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Phytopumping Indices for Evapotranspiration Bed

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Abstract: This study reports a novel indices to define phytopumping capability of plant. The indices are attempted to select a suitable plant for evapotranspiration bed application. Non coastal and coastal plants, three species of each, were studied in simulated evapotranspiration beds under greenhouse conditions. Evapotranspiration, evaporation and plant dry weight were measured that were represented as Et/E ratio and Relative Growth Rate (RGR). All tested plants (spinach, peanut, elephant grass, calos, cattapa, citrus) were shown to perform Et/E of more than 1. High Et/E corresponding to high RGR was significantly shown for the first three plants. Low Et/E corresponding to low RGR was the characteristic of calos and cattapa. These facts explained that water was absorbed and used for plant tissue building. The last coastal plant citrus (*Morinda citrafolia*) was found having high Et/E that corresponded to low RGR. This represents the indices for real phytopumping of water and suitable for the application in evapotranspiration bed.

Key words: Et/E, RGR, plants, phytopumping, evapotranspiration bed

INTRODUCTION

Phytopumping is defined as the capacity of plants to absorb water through roots and transpire water through leaves that is driven by solar energy. An upward flow through plant roots as transpiration stream and evaporation (E) to the air are the process of evapotranspiration (Et). Thus Et is nothing less than plant-water consumption that includes stored water used by the plant for transpiration and tissue building in addition to evaporation from plant and field surfaces (Marlow, 1999). The level of phytopumping could be measured as transpiration factor which was expressed as Et/E. Aquatic plant such as water hyacinth was well known water absorber that performs Et/E of more than 1 (Gopal and Sharma, 1981; Mangkoedihardjo, 2006a). Unfortunately, phytopumping study for terrestrial plants was far behind the progress of phyto-treatment aiming to remediate polluted environment which has been carried out intensively (ITRC, 2001; Coleman *et al*., 2001; Olson and Fletcher, 2000; Yirong and Puetpaiboon, 2004). Terrestrial plants are definitely required in response to the implementation of on-site sanitation system using evapotranspiration bed.

Phytopumping is attempted to divert wastewater to the air and hence, groundwater pollution is minimized. In case of high ground water table, phytopumping is a paramount important, aiming to allow wastewater flows to the air. The high ground water table is usual characteristics of coastal area where the conditions become more complicated due to the soil is affected by sea salts. Particular conditions are in the three biggest coastal cities in Indonesia, i.e., Jakarta-Western Java, Semarang-Central Java and Surabaya-East Java where on-site sanitation is prioritized due to lack of land for the provision of central wastewater treatment. However, the sustainability of using plants in evapotranspiration bed has to be assured. A technical measure of plants sustainability is plant growth which is expressed as increasing of dry mass.

Therefore, the current study was carried out using terrestrial plants species with an aim to define a real capability of plant to pump water without affecting the growth and which plant is a real phytopumping for water. This study will be useful for selecting plants that are qualify for evapotranspiration bed, hence, support the implementation of household-centered sanitation and enhancing the global sanitation services.

MATERIALS AND METHODS

A greenhouse study was conducted during six months for terrestrial plants, consisting of coastal and non-coastal plants. Three evaporation beds were prepared, each of them made of a mixture of sand and healthy garden soil that were placed in PVC pot with diameter of 0.60 m that has surface area of 0.28 sq m. The three evaporation beds were water saturated, but not flooded, to simulate natural soil profile in rainy season. This was attempted to study the capacity of upward flow under the worst conditions as well as avoiding water limiting factor. Evapotranspiration beds were arranged similar to evaporation beds except plants were planted in the evapotranspiration beds.

The plants tested were three non-coastal plants consisted of spinach (*Amarantus tricolor*), peanut (*Arachis hypogaea*) and elephant grass (*Pennisetum purpureum*). Three coastal plants consisted of calos (*Calophyllum inophyllum*), cattapa (*Terminalia cattapa* L.) and citrus (*Morinda citrafolia*) were applied. There was no special objective of choosing the plant species except the plants are native, readily available and mostly used in the above mention cities. Addition of commercial fertilizer was applied in water instead of bed media to make the evapotranspiration bed was comparable with evaporation bed. Also, addition of sodium chloride salt (pa) of 5 g L^{-1} was applied in water to simulate coastal land characteristics.

Each evaporation bed and evapotranspiration bed was connected to a covered container, containing fixed volume of water in the range of 10 to 1000 L. Measurements of evaporation and evapotranspiration were based on the time of complete emptying of water in containers as a result of water loss due to evaporation and evapotranspiration, respectively. Water was used instead of raw wastewater because the real evapotranspiration bed is receiving treated wastewater from septic tank. The ratio of evapotranspiration and evaporation (Et/E) could be measured. It should be noted that E is water evaporation from field-free plant surface which is differ from water evaporation from leaf surface (Et).

Measurements of plant Dry Weight (DW) were carried out for each plant for known Wet Weight (WW) before running the experiments. The dry weight was measured gravimetrically (Caicedo *et al*., 2000; Mangkoedihardjo, 2006b) by means of drying in oven 80°C for three days until constant weight was achieved. These were aiming to determine a DW/WW ratio of each plant by which DW could be calculated based on measurement of WW for each day of complete evapotranspiration. The DW would be used to assess the relative growth rate of each plant.

RESULTS

Triplicate results of the experiment were presented in Table 1 and 2 for non coastal plants and coastal plants, respectively. During the experiment for more than one month, all tested plants were healthy and no negative symptom was shown. Evapotranspiration and evaporation were measured based on the process dues (day) for completely emptying a fixed volume of water (m^3) from separated container with a known surface area (m^2). Each was calculated as the flux of disappearing water (m^3 m^{-2} day^{-1}) and hence, the flux ratio of both represent the dimension less of Et/E. The process dues

Table 1: Evapotranspiration to evaporation ratio and dry weight of non coastal plants

Spinach			Peanut			Elephant grass		
Et/E	Process dues for Et (days)	DW (g)	Et/E	Process dues for Et (days)	DW (g)	Et/E	Process dues for Et (days)	DW (g)
-	0	5.6	-	0	5.3	-	0	3.2
1.00	3	6.0	1.00	3	7.9	1.50	2	3.7
1.17	6	6.7	1.40	5	14.0	1.40	5	9.4
1.10	10	10.0	1.22	9	23.1	1.38	8	15.0
1.07	14	15.6	1.15	13	38.2	1.25	12	26.2
1.06	18	23.4	1.19	16	51.0	1.19	16	42.3
1.10	21	35.6	1.15	20	60.9	1.21	19	54.1
1.08	24	53.4	1.18	22	73.2	1.24	21	64.0
1.11	27	60.1	1.20	25	76.1	1.30	23	67.7
1.17	29	64.5	1.26	27	82.2	1.31	26	73.4
1.12	33	65.7	1.23	30	85.2	1.32	28	77.1
RGR (day^{-1})		10.6			15.1			23.2

Table 2: Evapotranspiration to evaporation ratio and dry weight of coastal plants

Calos			Cattapa			Citrus		
Et/E	Process dues for Et (days)	DW (g)	Et/E	Process dues for Et (days)	DW (g)	Et/E	Process dues for Et (days)	DW (g)
-	0	4.8	-	0	5.0	-	0	6.4
1.00	3	5.7	1.00	3	5.3	1.00	3	6.5
1.20	5	7.3	1.20	5	5.8	1.50	4	7.3
1.43	7	11.3	1.25	8	9.0	1.43	7	10.2
1.30	10	16.9	1.18	11	16.1	1.44	9	15.8
1.21	14	24.6	1.13	15	24.3	1.55	11	25.1
1.25	16	37.6	1.11	18	36.4	1.54	13	43.6
1.28	18	54.5	1.15	20	52.9	1.53	15	60.6
1.29	21	67.6	1.13	24	66.5	1.59	17	66.9
1.30	23	75.5	1.11	27	67.5	1.58	19	68.9
1.26	27	77.1	1.10	31	68.2	1.62	21	71.3
RGR (day^{-1})		15.1			12.7			10.1

of more than one month resulted in various Et/E that were more than 1 for all tested plants. Time profile of plant dry weight was determined according to the process dues in completion of evapotranspiration for a given water volume. The plants dry weight for each process dues were treated to find out RGR that was calculated based on the increasing rate of dry weight over the initial dry weight. Statistical analysis resulted in significantly different ($p<0.5$) for each Et/E and RGR of all tested plants.

DISCUSSION

These fact were clearly explained that the test plants were able to absorb more water than the atmospheric absorption. Et/E ratios identified elephant grass and citrus were the most water absorbing species for non coastal and coastal plant respectively. However, the use of Et/E ratio of more than 1 (Gopal and Sharma, 1981) should be verified to be indicative measure for plant that is likely capable to pump water. Studies on water use index or water use efficiency by researchers revealed the absorbed water was partially used for forming dry mass. Therefore, time profile of plant dry weight, representing the Relative Growth Rate (RGR) for multi species, has to be assessed in conjunction with Et/E.

The results of Et/E in conjunction with RGR was shown a high Et/E was corresponding to high RGR for non coastal plants. Growth analysis was clearly shown that all tested plants were kinetically first order (Mangkoedihardjo, 2006b) and this revealed the absorbed water was primarily used for plant growth. The current study did not find non coastal plant species that performs water absorption for non growth requirement and hence, further study is necessary to the purpose.

The non coastal plants phenomena for Et/E and RGR were not shown for coastal plants. The lowest (or highest) Et/E was not related to the lowest (or highest) RGR. Among the three coastal plants species, interestingly citrus performed the highest Et/E which resulted in the lowest RGR. Therefore citrus could be classified as the real phytopumping for water-affected salt.

CONCLUSIONS

A general phenomena of phytopumping indices are high Et/E corresponding to high RGR and high Et/E corresponding to low RGR. Plants having real phytopumping capability would result in high ET/E and low RGR. Plant selection to qualify for the application of evapotranspiration bed could be assessed according to the real phytopumping indices. However, further study is needed to quantify the level of high Et/E in relation to the level of low RGR.

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