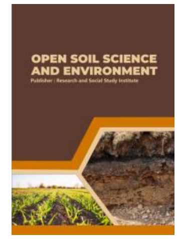
Open Soil Science and Environment 01 (01): 15-28 2022

Contents lists available at openscie.com

Open Soil Science and Environment

Journal homepage: https://soilenvironment.com



Determination of Kc Value of Pineapple Plants (*Ananas comusus*) at Different Ages and Different Types of Seeds

Lia Agustin[1], Sugeng Prijono[1], Pandu Risantyo[2]

[1] Department of Agrotechnology, Faculty of Agriculture, UniversityBrawijaya, Indonesia
[2]Research and Development Pineapple, PT. Great Giant Pineapple, Indonesia

*Correspondence: E-mail: liaagustin208@gmail.com

ARTICLE INFO

Article History:
Received 09 August 2022
Revised 18 August 2022
Accepted 22 August 2022
Published 5 September 2022

Keywords:
Evapotranspiration,
Kc,
Pineapple Plant,
Seed Types.

ABSTRACT

Pineapple plants are plants that are able to adapt in areas that have relatively low rainfall, but lack of water in pineapple plants will also cause pineapple growth. The currently available Kc value for pineapple is supported by data owned by FAO with 0.35 grass cover and 0.15 without cover. This research was conducted from January to May 2020 at the Research Location of PT. Great Giant Pineapple Central Lampung. This study used experimental methods and field observations to analyze data to determine the rate of evapotranspiration of GP3 pineapple plants and the age of 1-4 months. Based on the research that has been done, the Kc value of pineapple plants in the treatment of small, medium, large and small crown sucker seedlings was not significantly different. In pineapple plants aged 1-3 BST, The Kc value of pineapple plants tended to be the same, namely 0.45 and decreased at the age of 4BST, namely 0.35. from the Kc value of the plant that has been obtained.

1. Introduction

Pineapple plants are plants that are able to adapt in areas that have relatively low rainfall, but lack of water in pineapple plants will also cause the pineapple growth period to be longer and the weight of the fruit produced tends to decrease (Bartholomeuw et al., 2002). So that pineapple plants need to be given water according to their needs. The need for irrigation water as a whole needs to be known because it is one of the important stages needed in planning and managing irrigation systems.

Plant water needs are water needed by plants to meet evapotranspiration and other needs. The evapotranspiration value that ranges >99% indicates that all water requirements can be considered the same as evapotranspiration (ET) (Rosadi, 2012). When available groundwater is sufficient for plant water requirements, maximum evapotranspiration (ETm) occurs, but if available groundwater is reduced or cannot fully meet plant water requirements, plants will experience water stress and decrease the rate of evapotranspiration (Priyonugroho, 2014).

Evapotranspiration is a combination of evaporation and transpiration processes. Evaporation is the event that water becomes steam rising into the air and takes place continuously from the water surface, land surface, grasslands, rice fields, forests and others, while transpiration is the event of the movement of water from the soil to the atmosphere through roots, stems and leaves (Gani et al., 2019). Evapotranspiration is the amount of water lost by evaporation from the surface. Plants will grow optimally if the plant's evapotranspiration is met and there are no disturbances from other factors (Sapei and Fauzan, 2012).To be able to determine the rate of evapotranspiration, you must first know the coefficient ofplantpineapple (Kc). So the magnitude of the pineapple plant evapotranspiration rate can be determined. The rate of evapotranspiration of pineapple plants is used to determine the water needs of pineapple plants.

The value of potential evapotranspiration is directly proportional to the plant coefficient (Kc) (Sosrodarsono and Takeda, 2006). The currently available Kc value for pineapple is supported by data owned by FAO with 0.35 grass cover and 0.15 without cover. However, with the different types of plant vegetative age and various types of seeds owned by PT. GGP, so It is necessary to research the value of Kc in various types of seeds in order to provide appropriate water requirements at each age of the plant with different types of seeds.

2. Methods

This research was conducted from January to May 2020 at the Research Location of PT. Great Giant Pineapple, Terbanggi Besar District, Central Lampung, Lampung Province. Plants whose Kc value will be calculated will be placed in a closed place such as an artificial glass house which is covered with an ultraviolet plastic roof and the walls are lined with *paranet* so that the plants are not much influenced by environmental factors other than sunlight. Soil analysis was carried out at the Soil and Plants Laboratory of PT. Great Giant Pineapple Central Lampung.

This study used experimental methods and field observations to analyze data to determine the rate of evapotranspiration of GP3 pineapple plants and the age of 1-4 months. By the location and number of seeds used, then this research is a laboratory scale research. Observations were made every day until one month after planting. Observations include measuring soil evaporation measured using a *pan evaporimeter*, plant transpiration with lysimeter weighing method, and measurement of environmental temperature observations as supporting data for evapotranspiration. Observations were made at intervals1 time per week.The following is a schematic of the weigh lysimeter that will be used:

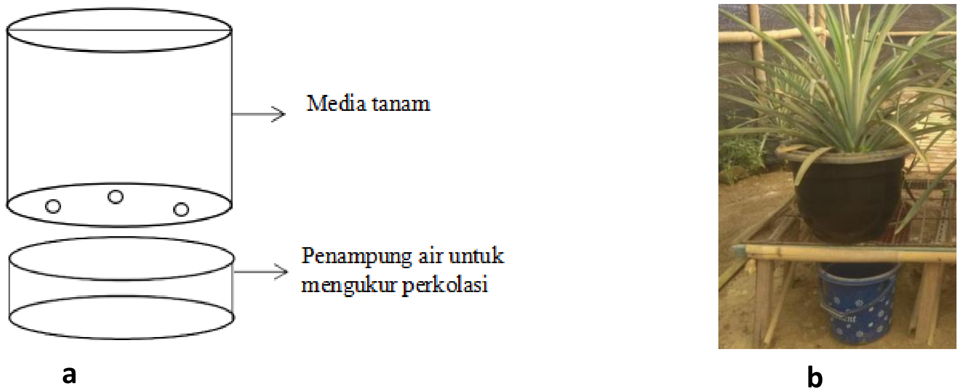


Figure. 1.a. Weigh lysimeter model design, b. lysimeter weigh used during research

Preparation of planting media

The planting media used in this study was an ultisol type which was sieved using a 2cm sieve and then re-sieved with an 8mm sieve. The soil used weighs 30 kg and is put into a pot for the size of the soil.

Preparation of pineapple seeds

Pineapple plant seeds with small crown, large sucker, medium sucker, and small sucker Clone GP3. Pineapple seeds sourced from the research location of PT. GGP. The small crown seeds are taken from the pineapple crown when harvest process. Meanwhile, small, medium and large sucker seedlings were taken from pineapple plants which were prepared for sucker harvesting. The size of the sucker seedlings was selected using a sucker seed gauge.

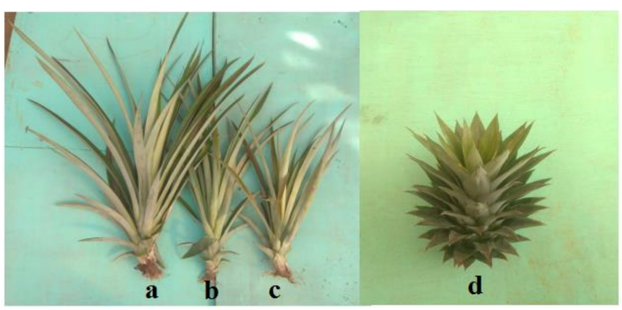


Figure 2. Seed class used in the study (a. big sucker, b. medium sucker, c. small sucker, d. small crown)

In this study, the criteria for small sucker seedlings used had a diameter of 2.9-3.4cm and a weight of 151-200g, while the criteria for medium sucker seedlings had a diameter of 3.9-4.2cm and a weight of 276-350g. The criteria for large sucker seeds are 4.8-5.3cm in diameter and 451-575g in weight. In small crown seedlings, the criteria for seedling length are 15-17cm and weight is 151-200g.

Determination of plant water supply during the experiment

Givingirrigation water on each plant is manually adjusted to the volume of water lost as long as there is each pot. Provision of water is carried out periodically but still takes into account the state of the soil in field conditions by measuring soil water content using a Moisture Probe Meter (MPM).

Picture1.Moisture Probe Meter (MPM) tool.

Weighing method

The weighing of the pots was carried out using a digital scale with an accuracy of 200 grams. Weighing of pots is done once every 7 days for 4 full months. In the control treatment, weighing was carried out only on pots containing soil without plants. DataThe observations taken were climatic data (air temperature, relative humidity, wind speed,intensity of solar radiation) irrigation water data, soil water content, and the amount of evaporation of plants with planting media (ETc). While the monthly data taken are data on length, width, D-leaf index of plants and leaf color of pineapple plants.

Measurement method

PWeighing of plants and growing media was carried out simultaneously usingscales. Weighing is done every 7 days to determine the interval of changes in plant weight after watering.Determination of water that is watered every day to reach field capacity is to add water to the amount of water lost every day.

Water loss analysis

The method of determining plant evapotranspiration is carried out using the following formula:

$$ETc = B2-B1$$

Where is ETcis E plant vapotranspiration (mm), B1 is the initial weight of the pot and B2 is the final weight of the pot. Provision of water only comes from irrigation so that rainfall is considered 0 or non-existent.

Calculation of crop coefficient

Determine the plant coefficient by using the lysimeter weigh method. The ETo value was obtained from the evaporation measured by the dick pot without the plant, while the ETo value was calculated by weighing the weight of the plant with the planting medium after adding 6000 ml of water (water given / irrigation) and left for one week for further weighing. Determination of the value of Kc is done by using the formula:

$ETC = Kc \times ETo$

Or

$Kc = ETc/Eto$

Where ETc is plant evapotranspiration (mm/day), ETo is evaporation constant / reference plant(mm/day), Kc is plant coefficient. ETo was obtained from the amount of evaporation in the control treatment without plants. The ETc value was obtained from the evaporation rate of each treatment on various types of seeds. So the value of Kc can be determined by dividing the value of ETC by ETo.

3. Results and dicussion

The results of the analysis of the physical properties of the soil

Based on the results of soil analysis, the following results were obtained:

Table 1. The results of the analysis of the physical properties of the soil

Soil Physical Properties		ResultsAanalysis	
Particle Distribution	Sand (57.50%)	Dust (10.04%)	Clay (32.46%)
Texture		Sandy clay loam	
Mass Weight		1.51g/cm3	
Specific gravity		2.30g/cm3	

The value of the sand fraction of the texturesoilobtained from measurements using a hydrometer on the reading in the 40th second is 57.50%. while the results of the dust fraction at 2 hours of measurement obtained the value of the dust fraction of 10.04%. The textures obtained from the hydrometer method in all treatments can be classified into sandy clay loam texture classes. Determination of texture class is obtained from the percentage of sand, silt and clay fractions in the texture triangle. Based on the texture, the ability of the soil to store water is quite good. According to Agus et al. (2004) Texture is the relative ratio between the fractions of sand, silt and clay, namely soil particles with an effective diameter of 2 mm. In texture analysis, organic matter fraction is not taken into account. According to Hasibuan (2011) soil texture is important to know because the composition of the three fractions of soil grains (sand, silt, and clay) will determine the physical properties of the soil.

Based on the value of soil density obtained using the gravimetric method, the results tend to be the same for each soil used as a planting medium. The density of the resulting soil was 1.51 g/cm3 which indicated that the soil used could still be penetrated by the roots of the pineapple plant and did not inhibit the uptake of water by the plant roots and also did not inhibit the growth of the pineapple plant. According to Islam and Utomo (1995) Plant roots grow and elongate between the spaces between soil solids (pore spaces), the same thing happens to the movement of water. According to Haryati (2014) The density of soil is closely related to the ease of root penetration into the soil, drainage and soil aeration with other soil properties such as total pore space and pore space distribution. This means that the soil is porous so that plant roots can easily penetrate into the soil.

Analysis of the specific gravity of the soil on the planting medium used in the experiment using the gravimetric method obtained results of 2.30g/cm3. This value indicates that the specific gravity of the soil used in the experiment is a good soil for storing water because its water storage capacity is quite large.

Observations of plant morphology 2BST-4BST (March-May 2020)

Morphological observations of pineapple plants were carried out at the age of 2BST-4BST. This was done because at the age of 1 BST, the pineapple plant observation parameters such as length, width and leaf color were not significantly different from the seeds at the beginning of planting. The main object of observation is the D-Leaf section of the pineapple plant. D-Leaf was chosen because it is the longest group of leaves on the pineapple plant. according to Sideris and Krauss (1936) in Souza and Reinhardt(2001), D-Leaf group is the longest leaf on the plantandhave soft leaf bases. D-Leaf can represent leaf standards in pineapple plants that are easily identified and can be used to index growth and evaluate the nutritional status of pineapple plants. Following are the results of observations on each parameter:

Pineapple Plant D-Leaf Length 2BST-4 BST

On the D-Leaf length of pineapple plants, observations were made from the age of 2 BST and carried outeverymonths until the pineapple plants are 4BST.Pobservationgrowth longThe D-Leaf that has been carried out shows the following results (Table 2).

Table 2. Long growth of D-Leaf pineapple plant age 2BST-4BST

Seed Type	P. D-leaf ±SD(cm)		
	2BST	**3 BST**	**4 BST**
*Crown*Ksmall	37.45 ±0.64a	45.75 ±0.78a	56,00±0.45a
Sucker Ksmall	44.30±0.66b	57.40±0.82b	70.05 ±0.31b
*Sucker*Sedang	48.25 ±0.48c	59.75 ±0.95c	78,00±0.10c
Sucker Besar	57.80±0.80d	73.12 ±0.32d	82.60±0.80d

Note: numbers followed by different letter notations in the same column show significantly different results based on the 5% DMRT test. SD: Standard Deviation.

Based on Table 2, the D-leaf length growth of pineapple plants was significant over time. The longest D-leaf was found in plants with large sucker class seeds and the lowest in plants with small crown classes. This is because the diversity of types of seeds will affect the vegetative growth of pineapple leaves, especially on the length of pineapple leaves. According to Samson (1980) in the vegetative phase, leaf length continued to increase to a maximum length in line with the age of the plant. Pineapple plants that have normal growth and development will have more than 35 complete leaves at about 12 months after planting.

Pineapple plant D-Leaf Width 2BST-4 BST

OnwideD-Leaf pineapple plants, observations were carried out starting at the age of 2BST and carried out every month until the pineapple plants were 4BST. From the observations that have been made show the following results (Table 3).

Table3.D-Leaf growth of pineapple plant age 2-4BST

Seed Type	**WideD-leaf ±SD(cm)**		
	2BST	**3 BST**	**4 BST**
*Crown*Ksmall	3.30±0.12a	3.70±0.03a	4.10±0.08a
Sucker Ksmall	3.40±0.12a	3.85 ±0.13a	4.15 ±0.02a
*Sucker*Sedang	3.65 ±0.06ab	3.90±0.08a	4.20±0.06a
Sucker Besar	3.90±0.31b	4,00±0.45a	4.60±0.08a

Note: numbers followed by the same letter notation in the same column show results that are not significantly different based on the 5% DMRT test. SD: Standard Deviation.

Based on Table 3, the D-Leaf width growth of pineapple plants had insignificant growth over time because the values tended to be the same during the observations. The widest D-Leaf was found in plants with large sucker class seeds and the lowest in plants with small crown seeds. This is because the leaf width of the pineapple plant still tends to be the same in the early vegetative period, so it is likely that the leaf width will change significantly when it enters the generative phase. According to Kristen et al. (2000) parameters of the plant at first slow then gradually fast until there is a maximum growth and decline.

Pineapple D-Leaf Index 2BST-4 BST

D-Leaf index is one of the observation parameters used as an index of pineapple plant growth. The measured D-Leaf index values on pineapple plants aged 2BST-4BST are as follows (Table 4).

Table 4. Pineapple D-Leaf Index 2BST-4 BST

Seed Type	Index. D-leaf		
	2BST	3 BST	4 BST
*Crown*Ksmall	117.44a	176.14a	235.2a

Sucker Ksmall	152.62b	212.93b	297.85b
*Sucker*Sedang	174.64c	230.98c	331.95c
Sucker Besar	227.03d	296.48d	389.22d

Note: numbers followed by different letter notations in the same column show significantly different results based on the 5% DMRT test.

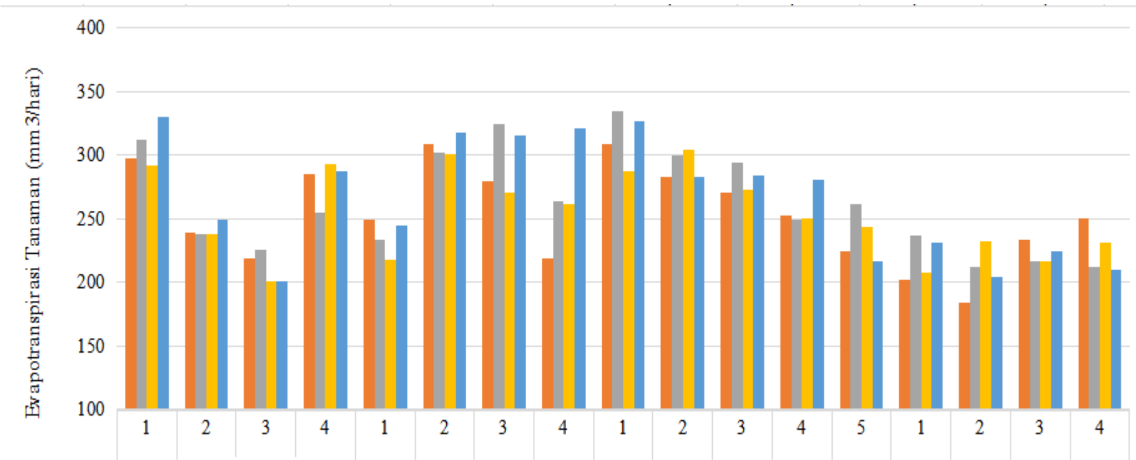
Based on Table 4, the growth of pineapple plants which can be seen from the value of the D-Leaf index of pineapple plants is significant over time. D-Leaf with the highest index was found in plants with large sucker class and the lowest in plants with small crown seeds. This is in accordance with the growth of leaf width and length, because the D-Leaf index is obtained from the product of the width and length of the D-Leaf. According to Zanon et al. (2015) Determination of leaf area in response to different agroecosystems and climatic conditions can assist in monitoring pineapple plant growth and improve management practices. Based on research conducted by Vilela et al. (2015) D-Leaf index was considered the most metabolically active in plants, reflecting the actual nutritional state and productive capacity of pineapples being the most important of crop cultivation.

Pineapple plant D-Leaf color percentage 2BST-4 BST

Observation parameters in the form of the percentage of D-Leaf color of pineapple plants on all types of seedlings aged 2BST-4BST treatment reached 100% or all were green with a percentage of N absorbed by 25-50%. This shows that the plants did not experience water stress such as flooding and lack of water during observations. According to Song and Banyo (2011) availability of water as the main factor that plays a role in plant physiological processes. Water is also a solvent for salts, gases and other substances that are transported between cells in tissues to maintain cell growth and maintain leaf shape stability. Water also plays a role in the process of opening and closing stomata. The response of plants to water drought is generally indicated by a decrease in leaf chlorophyll concentration. The decrease in chlorophyll content when plants lack water is related to the activity of photosynthetic apparatus and decreases the rate of plant photosynthesis. Lack of water will affect the content and organization of chlorophyll in chloroplasts in tissues.

A. *The results of observations of plant evapotranspiration in February-May 2020.*

In determining the plant coefficient value using the lysimeter weigh method, the data produced is the evapotranspiration of pineapple plants in each seed class during February-May 2020 (Figure 5).



	Februari				Maret				April					Mei			
	1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	4
crown kecil	297	240	219	285	249	308	280	219	308	283	270	252	225	202	185	233	250
sucker kecil	313	238	225	255	233	302	325	264	335	300	294	249	262	236	212	217	213
sedang	292	237	200	293	218	301	270	262	288	304	273	251	243	207	232	217	231
besar	330	249	201	288	245	318	315	321	327	283	285	281	217	231	205	225	210

Figure 5. Pineapple plant evapotranspiration during February-May 2020

Based on Figure 5, the results of observations of plant evapotranspiration on small crown seedlings, small suckers, medium suckers and large suckers that occurred at 1-4 BST (February-May 2020) showed fluctuating graphs. The highest plant evapotranspiration tended to occur in small sucker seedlings during February to May 2020. Meanwhile, plant evapotranspiration during observations of 4 BST tended to decrease and the lowest was at 4 BST. This can happen because the size of different types of seeds and plant growth every month will also affect the canopy area on pineapple plants so that the larger the pineapple plant in the vegetative period, the more covered the soil surface. It is possible that the evapotranspiration value will be different if the pineapple plant has entered the fast phase.

Another study conducted by Sajiwo (2017) stated that in the early period, evapotranspiration was lower because the plants were still small so that the plant surface area for evaporation was smaller, while in the fertilization phase the maximum growth phase and during the ripening period the fruit was old which was less productive and the metabolic process had started to slow down so that reduced water requirements.

B. Reference evapotranspiration (ET0) at 1-4 BST (February-May 2020) using the methodPenman-Monteith

Based on the results of climate observations over the last 10 years, the data obtained is processedforproduce the actual evapotranspiration value (ET_0).Data processing in determining the actual evapotranspiration is carried out using the Cropwatt application version 8.0.In Copwatt version 8.0, ETo assignment uses the Penman-Monteith method (Allen et al., 1998) which is described by the equation:

$$ET_0 = \frac{0.408\Delta(Rn - G) + \frac{900}{T + 273}U_2(es - ea)}{\Delta + \gamma(1 + 0.34U_2)}$$

Where ET0 is Reference evapotranspiration(mm/day),Rn as Net radiation on the plant surface(MJ/m2/day),G as Soil heat flux(MJ/m2/day),T as Daily temperature average at a height of 2 meters(^{0}C),U2 as Wind speed at a height of 2 meters,(m/sec), ice as Saturated vapor pressure (kPa)

Based on the above equation, the average monthly ET0 value calculated using Cropwatt version 8.0 is presented inGamber6.

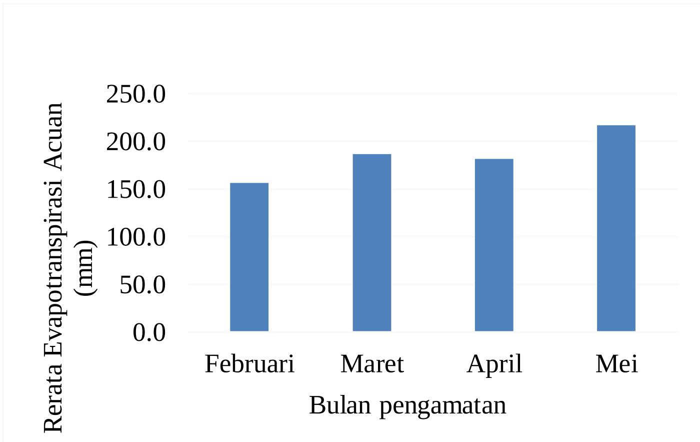


Figure 6. Average monthly ET0 value

Based on Figure 6, it shows that the lowest mean reference evapotranspiration (ET0) occurs inMonthFebruary is 156.2mm. The highest reference evapotranspiration value occurred in May, which was 216.7mm. The reference evapotranspiration value fluctuates due to different temperature and humidity factors in each month. According to Fuadi (2016) climatic factors that affect evapotranspiration are temperature, humidity, wind speed and solar radiation and latitude.

C. Pineapple plant coefficient values for several seed classes at 1-4 BST (February-May 2020)

On determinationThe coefficient value of pineapple plants, based on the results of the analysis of the actual plant evapotranspiration in each pot, the small crown seedling class and the small sucker seed class had the same results, so the plant coefficient value was determined based on the small, medium and large seed classes at the age of 1BST-4BST (Figure 7)

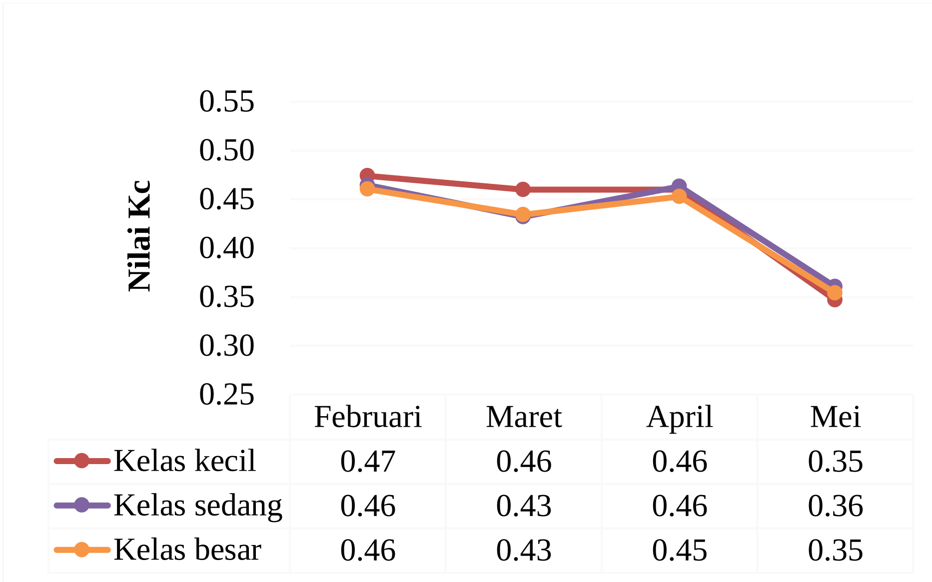


Figure 7. The Kc value of pineapple for small, medium and large seed classes at the age of 1-4 BST.

Based on Figure 9, the results of observing the Kc value of pineapple plants using the lysimeter weigh method, it was found that the coefficient value of pineapple plants tended to be the same in all seed classes. In the treatment of different types of seeds, the Kc value of pineapple plants was not significantly different. However, in terms of age of pineapple plants, the Kc value of pineapple plants decreased at the age of 4 BST, so that the Kc value of pineapple plants produced different values at different ages of plants.

The results of other coefficient values that areobtained from research de Azevedo et al. (2007) show different values. Different Kc values were obtained by dividing the vegetative phase into two phases which counted for approximately 84 days (3 BST) in phase 1 and phase 2. In phase 1 the Kc value obtained was around 0.88 and in the second phase was 0.91. This high Kc value can be caused by different climatic conditions. The factor of the value of plant evapotranspiration and evaporation greatly affects the results of the determination of Kc. Different climatic conditions every month will be the main factor in determining the Kc value, so that the Kc value is strongly influenced by the age of the pineapple plant.

D. *Analysis of pineapple plant water needs using Cropwatt version 8.0*

The pineapple plant coefficient values obtained at 1-4 BST were then divided into 2, namely 1-3 BST with Kc 0.45 as the initial growth phase and 4 BST with Kc 0.35 as the pre grand growth phase.

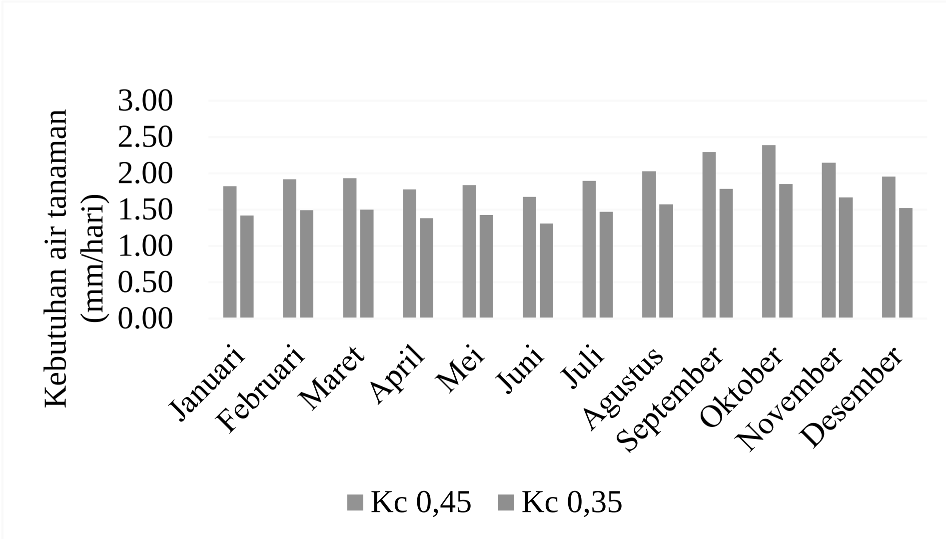


Figure 8. Pineapple plant water needs

Based on Figure 8, the highest water requirement for pineapple plants in October is 2.39mm/day in the initial growth phase and 1.86mm/day in the pre-grand growth phase. The lowest value of pineapple plant water needs occurs inIn June it was 1.68mm/day in the initial growth phase and 1.31mm/day in the pre-grand growth phase.

The measured Kc value is directly proportional to the water requirement of the pineapple plant. The higher the Kc value, the higher the water requirement for pineapple plants. According to Priyonugroho (2014), the overall water demand needs to be known because it is one of the important stages needed in the planning and management of the irrigation system.

E. Analysis of irrigation needs using 8.0 . cropwatt

The data obtained from observations were then analyzed using crop watts 8.0 to determine the irrigation water that needs to be given to pineapple plants in the next phase. Based on data analysis using Cropwat 8.0, the irrigation water requirements that need to be provided are as follows (Table 5).

Table 5. Pineapple irrigation water needs

Month	**Period**	**Phase**	**Irrigation Needs** mm/period	**Irrigation Needs** mm/day
June	3	*Development*	1.1	0.11
July	1	*Development*	2.3	0.23
	2	*Development*	4.9	0.49
	3	*Middle*	11.9	1.19
August	1	*Middle*	12.8	1.28
	2	*Middle*	15.8	1.58
	3	*Middle*	18.5	1.85
September	1	*Middle*	14.0	1.40
	2	*Middle*	13.8	1.38
	3	*Middle*	12.5	1.25

October	1	*Middle*	12.9	1.29
	2	*Middle*	12.4	1.24

Description: 1 Period=10 days.

Based onTable 5, irrigation water can be given in period 3 in June to period 3 in October. The highest irrigation water supply will be carried out in August at 1.85mm/day with an estimated plant being in the Middle phase. Determination of the provision of crop irrigation water based on the amount of effective rainfall that exists,so thatthe provision of water for each phase is not always the same.

4. Conclusions

Different types of plant seeds have no effect on the coefficient value of the plant. However, the age of the plant determines the coefficient of the plant the most. Plant coefficient value at the age of 1-3BSTis0.45 and at the age of 4 BST was 0.35. Analysis of the highest water demand for pineapple plants in October was 2.39mm/day in the initial growth phase and 1.86mm/day in the pre-grand growth phase. The lowest pineapple plant water requirement occurred in June of 1.68mm/day in the initial growth phase and 1.31mm/day in the pre-grand growth phase.

5. Acknowledgment

Acknowledgments are especially shown to the giverresearch facilities and infrastructure, namely PT. Great Giant Pineapple.Thanks can also be conveyed to those who helped carry out the research.

6. Authors Note

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

7. References

Allen RG Pereira LS, Raes D. and Smith M. (1998). Crop evapotranspiration: Guidelines for Computing Crop Water Requirements. Italy: FAO Irrigation and Drainage.

Agus, Fahmudin, Yusrial and Santoso. (2004). Determination of Soil Texture. Bogor: Center for Soil and Agroclimate Research and Development.

Bartholomew, DP, RE Paull and KG Rrohrbach. (2002). The pineapple UK: CABI. Wallingford.

Bartholomew, DP, RE Paull and KG Rrohrbach. (2003). The pineapple botany, production and uses. UK: CABI. Wallingford.

De Azevedo, Pedro V., de Souza, Cleber B., da Silva, Bernardo B. da Silva and Vicente PR (2007). Water requirements of pineapple crop grown in a tropical environment, Brazil. Agricultural Water Management, 88: 201–208.

Fuadi, NA, Purwanto, MYJ and Tarigan, SD. 2016. Study of Water Needs and Rice Water Productivity with SRI and Conventional Water Supply Systems Using Pipe Irrigation. Journal of Irrigation, 11(1): 23-32.

Gani, Ilham D., Jamil, M. and Sardju, Achmad P. (2019). Evaporation Pot Water Level Monitoring System Based on MCU Node Using Internet of Things Technology. PROTEK Journal, 6(2).

Haryati, Umi. (2014). Soil Physical Characteristics of Upland Vegetable Cultivation Areas, Its Relationship with Land Management Strategies. Journal of Land Resources, 8(2) : 125-138.

Hasibuan, BA (2011). Geology. Medan: USU Press.

Islami, T. and WH Utomo. (1995). Homeland Relations and Plants. Semarang: IKIP Semarang Press.

Kristen, F., T. Tan and Y. Ramandy. (2000). Study of Growth and Production Characteristics of Sweet Potato (Ipomoea batatas L. Lamb) in Single and Intercropping Systems with Mung Beans. hyphere. 2:26-32.

Priyonugroho, A. (2014). Analysis of Irrigation Water Needs (Case Study in Air Keban River Irrigation Area, Empat Lawang Regency). Journal of Civil and Environmental Engineering. 2 (3).
Rosadi, RAB (2012). Deficit Irrigation. Lampung University Research Institute.
Sajiwo I, Sumono and Harahap LA. (2017). Determination of Evapotranspiration Values and Plant Coefficients of Several Superior Varieties in Greenhouses, Faculty of Agriculture, University of North Sumatra. Journal of Food and Agricultural Engineering. 5(2): 370-374.
Samson, J.A. (1980). Tropical fruits. Longman, London.
Sapei, A., & Fauzan, M. (2012). Artificial impermeable layer to minimize percolation of rainfed paddy fields in favor of water-saving irrigation. Irrigation Journal. 7(1): 52–58.
Song, N. & Banyo, Y. (2011). Leaf chlorophyll concentration as an indicator of water shortage in plants. Scientific Journal of Science. 11(2):169-170.
Sosrodarsono & Takeda. (2000). Hydrology For Irrigation. Jakarta: Pradnya Paramita.
Souza, LFS & DH Reinhardt. (2001). Pineapple. Embrapa Mandioca e Fruticultra Tropical.
Vilela, GB, Pegoraro, RF & Maia, VM (2015). Production Prediction Of The Pineapple 'Vitória' by Means Of Phytotechnical And Autritional Characteristics. Agronomic Science Magazine. Fortaleza. 46(4): 724-732.
Zanon, AJ, Streck, NA, Richter, GL, Becker, CC, Roche, TSM., and Cera, JC (2015). Contribution Of Ramifications And The Evolution Of The Leaf Area Index In Modern Soybean Cultivars. Bragantia: Campinas.