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Evapotranspiration and crop coefficient of oil palm (*Elaeis guineensis* Jacq.) on the main nursery in a greenhouse

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Abstract. The estimation of crop water requirement is an important part of oil palm plantation because fruit yield of oil palm can be affected by water stress. Evapotranspiration and crop coefficient of oil palm using Tenera variety at 7-12 months old was determined. Soil texture was sandy loam with 73.8 % sand, 10.8 % silt, 15.77 % clay and 1.41 % organic matter. The results showed that the oil palm getting older decreased significantly in bulk density, particle density and porosity of soil caused the root of oil palm enlarged (19.42 g to 53.37 g). This was indicated by increased the dry root weight. On the other hand, the value of evapotranspiration and crop coefficient increased significantly, that was 1.85 to 2.00 mm/day and 0.8 to 0.87 respectively.

1. Introduction

Nursery is the first step which determines for the successful planting of oil palm. The nursery stage requires big amounts of water and it is therefore important to choose a location with a sufficient water source for the nursery [1][2]. Crop water requirements are closely related to the rate of evapotranspiration. Evapotranspiration process is combination of two separate processes i.e evaporation and transpiration process. Water is lost from the soil surface by evaporation which mainly determined by the fraction of solar radiation approaching the soil surface. This fraction decreases over the growing period as the crop develops and the crop canopy shades more and more of the ground area. On the other hand, water is lost from the crop by transpiration which is the vaporization of liquid water contained in plant tissues and the vapour removal to the atmosphere through stomata. When the crop is small, water is predominately lost by soil evaporation, but once the crop is well developed and completely covers the soil, transpiration becomes the main process. During the early stages of the crop a high population planting would normally require somewhat more water than low density planting due to quicker development of full ground cover. In irrigated agriculture plant population has been considered of little importance in terms of total water needs.

The rate of evapotranspiration is not easy to measure. Specific devices and accurate measurements of various physical parameters or the soil water balance in lysimeters are required to determine evapotranspiration. The methods are often expensive, demanding in terms of accuracy of measurement and can only be fully exploited by well-trained research personnel. Although the methods are inappropriate for routine measurements, they remain important for the evaluation of evapotranspiration estimates obtained by more indirect methods. To account for the effect of the crop characteristics on crop water requirements, crop coefficients (K_c) are presented to relate ET_o to crop evapotranspiration (ET_c). The K_c value relates to evapotranspiration of a disease-free crop grown in large fields under optimum soil water and fertility conditions and achieving full production potential under the given growing environment. This study aims to determined crop evapotranspiration and crop coefficient of oil palm with Pan Method.

2. Materials and Methods

2.1 Experimental design

The experiment was conducted in a greenhouse located in the experimental area of Agricultural Faculty, Universitas Sumatera Utara, Medan, Indonesia. Soil (Entisols type) was of sandy loam texture with percentages of sand, silt and clay of 73.8, 10.43 and 15.77 %, respectively, with 1.406 % soil organic matter, in polybag 21 cm diameter, 30 cm height and 22 cm soil height. Thirty-five polybag oil palm Tenera variety at 7 months old from Indonesian Oil Palm Research Institute (IOPRI) was used. The water requirements of the plants were filled by providing irrigation water on each plant manually with the same water volume that aims to fulfil the field capacity of the soil (36.79±1.54 % soil water content) and evapotranspiration. Provision of water is done periodically in accordance with the needs of water plants. Percolation (mm day^{-1}) was calculated by the ratio of water height (mm) to water moving time (day) for knowing water moving downward and through the soil horizons by the gravitational process for each month. Also, the wet roots weight (g) and dry roots weight (g) were determined as an indicator of water in the roots.

2.2 Calculation of crop evapotranspiration rate (ET)

Crop evapotranspiration rate (ET_c, mm day^{-1}) was determined according to volumetric soil moisture (Eq. 1), where θ represent volumetric soil moisture (%), h is soil depth (cm) and t is time (day).

$$ET_c = \frac{1}{2}\frac{\theta h}{t} \quad (1)$$

Volumetric soil moisture (θ, %) was calculated using Eq. 2, where M_c represent soil water content in dry basis (%), ρ_s is bulk density of soil (g cm^{-3}) and ρ_w is water density (1 gr cm^{-3}). The soil water content was determined by the conventional method using a standard hot air oven with a temperature setting 105 ^oC and a drying time of 24 h. On the other hand, soil bulk density (ρ_s, g cm^{-3}) was calculated by the ratio of dry soil weight (g) to soil volume (ring volume, 100.08 cm^{-3}). The experiment was repeated three times.

$$\theta = \frac{M_c \rho_s}{\rho_w} \quad (2)$$

2.3 Calculation of crop coefficient K_c

Crop coefficient (K_c, -) is defined as the ratio of the crop evapotranspiration to the reference evapotranspiration (ET_o, mm day^{-1}) according to pan evaporation method with class A type as described by Eq. 3. The average of reference crop evapotranspiration (ET_o) was 2.3 mm day^{-1}. This value was determined according to potential evaporation with pan evaporation method which was measured every day under 29.29 to 29.87 ^oC as a daily temperature. Every month crop evapotranspiration and crop coefficient were calculated in six months.

$$K_c = \frac{ET_c}{ET_o} \tag{3}$$

3. Results and *discussion*

The average of soil water content (M_c,% in d.b), soil bulk density (g cm^{-3}), crop evapotranspiration (ET_c, mm day^{-1}) and crop coefficient (K_c, -) for each month were determined as shown at Table 1. Based on Table 1 that soil moisture content increase with growing age of oil palm due to increasing water requirement as shown by crop evapotranspiration. Oil palm. A plant has different water needs at different stages of growth, crop type and evaporative demand [3-4]. Young plant requires less water than when it is in the reproductive stage and water needs drops when approaches maturity. For good plant growth, a soil must have adequate room for water and air movement, and for root growth [4]. According to [5] the effect of soil water content on evapotranspiration varies with crop and is conditioned primarily by type of soils and water holding characteristics, crop rooting characteristics and the meteorological factors determining the level of transpiration. Entisols soil type with sandy loam texture was used in this study. Sandy loam soils are capable of quickly draining excess water but can not hold significant amounts of water or nutrients for crops. Crops grown in this type of soil will require more frequent irrigation and fertilization than soils with a higher concentration of clay and sediment.

Table 1. The values of soil water content, soil bulk density, crop evapotranspiration and crop coefficient in different age of oil palm

Age of oil palm (Month)	Average of soil water content (%)	Average soil bulk density (g cm^{-3})	Crop Evapotranspiration (mm day^{-1})	Crop coefficient (-)
7	11.82	0.998	1.85	0.80
8	11.98	0.994	1.87	0.81
9	12.32	0.989	1.01	0.83
10	12.62	0.978	1.94	0.84
11	12.95	0.968	1.96	0.85
12	13.33	0.959	2.00	0.87

ET_c will be reduced if the rate of water supply to the roots is unable to cope with transpiration losses. This will be more pronounced in heavy textured than in light textured soils. Since reduction in evapotranspiration affects crop growth and/or crop yields, timing and magnitude of reduction in ET crop are important criteria for irrigation practices. Following an irrigation the crop will transpire at the predicted rate during the days immediately following irrigation. With time the soils become drier and the rate will decrease, more so under high as compared to low evaporative conditions. Whether or not the reduction in ETc is permissible during part or whole growing season can be determined only when the effect of soil water stress on yield during various stages of growth is known. The predicted ETc values should be applied unless specific objectives are pursued such as assuring that the greatest number of farmers benefit from irrigation or maximising yield per unit of water when available water supply is the limiting factor. However, available soil water has a balancing effect in meeting short duration, high ETc values; this effect is smaller for shallow, light soils than for deep, fine textured soils. Available soil water should therefore be considered. This calculation is usually done for months of peak water use.

Table 2 shows that percolation decreased with growing age of oil palm while wet and dry weight increased due to amount of water in root increased. Difference of percolation related to porosity of soil. Growing age of oil palm porosity decreases because of rootzone increases indicating with dry root weight increased (Table 2). This affects to the power of passing water to be smaller and the ability of soil to hold water stronger so that percolation is reduced. The big difference in percolation is also due to the water requirement of plants at the age of 12 months is greater due to larger plant size. So giving the same amount of water results in less unused water and is wasted through the percolation process. Water delivery should be given according to the needs of plant evapotranspiration, which is determined at the rate of growth and weather conditions.

Table 2. The values of percolation, wet root weight, dry root weight and amount of water in the root in different age oil palm

Age of oil palm (Month)	Percolation (mm day^{-1})	Average of wet root weight (g)	Average dry root weight (g)	Amount of water in the root (g)
7	1.8	85.69	19.42	66.27
8	1.54	99.49	25.96	73.53
9	1.23	129.21	36.38	92.83
10	1.04	137.90	41.33	96.57
11	0.83	143.89	45.33	98.56
12	0.54	190.36	63.37	126.99

4. Conclusions
The oil palm getting older decreased significantly in bulk density, particle density and porosity of soil caused the root of oil palm enlarged (19.42 g to 53.37 g). This was indicated by increased the dry root weight. On the other hand, the value of evapotranspiration and crop coefficient increased significantly, that was 1.85 to 2.00 mm/day and 0.8 to 0.87 respectively. The predicted ETc values should be applied unless specific objectives are pursued such as assuring that the greatest number of farmers benefit from irrigation or maximising yield per unit of water when available water supply is the limiting factor.

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