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# Evapotranspiration Rate of Lettuce (*Lactuca sativa* L., Asteraceae) in a Non-Circulating Hydroponics System

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**Abstract**

This paper analyzed how the evapotranspiration ($ET_c$) of lettuce in a non-circulating hydroponics system correlates with the reference crop evapotranspiration ($ET_o$) and the age of the plant. Regression analysis was carried out to determine the relationship between $ET_c$ with the $ET_o$ and the age of the plant. Fully developed and mature lettuce plants consumed much water, and the changes in climatic conditions also caused a significant change in water consumption during this stage of growth. The $ET_c$ of lettuce in non-circulating hydroponics correlates with the climatic condition and the age of the plant. Water demand for lettuce in non-circulating hydroponics is high at higher reference evapotranspiration and for mature plants.

**Keywords:** water demand, reference evapotranspiration, climatic condition, vegetable

## Introduction

Lettuce (*Lactuca sativa* L., Asteraceae) is a high-value vegetable grown in the Philippines and has been successfully raised in hydroponics system. In a non-circulating hydroponics system, the ideal practice is to prepare nutrient solution, poured at once to the growing box or container to supply the water requirement of the plants until harvest. The nutrient solution left in the growing box after harvest that is not suitable for re-use will be decanted and replaced with a new solution to start with a new planting batch. Freshwater scarcity necessitates the accurate utilization of water that would satisfy only the crop's irrigation requirement to reduce wastage due to excessive application of irrigation water. In hydroponics, irrigation requirement is only due to evapotranspiration. Thus, knowledge on crop's evapotranspiration is necessary to determine the crop's irrigation requirements at different growth stages and climatic condition. This paper analyzed how the actual evapotranspiration ($ET_c$) of lettuce in a non-circulating hydroponics system correlates with the reference crop evapotranspiration ($ET_o$) and the age of the plant. $ET_o$ is the evapotranspiration of a reference surface, a hypothetical grass reference crop with specific characteristics (FAO, 1998). The only factors affecting $ET_o$ are climatic parameters and thus, can be computed from weather data. The result of this study would help in optimizing the amount of irrigation water to be applied to lettuce plants in a non-circulating hydroponics system.

Several studies have been conducted to estimate the $ET_c$ of different crops. The crop coefficient approach calculates the $ET_c$ of a crop by multiplying the $ET_o$ by the crop coefficient ($K_c$) (FAO, 1998). $K_c$ factors of different crops have been developed in past studies such as those presented in British Columbia Ministry of Agriculture, Food and Fisheries (2001) and FAO (1998). The above approach estimates $ET_c$ under standard conditions viz. the crop is planted in the field or soil and is well-watered. Gallardo et al. (1996) developed a model to estimate $ET_c$ of crisphead lettuce planted in the soil using only

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$ET_o$ data as an input parameter.

$ET_c$ estimation using different approaches had been extensively studied in the past such as the crop coefficient approach and $ET_c$ models. However, the previous approaches are applicable only to crops that are planted in the soil. $ET_c$ of crops in a hydroponic production system has not been studied at length.

In this study, a field experiment is conducted to describe the evapotranspiration rate of lettuce in a non-circulating hydroponics system and to correlate the $ET_c$ of lettuce with the $ET_o$ and the age of the plant. The study is achieved by monitoring the daily mass of the growing boxes with lettuce plants in a non-circulating hydroponics system.

## Materials and Methods

### The Study Site

The study was conducted in the Philippine Rice Research Institute - Agusan Experiment Station (PhilRice-Agusan) in R.T. Romualdez, Agusan Del Norte, Philippines ($9^0$ 06' 00" N, $125^0$ 36' 00" E; 15m above MSL) from December 6, 2011 to January 8, 2012. The location was chosen because of the availability of the automatic weather station to monitor the daily climatic data throughout the duration of the study.

### The Hydroponics System

The study used the Simple Nutrient Addition Program (SNAP) hydroponics system, a non-circulating hydroponics system developed by the University of the Philippines - Los Baños College, Laguna and the Bureau of Agricultural Research of the Department of Agriculture (Santos and Ocampo, 2009). A UV-stabilized plastic having a thickness of 200 microns was provided as the protective roofing of the system.

The hydroponics system (Figure 1) was set-up close to the automatic weather station of PhilRice-Agusan with orientation on the north-south direction.

### The Experiment

A field experiment is designed to test the claim of the study. Two planting batches were conducted. Batch 1 and Batch 2 lettuce plants (Green Towers variety) were transplanted on December 5, 2011 and December 12, 2011, respectively. Each batch of the experiment utilized six styropor growing boxes having a planting area of 0.20 $m^2$ each. The planting density was 40 plants/$m^2$ (8 plants in every growing box). The experiment used the SNAP A and SNAP B liquid fertilizers for hydroponics developed by the University of the Philippines – Los Baños. The experimental set-up is shown in Figure 2.

### Data Gathering and Analysis

The climatic data was obtained through the automatic weather station. Each growing box was weighed daily (6AM and 6PM) using an electronic platform balance from transplanting until harvest to determine the $ET_c$. The $ET_o$ was calculated from climatic data using the Penman-Monteith equation (Allen et al., 1988) with an hourly time step calculation.

Correction was made to the weight of each growing box to exclude the weight of the plants in the computation of the amount of water lost through evapotranspiration using the formula:

$$W_{ci} = W_i - W_{pt} - \left(\frac{W_{ph} - W_{pt}}{N_d}\right) DAT \quad (1)$$

Where:

- $W_{ci}$ = corrected weight of each growing box in the $i$th day, g
- $W_i$ = measured weight of each growing box on the $i$th day after transplanting, g

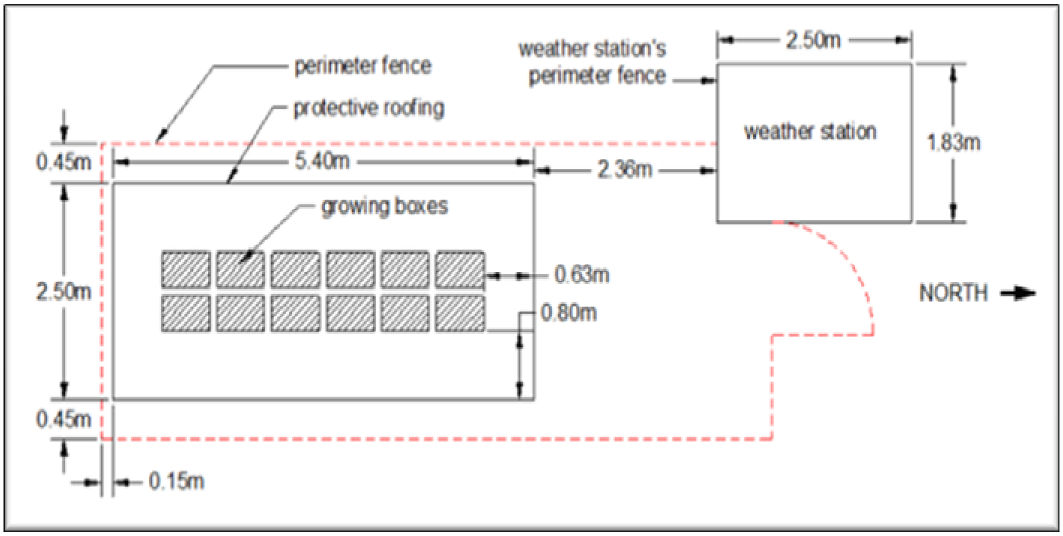


Figure 1: *Detail of the hydroponics system set-up.*

- $W_{pt}$ = total weight of the plants in a growing box during transplanting, g
- $W_{ph}$ = total weight of the plants in a growing box during harvest, g
- $N_d$ = number of days from transplanting to harvest
- $DAT$ = days after transplanting

The daily $ET_c$ of lettuce in each growing boxes was determined by applying the continuity equation,

$$\textit{change in storage} = \textit{inflow - outflow} \quad (2)$$

$$S_2 - S_1 = I_{added} - ET_c \quad (3)$$

Where:

- $S_1$ = corrected initial storage or weight of growing box (g)
- $S_2$ = corrected final storage or weight of growing box (g)
- $I_{added}$ = irrigation water or nutrient solution added (g)
- $ET_c$ = actual evapotranspiration of a growing box (g)

$ET_c$ in eqn. (3) was expressed as volume per unit planting area (L/m$^2$) by using the density of the nutrient solution assumed to be 1,000 g/L and the growing box' planting area (0.1988 m$^2$) which is equal to the surface area of the nutrient solution (Note: 1 L/m$^2$ = 1mm equivalent depth of water). Thus, from eqn. (3), $ET_c$ in L/m$^2$ (mm) is

$$ET_c = \frac{(I_{added} + S_1 - S_2)}{198.8} \quad (4)$$

Regression analysis was used to establish correlations between $ET_c$, $ET_o$ and $DAT$. The relationship between $ET_c$ with $ET_o$ and $DAT$ of hydroponic lettuce was partitioned into two growth stages in order to come up with a model that would closely fit with the actual data. In this study, 2 growth stages were considered as follows: a) Stage 1 (1-14 $DAT$) – this is the period when the plants have not yet came out of the styropor cup seedling plug, and b) Stage 2 (15-27 $DAT$) – this is the period where all the plants have already came out of the styropor cup seedling plug until full development and maturity.

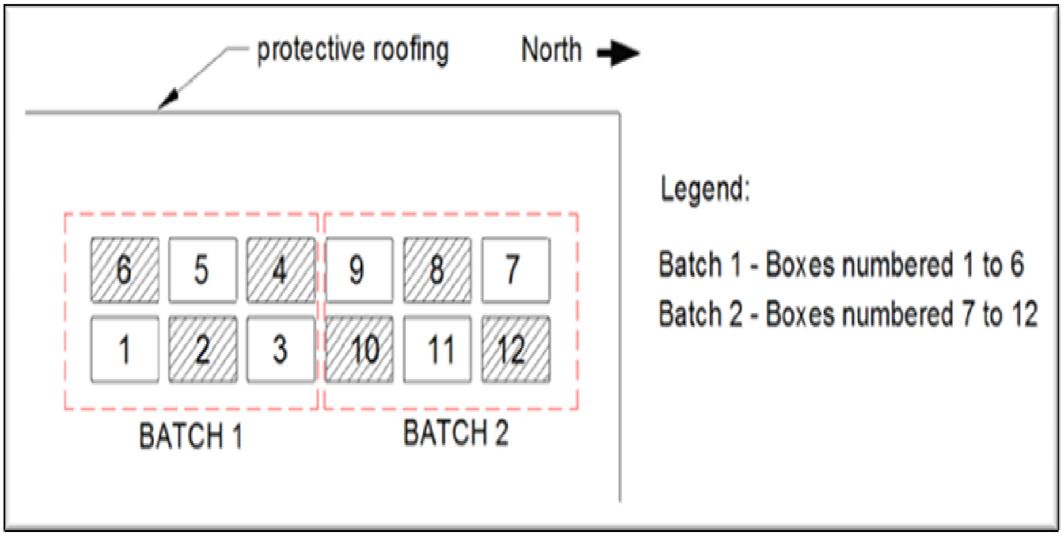


Figure 2: *Experimental set-up of the growing boxes.*

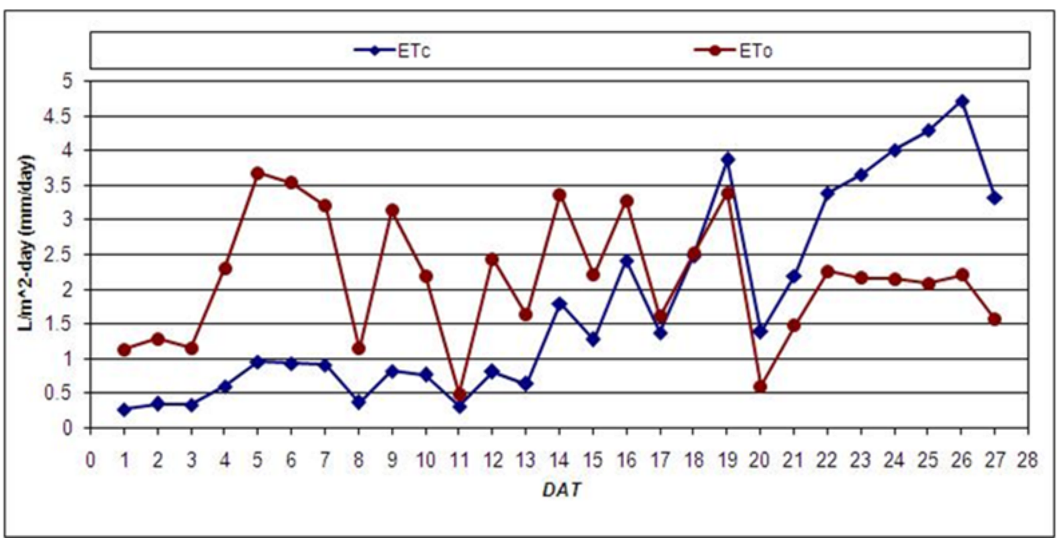


Figure 3: *Plot of observed $ET_c$ and $ET_o$ in Batch 1 experiment (December 6, 2011 – January 1, 2012).*

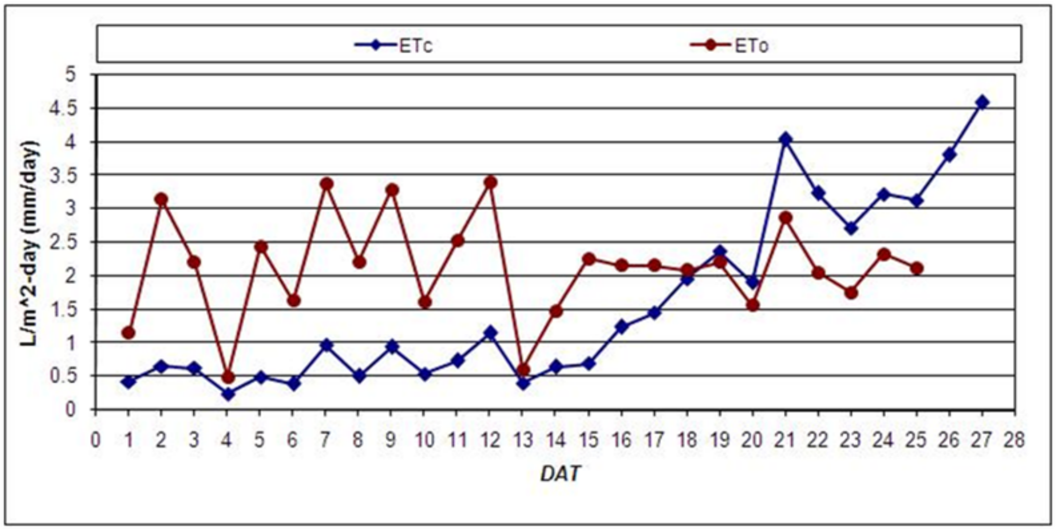


Figure 4: *Plot of observed $ET_c$ and $ET_o$ in Batch 2 experiment (December 13, 2011 – January 8, 2012).*

Table 1: $ET_c$ models of hydroponics lettuce (Green Towers variety) as a function of $DAT$ and $ET_o$.

| **Growth Stage** | **Model** | $\mathbf{R^2}$ | **Std. Error of Estimate** |
|---|---|---|---|
| Stage 1 (1-14 DAT) | $ET_c$ = -0.109 + 0.03$DAT$ + 0.256$ET_o$ | 0.77 | 0.163 |
| Stage 2 (15-27 DAT) | $ET_c$ = -5.420 + 0.287$DAT$ + 1.056$ET_o$ | 0.90 | 0.355 |

## Results and Discussion

Figures 3 and 4 show the plot of the $ET_c$ and $ET_o$ in the two batches of experiment. During the conduct of the study, the $ET_o$ calculated from climatic data (November 12, 2011 – January 5, 2012) ranges from 0.5 - 3.7 mm/day with an average of 2.3 mm/day. The figures reveal that at the early stage of growth of lettuce plants (DAT<14), the observed $ET_c$ in both batches of experiment is very low compared to the $ET_o$ while during the middle stage of growth and onward, the $ET_c$ was observed to goes up relative to the $ET_o$. The result suggests that during the early stage of growth when the plants are still small, the rate of water consumption is minimal and as the lettuce plants increased their size, the rate of water consumption also increased. This is in agreement with Jones (2005) who revealed that water lost by transpiration is affected as well by the ontogenetic age of the plant organ.

It can also be observed from the plots the pattern of the change of $ET_c$ as directly proportional to the change of $ET_o$. The result suggests that the $ET_c$ of lettuce in a non-circulating hydroponics can be estimated similar to the crop planted in the soil by crop coefficient approach provided that the $K_c$ is determined.

Table 1 shows the result of regression analysis establishing correlation between the $ET_c$ against the $ET_o$ and $DAT$. The result reveals that during the early growth stage (1-14 $DAT$) of the hydroponic lettuce, the water consumption (represented by $ET_c$) is not much affected by the age of the plant as well as by the changes of climatic conditions (represented by $ET_o$). On the other hand, during the second half of growing period of the hydroponic lettuce, one-day increase in age of the plant would cause to about more than a quarter increase in the water consumption. While every unit change of the $ET_o$ would cause a unit change also of the $ET_c$. The result suggests that the age of the plant influenced much on the water consumption. Fully developed and mature lettuce plants in hydroponics consumed much water and the changes in climatic conditions also caused the significant change of water consumption during this stage of growth.

## Conclusion

The actual evapotranspiration of lettuce in non-circulating hydroponics correlates with the climatic condition and the age of the plant. Water demand for lettuce in non-circulating hydroponics is high at higher reference evapotranspiration and for fully developed and mature plants.

## Acknowledgment

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