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Preliminary evaluation of dew condensers and their use for tree seedling irrigation in Puerto Rico[1,2]

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ABSTRACT

Dew condensers have been proposed as a means to reduce drought mortality of tree seedlings in early stages of reforestation projects. We investigated the amount of dew condensate produced by locally constructed dew condensers, constructed with three different infrared emitting surfaces: standard polyethylene/ TiO_2 / $BaSO_4$ foil, thermoplastic polyolefin (TPO), and plastic coated with locally available Lanco Urethanizer™[8] roofing paint. All surfaces produced similar amounts of total dew condensate, typically ranging between 0.05 and 0.25 L/m²/night. However, the materials differed in the fraction of dew running off the surfaces, which represents the water available for tree seedlings. Highest runoff fractions were obtained

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with painted surfaces, followed by polyethylene and polyolefin surfaces, respectively. Considerably greater amounts of nightly dew condensate were observed during the winter than in summer, attributed to differences in night length and cloud cover. A commercially available dew condenser, the Groasis Waterboxx™, did not generate more than 0.04 L per night of runoff dew, due primarily to a small condenser surface area of < 0.2 m^2. A field study showed that 1 m^2 dew condensers maintained the root zone of mahogany seedlings at matric potentials > -60 kPa during dry spells. Overall, results indicated that passive dew condensers with condenser areas of 1 m^2 are capable of producing sufficient water for survival of small tree seedlings during drought periods.

Key words: reforestation, tree seedling drought mortality, tree seedling irrigation, dew condensers

RESUMEN

Evaluación preliminar de condensadores de rocío y su utilización para riego de plántulas de árboles en Puerto Rico

Los condensadores de rocío se han propuesto como mecanismo para proveer agua a plántulas de árboles en etapas iniciales de reforestación. Se investigó el potencial de condensadores de fabricación local para producir agua. Se compararon condensadores construidos con tres diferentes superficies emisoras en infrarrojo: lámina estándar de polietileno impregnado con TiO_2 y $BaSO_4$, poli-olefina termoplástica (TPO), y plástico recubierto con pintura Lanco Urethanizer™ disponible en ferreterías locales. Todas las superficies produjeron cantidades similares de condensado total de rocío, por lo general entre 0.05 y 0.25 L /m^2/noche. Sin embargo, los materiales variaron en la fracción del condensado escurrido desde las superficies, lo cual representa el agua disponible para las plántulas. Las fracciones de escorrentía más altas se obtuvieron con las superficies pintadas, seguido por las superficies de polietileno y de poli-olefina, respectivamente. Las cantidades de condensado durante el invierno fueron mayores que en verano, probablemente debido a noches más largas y menor nubosidad en invierno. Se evaluó el volumen de rocío (escorrentía) producido por un modelo comercial de condensador de rocío, el Groasis Waterboxx™. Este nunca superó 0.04 L por noche, atribuido principalmente a la pequeña área de superficie (< 0.2 m^2) del condensador. Un experimento de campo mostró que condensadores de rocío de 1 m^2 mantuvieron el potencial matricial de agua en la zona de raíces de plántulas de caoba en valores > -60 kPa durante periodos de sequía. En general, los resultados indicaron que los condensadores de rocío con áreas superficiales de 1 m^2 producen suficiente agua para la supervivencia de pequeñas plántulas de árboles.

Palabras clave: reforestación, mortalidad por sequía de plántulas de árboles, riego de plántulas de árboles, condensadores de rocío.

INTRODUCTION

Dew condensation based on passive radiative cooling has attracted worldwide attention over the past two decades as a means to enhance drinking water supplies in arid regions (Nilsson et al., 1994; Beysens et al., 2006; Muselli et al., 2009) and to reduce drought mortality of tree seedlings in reforestation projects (Nilsson et al., 1994; Liu et al., 2014; Tomaszkiewicz et al., 2017). Studies have indicated that on clear nights dew condensation rates ≥ 0.1 L/night are easily obtainable on condenser surfaces of 1 m^2, comparable to or exceeding minimum water demands of ≈ 0.05 L/day observed for small tree seedlings (Rajvanishi and Zende, 1991; Kumsopa et al., 1997; Mng'omba et al., 2011; Seldon, 2013).

Basically, a dew condenser consists of an upward facing water-impermeable surface with a high radiative emissivity in the 8-13 μm infrared band (the so-called atmospheric window), which is thermally insulated on its underside (Nilsson et al., 1994). A schematic cross sectional diagram is given in Figure 1. On clear nights, energy loss from the surface in form of infrared radiation cools the surface below the dew point, causing atmospheric water vapor to condense on the surface. The underlying insulation layer, which in the case of 5-cm thick styrofoam has a heat transfer coefficient of approximately 0.7 Watts/m^2/K (Nilsson et al., 1994), reduces conductive heat transfer to the back side of the condenser surface, thereby maximizing the cooling and condensation effect on the upper surface. Radiative heat transfer from the ground to the condenser can be reduced by covering the underside of the insulation layer with reflecting foil. Condensation can be maintained even for some time after sunrise, by using white surfaces with high reflectance that minimize solar heating (Nilsson et al., 1994; Beysens et al., 2007).

The radiating surface is usually inclined at about 30° relative to the horizontal, to facilitate runoff and collection of the condensed water. Convective heating of the radiating surface by wind can be a serious problem and is reduced by placing the insulated back side of

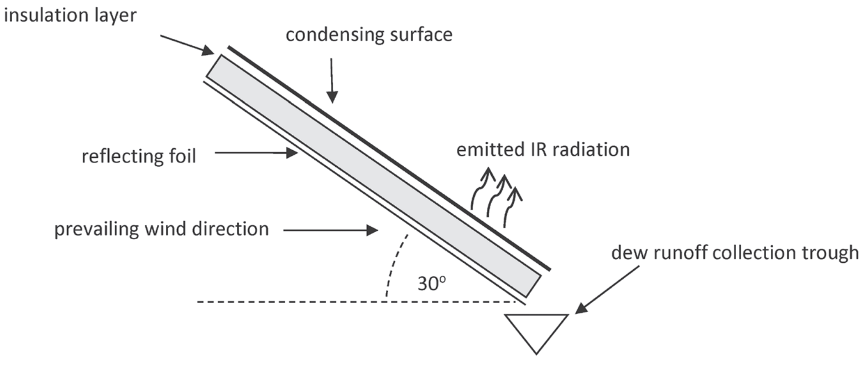

FIGURE 1. Schematic diagram (cross section) of a dew condenser

the condenser toward the prevailing wind, or by using cone shaped dew condensers which block wind coming from any direction. Photos of locally constructed planar and cone-shaped dew condensers are shown in Figures 2 and 3, respectively.

The theoretical maximum dew yield, based on the available radiative cooling power (25 to 100 W/m^2) and the latent heat of condensation of water (2,500 kJ/kg), is approximately 0.8 L/m^2/night (Clus et al., 2008; Muselli et al., 2009). Maximum amounts actually measured are approximately 0. 6 L/ m^2/night (Berkowicz et al., 1994; Muselli et al., 2009), with "typical" yields being generally lower, ranging between 0.1 to 0.3 L/m^2/ night (Beysens et al., 2006; Clus et al., 2008; Muselli et al., 2009). One of the major factors reducing dew yield is nocturnal cloud cover, which blocks the net loss of infrared radiant energy necessary for the cooling effect (Nilsson et al., 1994). Other determining factors are temperature, relative humidity, atmospheric transparency to infrared radiation, and convective and diffusive transport of atmospheric heat and moisture to the condenser surface (Nilsson et al., 1994; Beysens et al., 2006; Muselli et al., 2009). Shorter evening periods in the tropics and during summer months at high latitudes can reduce the time available for radiative cooling, but even then significant dew amounts have been observed (Berkowicz et al., 1994). Kidron (1999) observed a significant effect of altitude on dew condensation, with an increase of approximately 15 ml/m^2/night per 100 m increase in elevation above sea level.

Dew condensers also serve as rainfall collectors, translating each millimeter of rainfall into a volume of 1 L of water/m^2 of condenser surface. The combined effect of dew condensation and rainfall collection can be particularly useful in situations where very light rainfall events (< 1 mm) occur at night or in the early morning hours. If such small rainfall amounts were to occur on initially dry surfaces, most of the water would remain on the surfaces and evaporate the next day. However, if the surfaces are smooth and already wet from dew condensation, virtually all of the rainfall will run off, allowing its efficient collection and utilization.

Most research-grade dew condenser surfaces employ a standard white polyethylene foil impregnated with TiO_2 and $BaSO_4$, with an infrared emissivity in the 8 to 13 μm range of about 0.9. The material is manufactured and sold by the International Organization for Dew Utilization (OPUR), and has been described by Nilsson et al. (1994). If protected from direct ground heating by thermal insulation, it has a cooling power of about 50 W/m^2 (Beysens et al., 2007). A major limitation of the material is its high cost (on the order of US $10 to $15 per m^2). Our own experience has also indicated that within two or three months in tropical environments the material tends to degrade to a highly brittle state. Nilsson et al. (1994) have stressed the need to identify durable low cost infrared emitting materials for constructing practical dew condensers.

Commercially available dew condensers (Groasis Waterboxx, Aqua Pro Holland™) have recently been introduced for reforestation purposes. In these devices, the condenser surface overlies a water storage tank from which water is slowly released to the soil via a wick mechanism. Large excesses of rainwater are diverted off to the side of the storage tank by an overflow outlet, minimizing waterlogging in the root zone. Photos of the Waterboxx are shown in Figures 4 and 5. A limitation of the Waterboxx is its cost (on the order of US $30 per unit), which must be considered if the equipment is contemplated for large reforestation projects.

For dew condensers used in reforestation, an important design requirement is maximizing the amount of dew that actually runs off condenser surfaces, relative to that remaining on the surfaces in the form of water droplets. Muselli et al. (2009) found that often more than 50 percent of the total dew condensate was retained as droplets on standard OPUR condenser surfaces, even for surfaces sloped at a 30° angle. Full dew harvesting under such circumstances requires scraping the droplets off the surface early each morning before they can evaporate. However, daily scraping is impractical for large tree plantings in remote areas, requiring condenser designs that maximize the runoff fraction. The Groassis Waterboxx uses corrugated condenser surfaces coated with a super-hydrophobic material, which in principle facilitates runoff of water droplets (Miwa et al., 2000). However, the super-hydrophobic state tends to be metastable, giving way over time to a state where a greater fraction of the liquid is entrapped within surface irregularities (Beysens, 2006). It also appears uncertain whether super-hydrophobic conditions may reduce the rate of dew condensation. Beysens (2006) and Beysens et al. (2007) have recommended that condenser surfaces be highly wettable (hydrophilic) rather than hydrophobic, on grounds that this reduces the nucleation barrier for condensation, and furthermore promotes continuous water films facilitating runoff under gravity. More research appears necessary regarding surface properties maximizing both dew condensation and runoff.

In the Caribbean area, familiarity and experience with dew condensation technology appears to be nil, judging by the total lack of literature on using the technology in the area. Consequently, the first objective of this paper, already achieved above, is to provide a reasonably comprehensive review of the current state of the art in dew condensation technology. A second objective is to report results of preliminary research for developing low cost dew condensers with high runoff efficiency, constructed from materials available in local hardware stores. This paper describes two of our "home-made" condenser designs, and compares their performance relative to each other and to a standard condenser design reported in the literature, as well to a Groasis Waterboxx unit. A preliminary field study is described documenting effects of homemade dew condensers on the soil moisture regime in the root zone of mahogany (*Swietenia macrophylla* King) during a dry spell. Data on seasonal patterns of dew condensation are reported for the northern coastal city of San Juan, Puerto Rico.

The research was largely "hit-or-miss" in character, involving evaluation of many design options, of which only the most successful are reported here. Because of the large number of variables examined, comparisons usually involved only one or two replicate dew condensers per design. Limited or no replication is typical of many dew condenser comparisons reported in the literature (Muselli et al., 2006, 2009; Beysens et al., 2006, 2007; Sharan et al., 2007; Clus et al., 2008; Jacobs et al., 2008). Lack of extensive replication imparts a certain level of uncertainty to the reported results. However, this is largely counterbalanced if, as in the present study, all components used to construct dew condensers are industrially available materials with repeatable quality control standards. Further confidence is achieved if the dew condensers evaluated are fairly large (1 m^2 in surface area) and are evaluated over many successive nights, thereby integrating out small-scale spatial and temporal variability. By comparison, in the experimental measurement of rainfall, the usual practice is to install relatively small rain gauges (< 30 cm in diameter) and to use only one rain gauge (as opposed to many replicate gauges) at a given site. In the studies reported here, all except one of our experiments evaluated non-biological factors, thereby avoiding the high variability typically encountered in experiments with living organisms. The single experiment which did involve living organisms (mahogany seedlings) was replicated (n=3) thereby addressing statistical uncertainty. For these reasons, we consider that results reported here are at least indicative of the potential water production by dew condensers, and also serve to identify design and performance aspects which must be considered in future work.

MATERIALS AND METHODS

Design and construction of homemade dew condensers

We constructed both planar and cone shaped dew condensers, as shown in Figures 2 and 3, respectively.

Planar condensers

These were essentially square three-layer composites (as illustrated in Figure 2) with planar dimensions of 1 m on each side. The top

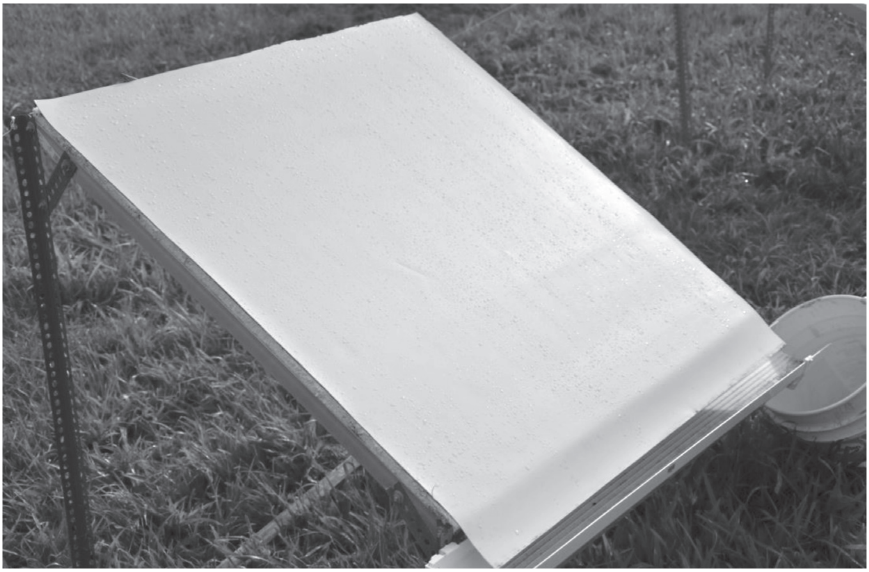

FIGURE 2. Planar dew condenser constructed and installed at the University of Puerto Rico Agricultural Experiment Station, Río Piedras, Puerto Rico.

layer was a sheet of infrared emitting plastic, overlying a layer of 5 cm thick insulation of rigid styrofoam (The Home Depot, Inc.) or else flexible polyurethane foam commonly used as padding in the furniture industry (American Plastics, Inc.). The insulation layer was covered on the underside with TekFoil™ (FarmTek, Inc.), which is basically a thin layer of polyethylene bubble insulation coated on one side with infrared reflecting aluminum foil. The TekFoil was placed with the bubble layer facing inwards (toward the insulation) and the reflecting foil facing downward. The purpose of the foil surface was to reflect infrared radiation originating from the ground surface, reducing the amount of heat reaching the insulation layer.

In our initial prototypes, the three layers of TekFoil, Styrofoam and infrared emitting plastic were glued together. However, they tended to become unglued over time. The need for glue was later overcome by placing the layers on a flat plywood or wire mesh surface bounded by a wood or metal frame, and clamping them together along the borders.

Three materials were tested as infrared emitting surfaces. The first was standard polyethylene foil impregnated with microspheres of TiO_2 and $BaSO_4$, manufactured specifically for dew condensation research by the International Organization for Dew Utilization (OPUR). The rated thermal emissivity of this material is approximately 0.91 (Nilsson et al.,

FIGURE 3. Cone shaped dew condenser surrounding a mahogany seedling at Corozal, Puerto Rico. The condenser surface is a 1-m^2 sheet of thermoplastic polyolephin (TPO), underlain by 5 cm of flexible polyurethane foam and a layer of reflecting Tek-Foil. The brown tape strip shows where the condenser can be opened up to allow placing it around a tree or removing it. The condenser is maintained upright by nylon cords leading from the condenser corners to stakes in the ground.

1994). The second material was a rubber roofing product coated with thermoplastic polyolefin (TPO), manufactured by Mulehide Corp. and distributed in Puerto Rico by Danosa, Inc. TPO has a rated emissivity of about 0.9, comparable to that of the OPUR foil. The third material was plastic coated with a locally manufactured roofing paint (Urethanizer™, Lanco, Inc.), containing ceramic microspheres and with a rated infrared emissivity of 0.87 when dry. Three consecutive coatings of this paint were applied to a rubber base (in this case the TPO roofing material from Danosa). The paint coats were brushed on by hand, using vertical brush strokes with the purpose of creating vertical "micro-channels" which would facilitate runoff from the painted surface once it was placed at a 30° angle.

Cone shaped dew condensers for tree seedling irrigation

Square dew condensers, with a surface area of 1 m^2, were constructed by gluing together layers of TPO, flexible polyurethane insulation and TekFoil. A 30° notch was cut into one side of the square, with the apex of the notch at the center of the square. The system was then placed around a tree seedling stem, with the stem at the notch apex, and the two sides of the notch were then drawn together and fastened with clamps and plastic tape, forming a cone-shaped dew condenser surrounding the seedling as shown in Figure 3.

Commercial dew condensers (Groasis Waterboxx)

Several Groasis Waterboxx units were purchased from the manufacturer (AquaPro Holland, Inc.). A photograph of one of these units, surrounding a tree seedling, is shown in Figure 4. A second photo (Figure 5) shows the Waterboxx placed sideways to illustrate the wick system protruding from the bottom of the storage tank. The effective surface area for dew condensation per unit was approximately 0.16 m^2. Insulation in Waterboxx units is achieved by an air pocket between the condensing surface and the water storage container.

Experimental Evaluation of Dew Condensers

Comparison of dew condensation with different infrared emitting surface materials

Two experiments were performed in an open space on grounds of the Agricultural Experiment Station, Río Piedras, Puerto Rico. The first study compared dew condensation by an unpainted TPO surface to condensation by a surface coated with Urethanizer paint. Duplicate condensers of each type were used in this study. The second experiment, during a different time period, compared condensation on the Urethanizer surface to that on standard OPUR polyethylene foil. Only one of each type of condenser was used in this study. In all cases the dew condensers were of the planar type (Figure 2), with a condensation area of 1 m^2. The experiments consisted of placing the respective condensers side by side under identical environmental conditions. Early in the morning after a given dew-producing night, the volume of dew water in the collection buckets was measured in a 500-ml graduated cylinder. This volume was recorded as “runoff dew”. Water remaining on the surface, termed “retained dew”, was then scraped off the condenser surfaces, and the corresponding volume was collected and measured in the graduated cylinder.

The above readings were only those occurring on rainless nights. Nightly rainfall was measured with a plastic graduated rain gauge installed at the site, and all dew condenser readings occurring on nights with measurable rainfall were discarded. As a further precaution against spurious results caused by overnight rainfall, any condenser runoff measurements > 400 ml/m^2/night were discarded. It was noticed that on some nights very light drizzles occurred which

FIGURE 4. Groassis Waterboxx dew condenser surrounding a tree seedling at the University of Puerto Rico Agricultural Experiment Station, Río Piedras, Puerto Rico.

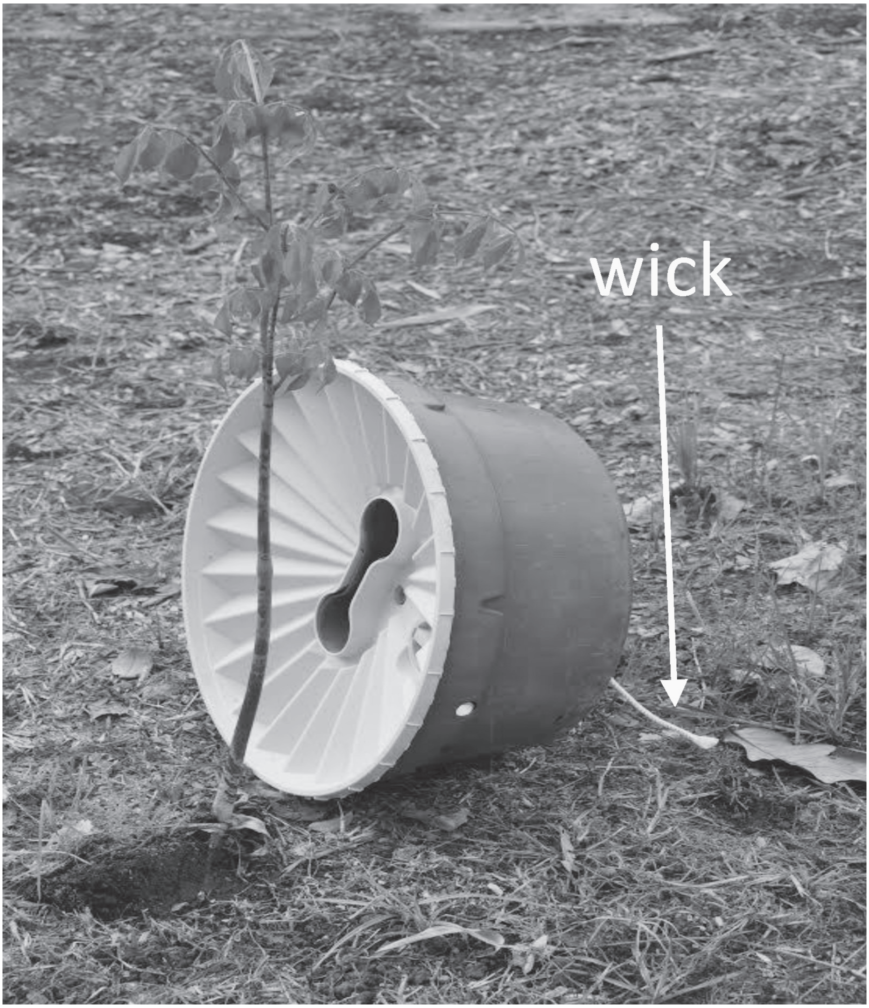

FIGURE 5. Groassis Waterboxx dew condenser placed on its side, showing wick (white cord on lower right) protruding from bottom of the water storage tank.

were not clearly reflected in rain-gauge readings, but nevertheless caused noticeable spikes in dew condenser runoff.

Comparison of runoff dew production by a Groassis Waterboxx and a planar condenser with Urethanizer paint surface

The two condensers were placed side by side in an open grassed area (Figure 6), and runoff dew produced on clear nights was measured during a period of three months.

FIGURE 6. Planar dew condenser (condensing area = 1 m^2) and Groassis Waterboxx (condensing area approximately 0.16 m^2) placed alongside each other for comparison of dew condensation.

Measurement of dew condensation as a function of time of year

In order to determine seasonal effects on the amount of dew condensed, daily measurements were made beginning 1 February 2010 and ending a year later on 30 September 2012. The condensers were the flat type, with Urethanizer-painted surfaces or TPO surfaces that had aged sufficiently under outdoor conditions to become as hydrophilic as the Urethanizer surfaces. For these surfaces most of the dew occurred as runoff dew, with only 30 to 40 ml/night retained on the condenser surface regardless of the total amount of dew produced. Measurements were performed at the same site at Río Piedras described previously.

Performance of conical dew condensers on soil moisture regime in root zone of mahogany seedlings

The effect of dew condensers on soil moisture regime was evaluated in a newly established plantation of mahogany (*Swietenia* spp.) at the Corozal experimental farm of the University of Puerto Rico Agricultural Experiment Station. The seedlings were approximately 60-cm tall at the time of the experiment. Condenser units were placed around the stems of three replicate seedlings (Figure 3). For these seedlings and three control seedlings surrounded by natural weed vegetation with no condensers, soil water matric potential sensors (model MPS-1, Decagon, Inc.) were installed in the 5- to 10-cm depth interval of the soil at a horizontal distance of 15 cm from the tree stems, and connected to Em-50 data loggers (Decagon, Inc.). Sensor readings were monitored continuously at hourly intervals for several months, paying particular attention to dry periods with little or no rainfall.

RESULTS AND DISCUSSION

Experiment 1. Comparison of dew condensation surfaces

In Figures 7 and 8, the total amount of dew condensation by TPO and OPUR foils are compared to condensation on painted surfaces. In both cases the data conformed to a simple linear homogeneous regression model, with a coefficient of determination (R^2) > 0.95. The slopes of the corresponding regression lines are near unity, indicating that both the TPO and OPUR surfaces produced essentially the same total amount of dew as the painted surface.

However, the three surfaces behaved differently in terms of the amounts of retained vs. runoff dew, with the magnitude of the differ-

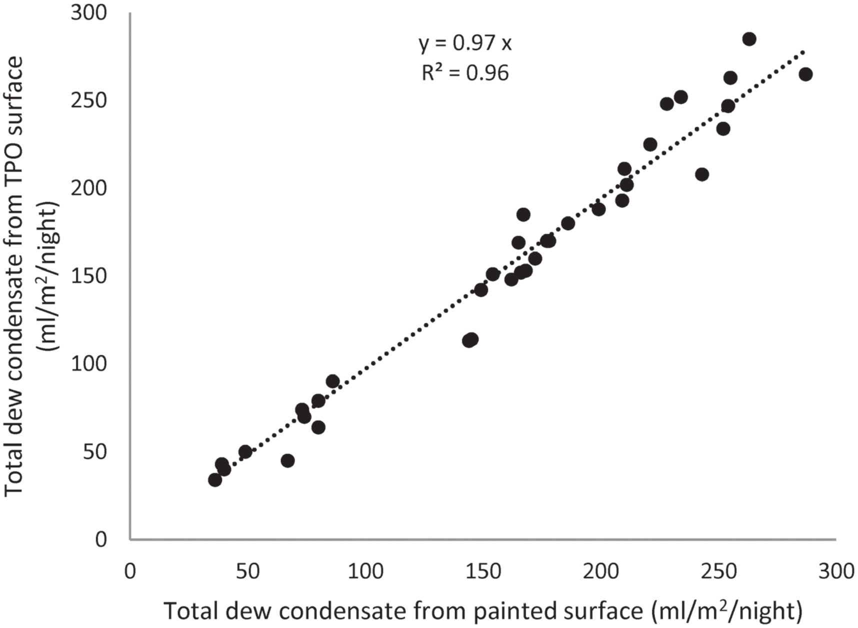

FIGURE 7. Comparison of total dew production by a TPO surface and a surface coated with Urethanizer paint.

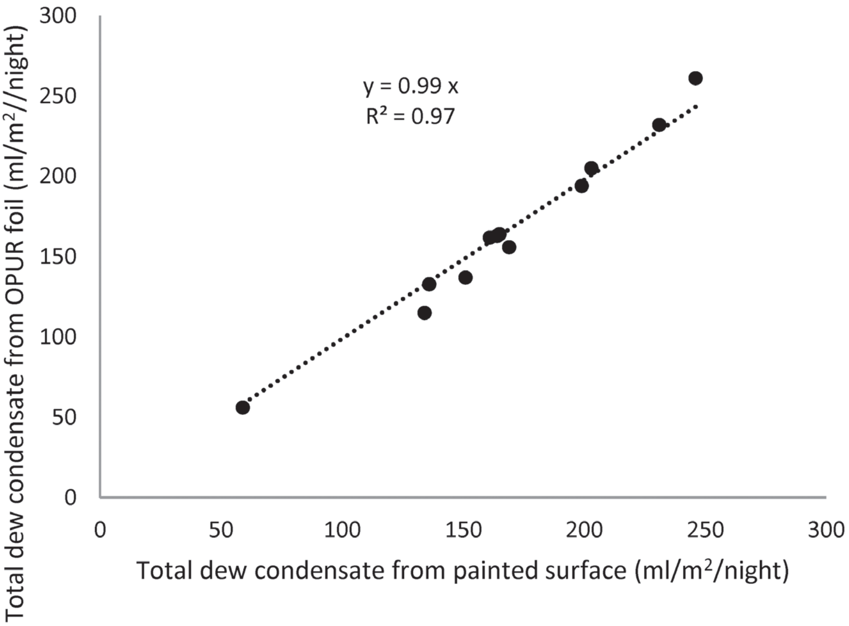

FIGURE 8. Comparison of total dew production by a standard OPUR foil surface and a surface coated with Urethanizer paint.

ences depending on the total volume of dew produced (Figure 9). All three surfaces produced similar high runoff fractions (approximately 0.8) for total dew production exceeding 200 ml/night. However, once total dew production dropped below approximately 200 ml/night, the runoff fractions for OPUR and TPO surfaces tended to decrease considerably with decreasing total dew production, whereas the runoff fraction for the painted surface remained high (in the range between 0.5 and 0.8). The rate of decrease of runoff fraction tended to be greater for TPO than for the OPUR surface.

We attribute these results to formation of continuous water films facilitating runoff on the more hydrophilic painted surface. In the case of the more hydrophobic TPO and OPUR surfaces, runoff presumably did not occur until the number of water droplets per unit area was sufficient to initiate rapid droplet coalescence, leading to a "cascading" effect and significant runoff.

Comparison of runoff dew produced by a painted planar dew condenser and a Groasis Waterboxx unit

Results for the comparison between painted planar dew condensers and the Groasis Waterboxx are shown in Figure 10. The data con-

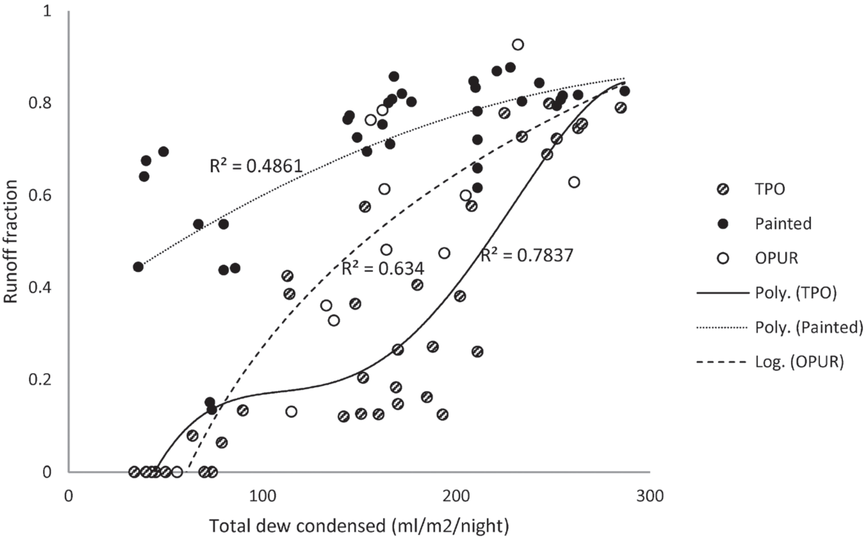

FIGURE 9. Fraction of runoff dew as a function of total dew condensed for TPO, OPUR and painted surfaces. The lines drawn through the data points are best-fit curves obtained from a menu of regression functions available in the Excel spreadsheet program. The curves are intended only as indicators of general trends.

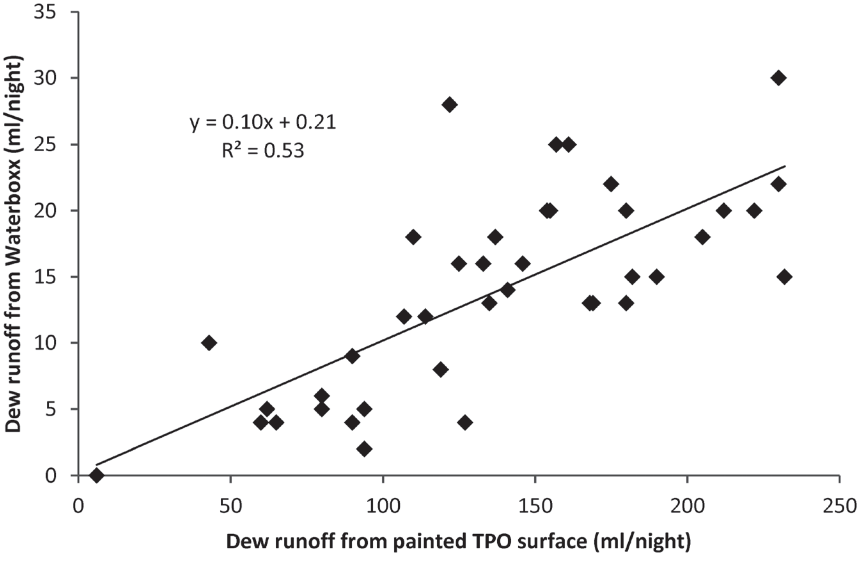

FIGURE 10. Comparison of runoff dew produced by a Groasis Waterboxx and a planar dew condenser coated with Lanco Urethanizer paint.

formed reasonably well to a linear homogeneous relation ($R^2 = 0.53$) with a regression coefficient of 0.10, indicating that the Waterboxx dew production was about 10 percent of that for the painted planar condenser. The maximum nightly amount of runoff dew produced by the Waterboxx was about 30 ml/night. This is near the minimum amount of irrigation water required for small tree seedlings to survive during rainless periods, even for efficient placement of irrigation water near the tree stem (Kumsopa et al., 1997; Seldon, 2013). The lower condensation by the Waterboxx relative to the painted surface was largely due to its low condensing surface area (0.16 m^2 relative to 1 m^2 for the painted surface). Therefore, the condensing surface area of the Waterboxx should probably be increased to ensure sufficient irrigation water in extremely arid environments with infrequent rainfall. The additional condensation area could, in principle, be achieved without significant cost or design alterations, by simply attaching condenser extensions to the sides of the Waterboxx.

Seasonal distribution of dew condensation at Río Piedras, Puerto Rico

Figure 11 shows the amount of runoff dew collected with painted dew condensers during the period 15 February to 15 September 2012, at the Río Piedras Research Center. Figure 12 shows pooled runoff data from both painted and TPO condensers collected on different dates

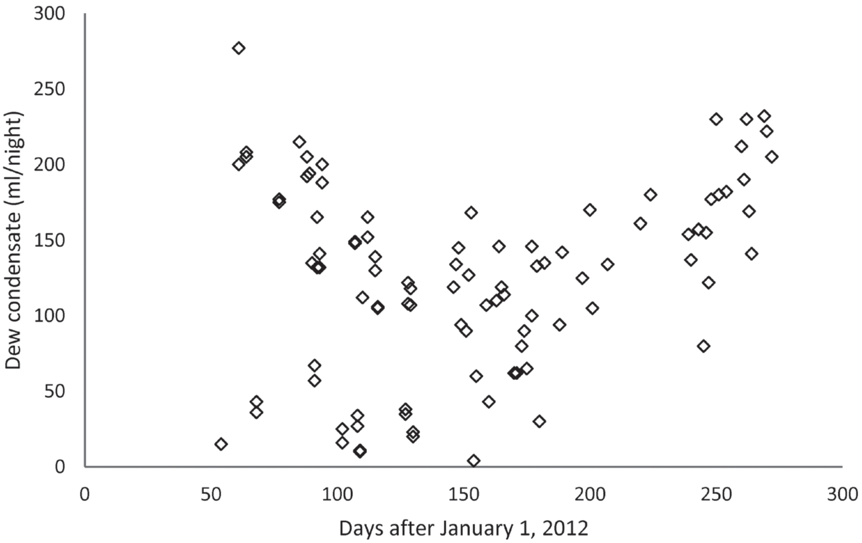

FIGURE 11. Runoff dew production by hydrophilic painted condensers, during the period 15 February – 15 September 2012.

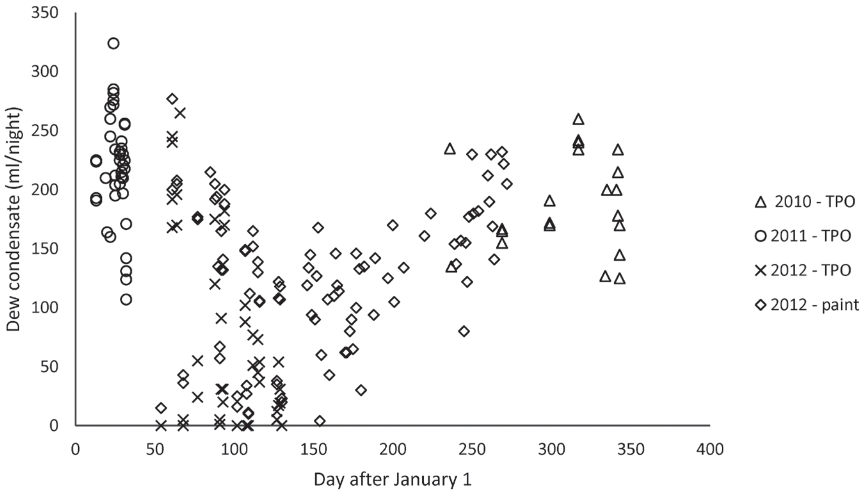

FIGURE 12. Pooled runoff dew production by painted and TPO condensers, during the period 2010 -2012.

during the period 2010 to 2012. All data points correspond to rainless nights; if even a small drizzle occurred, the data were discarded.

A strong seasonal effect is evident, with the greatest dew production occurring in the winter months and the lowest and most erratic production occurring between late spring and early fall. The most likely cause of the observed seasonal differences is that winter nights at Puerto Rico's latitude (18°N) are approximately two hours longer than summer nights, providing more time for radiative cooling and dew condensation. Another possible factor is greater cloud cover during the generally more humid summer nights. A cluster of very low runoff values is evident during the period between 50 and 139 days after 1 January, corresponding approximately to the period of 1 March through 15 May. Our best (and admittedly speculative) explanation for this is that, due to combined effects of increased nocturnal cloudiness and short nights, there was insufficient time for droplet coalescence so that much of the dew remained on the condenser and was therefore not measured.

Even during the summer months, the amount of dew frequently exceeded the critical value of 50 ml/night, which was cited above as an approximate irrigation threshold for survival of small tree seedlings. Furthermore, considerable rainfall (not reflected in the dew collection data) usually falls during this period. Therefore, dew condensation throughout the year appeared sufficient to insure the minimum water requirement for tree seedling survival.

Effect of dew condensers on soil moisture regime in the root zone of mahogany seedlings

Figure 13 shows soil water matric potential values in the root zone of mahogany seedlings with and without dew condensers, during a 40-day period at Corozal. Soil moisture was actually monitored over a full year, but rainfall during 2011 was unusually high, so that the longest period with significant dry spells was approximately 40 days. However, even during this short period of time significant treatment differences were observed. For all seedlings without dew condensers, average soil water matric potential values decreased to -150 kPa or lower at the peak of the dry periods. On the other hand, average matric potential for the dew condensers never dropped below about -50 kPa. It is possible that the higher soil moisture conditions under the dew condensers was attributable not only to condensed dew, but also to the condenser shading the soil which reduced evaporation.

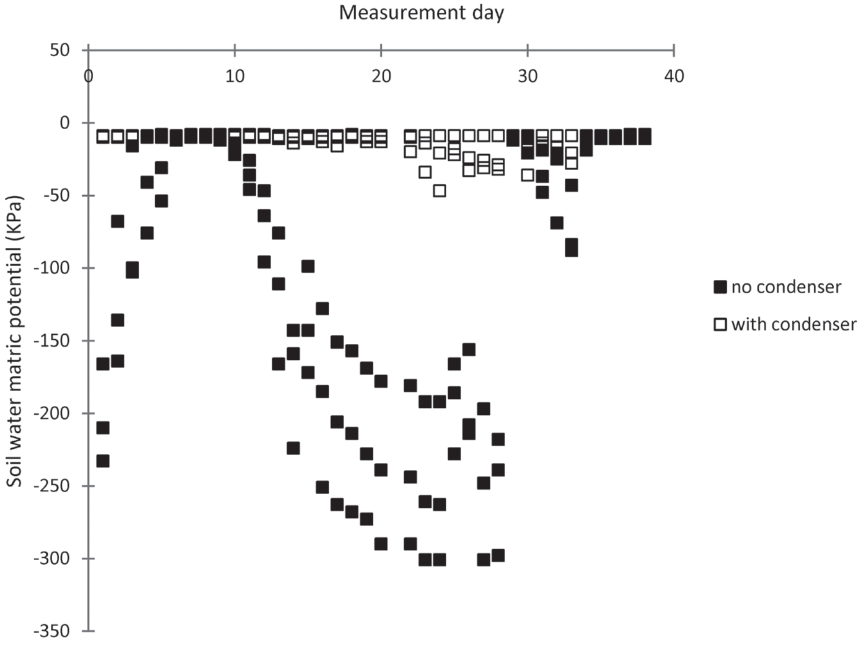

FIGURE 13. Soil water matric potential at 10-cm depth at 12:00 noon during a 40-day period in a young mahogany plantation, for seedlings surrounded by natural weed vegetation with and without dew condensers. Short rainfall periods occurred at about eight and 28 days, with the remaining days being rainless. Data points are for three replicate plots per treatment.

SUMMARY AND CONCLUSIONS

Dew condensers were constructed using three different condenser materials, and evaluated for dew production capacity and fractions of runoff dew. All produced similar amounts of total dew condensate, typically ranging between 0.05 and 0.25 L/night. However, the three materials differed considerably in the fraction of runoff dew. The highest fraction was obtained for surfaces coated with inexpensive Lanco Urethanizer paint, followed by the OPUR and TPO surfaces, respectively. Considerably greater amounts of nightly dew condensate were observed during the winter months, characterized by longer nights, than during the summer when nights are approximately two hours shorter.

A commercially available dew condenser, the Groasis Waterboxx^{TM}, was compared to the homemade painted dew condenser. The maximum observed condensation for the Waterboxx was about 0.04 L/night, which was considerably less than for the painted condenser, even after accounting for differences in surface area. This result indicated that even though the Waterboxx unit incorporates desirable qualities of ruggedness, portability and mechanisms for storage and slow release of water, its capacity for runoff dew generation needs to be improved. In principle, this could be achieved by simply attaching extensions to the existing dew condenser surface. A preliminary field experiment showed that dew condensers maintained the root zone of mahogany seedlings at matric potentials > -50 kPa during dry spells, versus control seedlings with no condensers where matric potential reached values < -150 kPa.

Overall, our results indicate that passive radiative dew condensers with condenser areas of 1 m^2 or less are capable of producing sufficient water for survival of small tree seedlings during rainless periods. This warrants further research aimed primarily at reducing costs and increasing condensation efficiency, and evaluating effects of dew condensers in the success of reforestation projects.

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