeters keeping another four lysimeters as blank controls. Trees were surface irrigated as per requirement for the first 6 months. From February 2007 onwards irrigation was gradually directed through the bottom of the lysimeter through the observation well pipe. A fertilizer of 100 g of urea and 100 g of KH_2PO_4 was applied annually in two split doses one each in 1st week of July and 1st week of February.

Calibration of lysimeters

For quantification of water transpired, water table fluctuation in the lysimeter was monitored. Measured amount of water

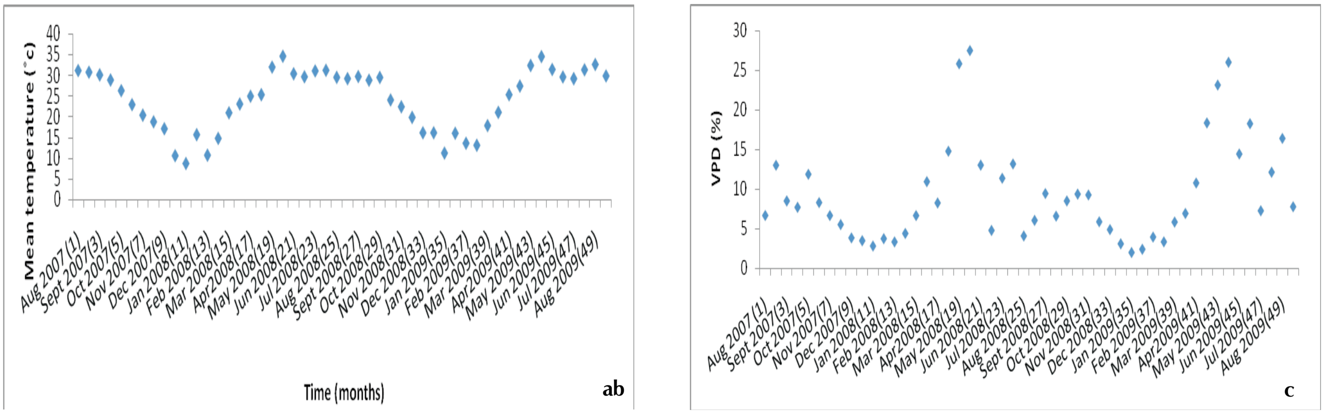

Figure 3(a): Mean temperature (°C), (b) Mean relative humidity (%), (c) Vapor pressure deficit (%) during the course of the experimental observation

Figure 4: Height of lysimeter grown tree of (a) *E. tereticornis* clone 10 and (b) *P. juliflora*. White bar indicates 1 m

could always be directly added to, or taken out from the water table through the observation well. At the time of start of the experiment lysimetric soil was compacted to an average bulk density of 1.5 g/cm^3. Necessary calibration was done by adding sufficient water to each observation well so as to maintain the water table at the depth of about 90 cm from surface. Twenty liters of water was added to each lysimeter through the observation well. Surface of each lysimeter was sealed immediately with thick polythene sheet to prevent any evaporation from the lysimeter soil surface. After 12 hours of equilibration the polythene cover was removed and water table level in each well was again recorded. It was found that for 20 liters of water added the water table increased by an average of 180 mm. Thus for every 1 liter addition/deletion of water the water table increased/decreased by a factor of 9 mm. This procedure was again repeated in the year 2007, in all the control lysimeters and results were found to be the same. This calibration provided a convenient and accurate method of measurement of water loss through evapotranspiration. Therefore, for all experimental measurements water table was adjusted to depth between 80-90 cm which was individually measured between 11.00 a.m. to 12.00 noon. The depth was again measured after 24 hours on the next day. The volume of water evapotranspired in liters was measured by multiplying the difference in the level of water tables multiplied by the calibration factor of 0.9. In tree species where predisposition of the evapotranspiration was expected to be around 40 liters or more and the water table was likely to hit bottom of the lysimeter, measured amount of water was added beforehand after taking the initial reading. The added water volume was adjusted in the next day reading. By and large the rainfall was scanty and the rainfall water never filled up the drums and spilled over. Loss of water through evaporation (We) was measured from the control lysimeters which were without any trees but with water table between 80-90 cm like other lysimeters. Water evapotranspired (Wt) was measured in all the other lysimeters with trees by taking into account the difference in the water table at 24 hours interval. Water biodrained (Wb) by an individual tree in the lysimeter was calculated by subtracting water evaporated from water evapotranspired as per the following equation:

$$Wb = Wt - We$$

This procedure gave results that should be expected to be nearest to the exact, as water evaporated from the control lysimeters is likely to be more because of lack of surface shading

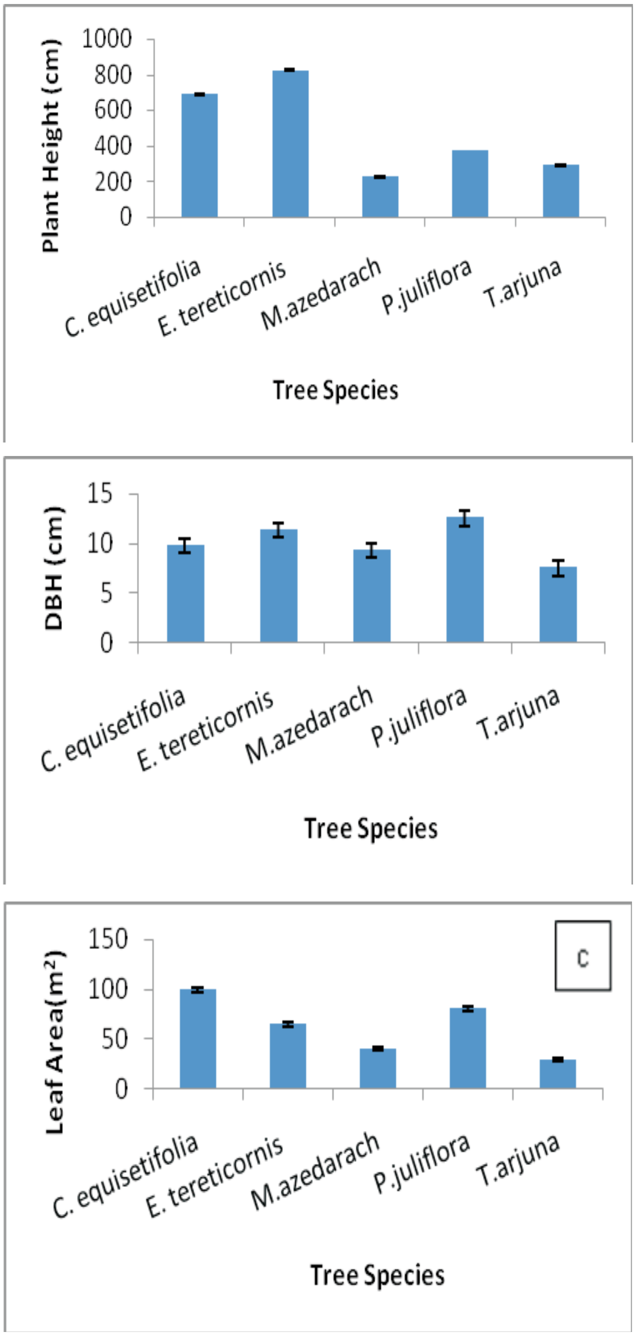

Figure 5(a): Height (CD at 5% = 9.15), (b) DBH (CD at 5% = 0.31 and (c) Leaf area (CD at 5% = 4.07) of different lysimeter grown tree species

and increased soil temperature, less accumulation of litter etc. on the soil surface.

Leaf area measurements

Leaf area was measured using Hemiview leaf area measurement system (version 2.1 Delta-T Devices, UK). For this a hemispherical image of the tree canopy was taken from the base of the tree crown, as close to the centre as possible, with the help of fish eye lens, fitted to camera system of the Hemiview instrument. The hemispherical image was edited in Adobe Photoshop by ignoring the areas dominated by tree trunks or other vegetation using an image editor. The edited hemispherical image was fed to computer software supplied by the Delta-T Devices for the calculation of leaf area of single tree corresponding to the shape that best fits the tree. This interpreted the image for computation of leaf area using some subsequent calculations in Microsoft Excel solver, using "least squares" technique which calculated its best fit estimates for ELADP (Ellipsoidal leaf angle distribution parameters), LD (Leaf area density) and DLLAI (Drip line leaf area index) and give direct values for the tree leaf area.

Meteorological data

The daily variations in mean temperature (ÚC) (Fig. 3a), mean relative humidity (%) (Fig. 3b), mean vapor pressure deficit (Fig.3c) were obtained from field meteorological laboratory of CCS Haryana Agricultural University located about 500 m from the experiment site.

Statistical analysis

Data of the present experiment was analyzed for Analysis of Variance and Correlation Analysis by OP STAT Package available at the CCS Haryana Agricultural University, Hisar website (http://www.hau.ernet.in).

RESULTS AND DISCUSSION

Plant height, DBH and leaf area

It may be noted at the outset that the plants raised in lysimeters

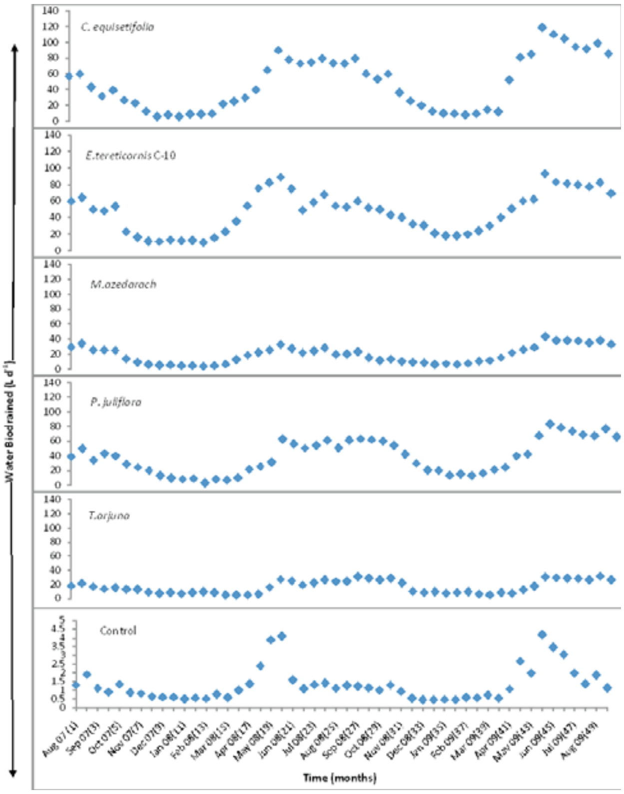

Figure 6: Water biodrained (Wb) by different lysimeter-grown tree species as well as evaporation from the blank (control) lysimeters (CD at 5% = 4.098)

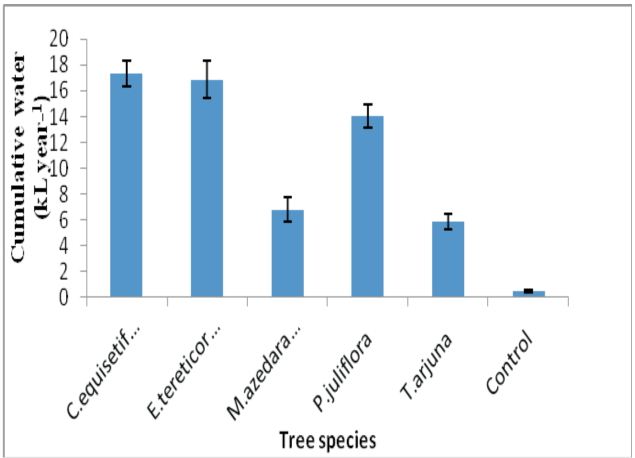

Figure 7: Cumulative water biodrained per year (kL year^{-1}) by different lysimeter grown tree species

were about 3 years and six months old towards August, 2007 and had attained tree like proportions when the results reported were recorded. All the trees had completed their juvenile phase as these showed flowering and even fruit setting. Maximum tree height (Fig. 5a) towards August 2009 was obtained by *E. tereticornis* C-10 (824 cm) (Fig.4a) followed by *C. equisetifolia* (690 cm), *P. juliflora* (374 cm) (Fig. 4b), *T. arjuna* (291 cm) followed by *M. azedarach* (226 cm). Diameter at breast height (Fig. 5b) was maximum in *P. juliflora* followed by *E. tereticornis*. Again it is seen (Fig. 5c) that maximum mean leaf area was observed in *C. equisetifolia* followed by *P. juliflora* and *E. tereticornis*.

Water biodrained

It is seen (Fig. 6) that water Wb (L d^{-1}) by tree species is highly variable. In general it has peaks in every species in May both during 2008 and 2009. *M. azedarach* and *T. arjuna* do not show such peaks as these are spring and early-summer deciduous, respectively. A very marked decline in the Wb is observed in winter (December to February) months of both years.

Fig. 7 depicts that *C. equisetifolia, E. tereticornis* and *P. juliflora* were luxuriant biodrainers losing about 16.7, 16.3 and 14 kL^{-1} of water per annum, respectively. Wb magnitude is further correlated and discussed under suitable heads in subsequent part of this paper.

Leaf area and Wb

A comparison of Fig. 5a and Fig. 6 shows that leaf area (LA) has a very clear cut positive effect on tree Wb. The strong significant correlation of LA with Wb (Table 1) as also reflected in correlation values of *C. equisetifolia* (r = 0.82**), *E. tereticornis* C-10 (r = 0.62**), *M. azedarach* (r = 0.93**), *P. juliflora* (r = 0.82**) and *T.arjuna* (r = 0.61**) is also a pointer in this direction. Species like *C. equisetifolia* and *E. tereticornis* C-10 which have high leaf area values and are evergreen show the highest water use values. According to Bora and Joshi (2014) *Azadirachta indica, Ficus religiosa, Saraca indica* and *Eucalyptus* sp. were categorized as very good performer having spreading dense canopy of evergreen foliage. The significance of leaf area as a biodrainage factor is further elucidated by the deciduous species. For example *M. azedarach* which had a leaf area of 42.4 m^2 in the month of end July 2009 showed a Wb of 34.8 L d^{-1}, where as in the month of January 2009 the leaf area was almost nil, the Wb was 6.7 L d^{-1} showing a % reduction of 80.7.

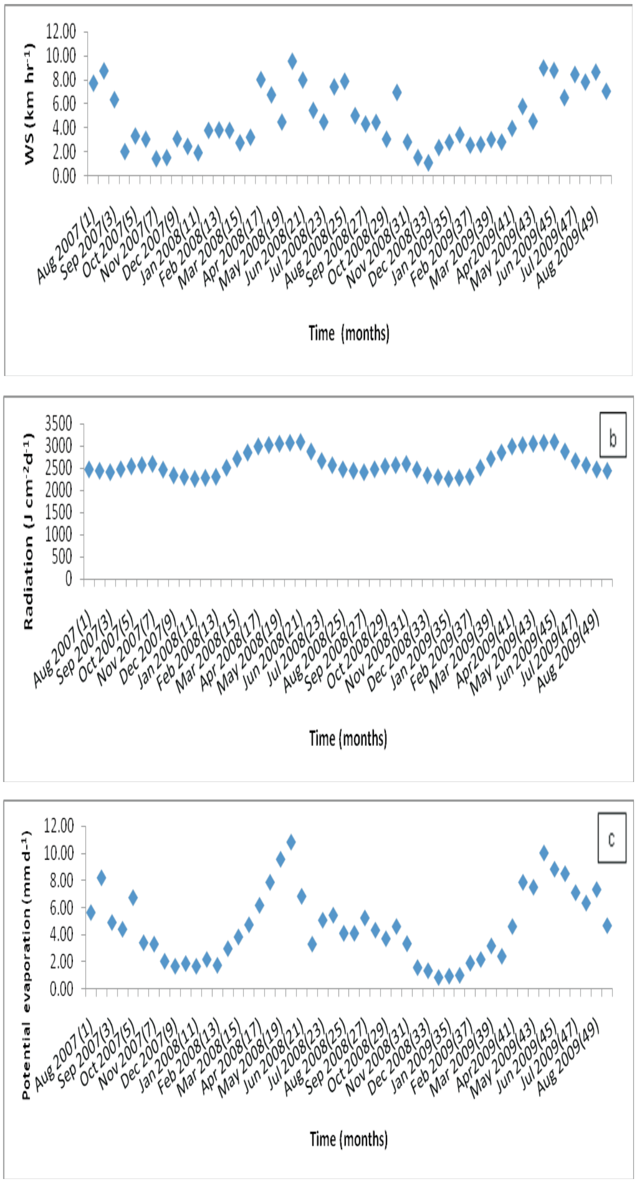

Figure 8(a): Wind speed (km h^{-1}), (b) Radiation (J cm^{-2} d^{-1}), (c) Potential evaporation (mm d^{-1}) obtained during the course of experimentation

An even more interesting situation is encountered in the summer deciduous *T. arjuna* where the peak leaf area in the month of end July was 28.2 m^2 vis-à-vis Wb of 29 L d^{-1} as compared to the leaf area values near zero in the summer month of end April *vis-à-vis* Wb of 12.3 L d^{-1}, showing a decline of 57.6 % in this case. This may also account for the relatively lower correlation coefficient value (r = 0.61**) in this species as compared with the other four tree species. Dale (1992) estimated that a forest stand having a spread of one hectare displays a leaf area of 20 ha. This manifold increase in the transpiration area per unit of land area results in the increased

Table 1: Summary table of correlation coefficients (r) between different morphological and environmental parameters and water biodrained of different tree species

	Wb	Height	DBH	LA	T(mean)	RH(mean)	VPD	WS	Rad	Ep
C. equisetifolia	1	0.366**	0.367**	0.816**	0.881**	-0.236	0.704**	0.786**	0.531**	0.809**
*E. tereticornis*C-10	1	0.269	0.339*	0.624**	0.902**	-0.363**	0.797**	0.802**	0.647**	0.906**
M. azedarach	1	0.232	0.343*	0.928**	0.869**	-0.258	0.719**	0.812**	0.536**	0.869**
P. juliflora	1	0.401**	0.396**	0.823**	0.861**	-0.103	0.719**	0.688**	0.399**	0.869**
T. arjuna	1	0.276	0.277	0.613**	0.750**	0.037	0.434**	0.645**	0.159	0.557**
Mean	1	0.309	0.344	0.761	0.853	0.199	0.675	0.747	0.454	0.802

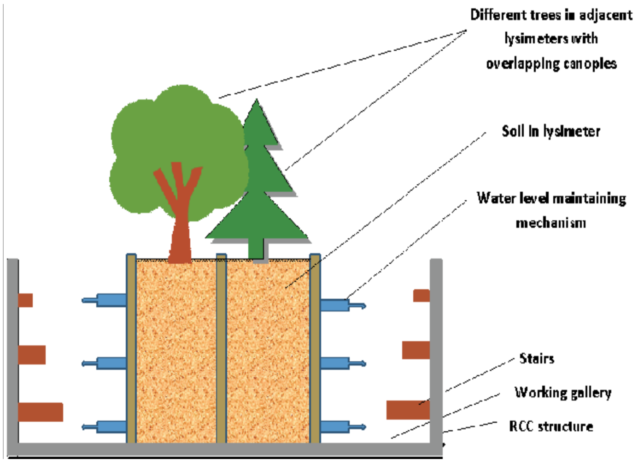

Figure 9: Cross section representation of conventional drainage-type lysimetric/microplot design showing two adjacent lysimeter rows and the working gallery. Note that in this case trees in adjacent lysimeters are different due to randomization and have variously overlapping canopies. The distance between the two rows as above shall also vary with the rows both on the left and right of the gallery (not shown)

rates of soil water drainage by the tree vegetation. High water content within a plant body will help to maintain its physiological balance under stress conditions when the transpiration rates are usually high (Thakar and Mishra, 2010).

Literature is replete with reports demonstrating increased transpiration or biodrainage with increasing leaf area in trees (Howard *et al.*, 1995; Chave *et al.*, 2005; Radersma *et al.*, 2006). Another point which needs to be highlighted is that, as also enumerated in the above paragraph, even when the leaf area is nearly zero due to deciduous nature of the tree it nevertheless continues to lose considerable water into the atmosphere 8.2 L d^{-1} in *M. azedarach* in early December and 12.3 L d^{-1} in *T. arjuna* in end April. This fact indicates that even in the absence of leaves, the tree branches lose considerable amount of water in winter as well as in summer. Wittmann and Pfanz (2008) reported that peridermal transpiration of stem of various deciduous trees lied in the range of 5 to 20 % of leaf transpiration. The water biodrained from different species at monthly intervals during August 2007 through 2009 is given (Fig. 6). For the sake of brevity only the main trends of biodrainage with different environmental factors are highlighted in text.

Temperature and Wb

A careful comparison of Fig. 6 with Fig. 3a shows that in general the Wb increased with increase in temperature (T) (maximum, minimum and mean) and decreased with decrease in T. The correlation coefficients (Table 1) between maximum, minimum and mean with all the five tree species are highly positively significant for mean T, respectively, indicating the domineering effect temperature has on transpiration or biodrainage. Thus, for example in case of *C. equisetifolia* when the maximum T was around 42°c in end May 2009, the Wb was 118.8 L d^{-1} and when the T was at a minimum low 3°c in early January month the Wb was 10 L d^{-1}. It is interesting to note that T *perse* maximum, minimum or mean has a dominant effect on Wb. Our observation are in accord with Zeppel *et al.* (2006) who reported minimal (< 1 mm/day) transpiration rates during winter in an evergreen *Callitris/Eucalyptus* woodland in southeast Australia showed as compared to very high (>3.5 mm/day) in summer. Even in some parts of the tropics, seasonal cycles in transpiration occur because of variations in rainfall, humidity and soil moisture.

Actual vapor pressure and Wb

A comparison of Fig. 6 and Fig. 3c reveals that an increase in the actual vapor pressure (Avp) (morning, evening and mean) had an increasing effect on Wb. These observations are further corroborated by the correlation coefficients (Table 1). Thus the range of Avp in five tree species was 0.66** to 0.79** in morning, 0.54** to 0.69** in evening and 0.61** to 0.74** in mean. It will be worthwhile to note here that the Avp morning values have a greater magnitude of positive correlation coefficients with Wb as compared to the evening Avp. Pallardy (2008) noted that the reason evaporation and transpiration increase with increasing temperature is because the vapor concentration of water in leaves increases more rapidly than that in the unsaturated air, not as is often erroneously supposed because the relative humidity decreases. Avp is one of the agrometeorological parameter recorded as such. It's derived form *i.e.* VPD is a much more useful indicator and is discussed under a subsequent head in this chapter.

Relative humidity and Wb

A careful consideration of Fig. 6 and Fig. 3b along with Table1 indicates relative humidity (RH) has a complex interaction with Wb. We shall first consider the fact that peak values of Wb both in May 2008 and 2009 in all the tree species are obtained when the mean RH during this period is at a low of about 25%. However, these trends are not maintained subsequently due to weird values of RH. Thus, RH is about 60 % during December 2008 (62.8) as well as in June 2009 (60.0). Therefore, correlation coefficients of RH morning, evening and mean vary from -0.26 to -0.67** in morning, -0.03 to 0.28 in evening and 0.04 to -0.36** in mean, respectively, in all the five tree species. The only consistent trend in this data is the negative correlation of RH morning with Wb which is understandable as barring the months of April and May, morning RH remains 70-95% resulting in low evapotranspiration. Based on their observations on road side trees of *Quercus myrsinifolia*, Huang *et al.,* (2010) also concluded that the influence of RH of air on the total amount of transpiration was not significant. Nevertheless, consideration of RH is extremely important. This is explained under the subsequent head of VPD.

Vapor pressure deficit and Wb

The data presented in Fig. 6 as compared with Fig. 3c considered along with correlation coefficient Table 1 clearly indicates that vapor pressure deficit (VPD) has consistent positive significant correlation in the range of 0.43** to 0.80** in different tree species. A straight forward consideration of factors like T, Avp and RH on Wb or evapotranspiration may be misleading on occasions due to the complex interaction of these factors with each other. Thus VPD is an upgrading over RH alone as the former takes into consideration of the water holding capacity of air which roughly doubles with every 11.4°C increase in T (Muller and Lambs 2009). Morris *et al.,* (2006) also found that day time transpiration in *Eucalyptus camaldulensis* trees at Pucca Anna, Pakistan was linearly correlated with VPD.

Wind speed and Wb

Episodes of high wind speed (WS) characteristically take place in the months of end April to end July (Fig. 8a). These periods are also characterized by high values of Wb (Fig. 6). These observations are further authenticated by the high positive correlation with WS and Wb in the range of 0.65** to 0.81** in the five tree species (Table1). Xu *et al.,* (2006) found that pan coefficient (ratio of evapotranspiration to pan evaporation) is significantly influenced by wind speed and relative humidity in the Changjiang (Yangtze River) catchment area of China. Higher values of the pan coefficient were found in the central area of the catchment with a relatively high humidity (as compared with the upper area) and a very low wind speed (as compared with other areas).

Radiation and Wb

It is seen from Fig. 8b that there is a considerable increase in the incident radiation (Rad**)** during the summer months of May and June when it was in the range of 3051-3089 J cm^{-2} d^{-1} and decrease in the month of mid December to January when it was in the range of 2253-2276 J cm^{-2} d^{-1}. Higher Rad by and large increases the T and vice-versa. The significant positive correlation of Rad with Wb (Fig. 6 and 8b) in the range of 0.16 to 0.65** (Table 1) further asserts these arguments. Huang *et al.,* (2010) found that transpiration of road side trees *Quercus myrsinifolia* was most significantly influenced by solar radiation or photosynthetically active radiation, followed by the leaf or air temperature. Our results on the role of Rad on transpiration or Wb assume significance in light of the hypothesis put forth by Pieruschka *et al*., (2010) who reexamined the transpiration based hydrological cycle and attributed a domineering role of radiation in the process of transpiration. They ruled out the current concepts of stomata-based control of transpiration. It was suggested there is a radiation controlled rate of vapor production in the leaf interior that governs transpiration. Thus unlike imposed evaporation where water vapor is pulled from a wet surface by a diffusion gradient, in equilibrium evaporation water vapor is pushed into the surrounding air by the input of heat.

Potential evaporation and Wb

Potential evaporation (Ep) is a measure of evaporation from the exposed water surface into the atmosphere encompasses all the afore discussed parameters like T, Avp, VPD, RH, Rad etc. that have a direct bearing on evapotranspiration or Wb. It is therefore not unexpected those higher values of Ep (Fig. 8c) coincide with Wb (Fig. 6) of different tree species. These trends are also confirmed by the significant positive correlation in the different lysimeter grown tree which is in the range of 0.56** to 0.91** (Table 1).

(LA: leaf area, T (mean): mean, maximum and minimum temperature, RH (mean): relative humidity maximum, minimum and mean, VPD: vapor pressure deficit, WS: wind speed, Rad: radiation, Ep: pan evaporation)

A novel lysimetric design

As mentioned in the Material and Methods the design of drainage type RCC (reinforced cement concrete) lysimeters used by (Chhabra and Thakur, 1998) was drastically modified in the present studies. The aforementioned RCC lysimeters are costly to fabricate and have the problem of narrow lysimeter-to-lysimeter space due to the presence of a common working gallery between rows or clusters of lysimeters (Fig. 9). Such structures are very suitable for low lying herbaceous plant canopies but not with trees where plant height is several meters and lateral expanse of the plants is also too much. Here, excessive tree to tree shading may impair growth and cause observational errors. For example if tree to tree spacing is to be kept 5 meters or even more (as in the present experimentation) the cemented working gallery has also to be extended causing exorbitant cost escalations. Further the RCC structure is liable to develop cracks which may cause leakage and are difficult to detect and repair. In the aforementioned background the present design of PVC based lysimeters with a provision of observation well (Fig. 2b) is a cheaper and more practical way of measuring tree water use. Here there is no need for skilled and costly RCC masonry. The number and spacing of lysimeters can be adjusted as per requirement without any additional expenditure. At CCS Haryana Agricultural University the cost of construction of the present PVC lysimeter was Rs 16000 per lysimeter. The same cost for 16 RCC lysimeter (Lysimeter to lysimeter distance 13 cm, gallery 74 cm wide) was Rs 25000 per lysimeter. This would nearly triple if tree-to-tree distance is 5*5 m alongwith a working gallery. Therefore it is concluded that present fabrication and testing of the soil-embedded PVC lysimeter with an observation well is a simple but well thought of innovative design as it permits flexible lysimeter to lysimeter spacing much desired in water use experimentation in trees.

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