Advances in Biological Sciences Research, volume 19
Proceedings of the 2nd International Conference on Smart and Innovative Agriculture (ICoSIA 2021)

The Interactions of Daily Microclimate and Rice Plant Growth by System of Rice Intensification (SRI) Method in Dry-climate Land

Tobyas S Santosa[1*], Bayu Dwi Apri Nugroho[2], and Rose Tirtalistyani[2,3]

[1] *Undergraduate student of Department of Agricultural and Biosystem Engineering, Faculty of Agricultural Technology University of Gadjah Mada*
[2] *Department of Agricultural and Biosystem Engineering, Faculty of Agricultural Technology University of Gadjah Mada*
[3] *Department of Agricultural and Biosystems Engineering, Iowa State University, 4326 Elings, 605 Bissell Rd., Ames, IA 50011-1098, USA*
[*] *Corresponding author. Email:* tobyas.santosa@mail.ugm.ac.id

ABSTRACT
Indonesia is quite blessed to have a proper climate condition to cultivate rice plants as the demand for rice is becoming one of the highest among the other foodstuffs. Even so, the climate condition in Indonesia quite varies, where some regions are classified as dry climate area and one of them is East Nusa Tenggara Province, more precisely on Sumba Island. A region with a dry climate has its challenge regarding water availability. One of the ways to overcome such difficulty in rice cultivations is by applying the System of Rice Intensification (SRI) method. SRI method is known for its sustainability as this method conserves the water resource of a place but at the same time, this method can increase crop productivity. Furthermore, the SRI method planted rice is still an agricultural process that is sensitive to its environmental conditions, including the climate conditions. Based on that, this research is conducted to analyze the interaction of the daily microclimate on the dry-climate land and the growth of the SRI method planted rice. This paper aims to inspect the fluctuation of the microclimate in the rice field through the planting season and to develop mathematical models on rice tillers and plant height of the rice growth to see their performance. Research is conducted in East Sumba Region, Sumba Island. Researchers use a 0.25 ha area of land and divide it into 3 plots. The first plot uses the SRI method with a 30×30 planting pattern. As for the second plot, researchers apply the SRI method but with the jajar legowo 2:1 planting pattern. The last plot of land use the conventional method as a comparison. The micro-climate data were collected by utilizing six sensors including precipitation, solar radiation, air temperature, relative humidity, and wind speed. Those sensors are connected to the ZL6 Cloud data logger that records those data and uploads them to the cloud storage. Rice tillers and plant height growth are measured every ten days until the rice to be harvested. After that, mathematical models are developed that include rice tiller's growth model that matches with the second order of exponential polynomial function and plant height's model that equivalent to the monomolecular function.

Keywords: *Microclimate, SRI, dry climate land, mathematical model, crop physiology.*

1. INTRODUCTION

Rice is one of the staple food for almost all people in Indonesia, including people in East Nusa Tenggara Province. BPS reported that rice has the highest consumption rate per capita in East Nusa Tenggara Province in 2017, almost reach 606 thousand tonnes [1]. The great amount of rice demand challenges our farmers to keep up with that high number. That thing aside, our farmers in some regions in East Nusa Tenggara face obstacle regarding climate condition. Subagio and Aqil stated that most of land in East Nusa Tenggara has a dry climate. Dry climate condition could mean a low precipitation rate. The dry season hit longer, ±8 months in a year. There even could be four months without any rainfall in that season [2]. Due to its low rainfall rate, dry climate is a problem for rice cultivation. That kind of climate condition can lead to low water availability on that land. Water, as we know, is essential to rice cultivation or any other sort of plant. When we cannot fulfill the needed amount of it, it will impact crop production.

One solution for water shortage in rice cultivation is by implementing the System of Rice Intensification (SRI). SRI method was developed in Madagascar and introduced to Indonesia in the late 90s. SRI method is known to be able to minimize water usage on the field and increase crop productivity. Besides that, this method also brings many other benefits such as strengthen the plant roots, improve the soil aeration, and shorten the crop growth period [3].

As stated above, rice cultivation, or agriculture in general, is sensitive to climate conditions. The climate within each area could influence plant growth either directly or not. Climate conditions affect plant growth right away on its physiological process inside. Climate conditions could also indirectly impact the cultivation activity by provoking any disease, insect, or pest [4]. The analysis between climate conditions and rice cultivation is a necessary thing to do to oversee crop growth. We would also be able to examine the suitability of that area as a cultivation field on a particular plant and on a specific method of cultivation.

The objective of this study is to examine the rice plant growth by reviewing the plant height and the number of tillers on a dry climate land that is cultivated by SRI method. Furthermore, we also want to review the interaction between the crop growth and the climate conditions specifically, the microclimate on the land.

Each area will show different climate circumstances. Therefore, we need to classify each place by its climate because different conditions must have distinct treatments in any context [5]. Many researchers have developed climate classification systems, one of them is the Oldeman system. Oldeman climate classification is based on rainfall and its relevance to the water need of plants especially seasonal crops plants such as rice [6]. Oldeman used the term of dry months and wet months on the grouping. It considered as wet month if the rainfall is more than 200 mm in a month, while it is defined as dry month if there's no more than 100 mm of rainfall in a month. The climate classification can be put down as below.

Table 1. Oldeman Climate Classification

Main type	Amount of Consecutive Wet Month
A	>9
B	7-9
C	5-6
D	3-4
E	<3

Sub-type	Amount of Consecutive Dry Month
1	<2
2	2-3
3	4-6
4	>6

(Source: Dewi, 2005)

Climate also can be categorized based on time and area scale into 1) microclimate, 2) local climate, 3) meso climate, and 4) macroclimate [7]. Microclimate state the climate conditions of a small area. Many factors affect the microclimate of a place such as the topography and land altitude. Those factors cause the dissimilarity of the temperature, humidity, and wind intensity in the atmosphere and near-soil air layers. The microclimate also depends on other factors like the exposure rate of solar radiation, fluctuating land relief, or even the vegetation in that area. Analysis of the microclimate is performed by measuring the climate elements: maximum and minimum temperature, air humidity, and wind activity [8]. There are also other essential climate elements which are solar radiation and rainfall [9].

System of Rice Intensification (SRI) has the advantage that it saves water (during the vegetative phase the land is in a patchy state or in field capacity until hair-cracks phase), entering the generative phase the land is irrigated a maximum of 2 cm. This patchy state is cultivated until 25 days before harvest. The age of transplanting seedlings is earlier, making plants freer to grow and develop, making tillers form up to 12 times until the exponential tillers occur. Wider spacing makes the microclimate better, as a result the plants grow and develop ideally. Less water is used, water is only needed in the generative phase, because the land is not always in a state of flooding [10]. Some research that show SRI could save water SRI method could lower the water use up to 40% [11].

2. METHODOLOGY

This study was conducted on a 0,25 ha demonstration plot in Kawangu, Pandawai District, East Sumba Region, East Nusa Tenggara, started on May 20th, 2021 and ended on August 27th, 2021. This study used IF-16 variety of rice seed and was planted in three plot of lands. The first plot of land had area size of 22,15×36,7 m2 and rice was planted there with SRI method and 30×30 planting pattern. The second plot of land's wide area is 23,75×32 m2 and also used the SRI method but we planted the rice plant on the jajar legowo 2:1 (Jarwo) planting pattern. The last plot has an area of 25,45×36,7 m2 of land used conventional method of the planting process, the usual practice of the locals on planting rice.

2.1. Tools and Materials

The tools and material that was used for this study are listed below

a. ECRN-50 rainfall sensor
b. PYR solar radiation sensor
c. Davis cup wind speed sensor
d. VP-4 vapor pressure and temperature sensor
e. ZL6 cloud data logger
f. Ruler
g. Measuring tape
h. 0,25 ha of land
i. IF-16 rice seed
j. Climate data of East Sumba; 2011-2020

2.2. Data Acquisition

Daily Microclimate

The microclimate of the land was collected by using four sensors with each use for each element. ECRN-50 was used for recording the rainfall data. PYR sensor was utilized for calculating the sun radiation value on the land. Davis cup sensor was used for measuring the wind speed on the land. Lastly, we used VP-4 sensor for computing the relative humidity and measure the temperature. Every sensor record each element of climate every 10 minutes. Then the data logger will collect them and upload those data into the cloud storage every hour so we able to access the microclimate data online through zentracloud.com.

Rice Plant Growth

The growth of the rice plant on each plot of land was observed through the plant's height and growth of the rice tiller. For each plot of land, researcher took six samples of rice plants and evaluated the height and the amount of rice tillers every ten days. The rice plants' height was measured by using ruler or measuring tape and the rice tillers were determined by direct observation on the plants.

2.3. Data Analysis

The Fluctuation of Microclimate

The acquired microclimate data from before are then converted into daily data. The number of rainfall are summed for each day. The temperature data are picked into the maximum and minimum for each day. The data of relative humidity, solar radiation, and the wind speed are averaged each on the daily basis. After that, data of each microclimate are plotted over time (day) to see the fluctuation all through the planting.

Rice Tillers

The number of rice tillers could be plotted in a graph to time and close to the second-order polynomial exponential function, similar to function of plant dry weight (W) to time (t) [12]. That function can be expressed as equation 2.1

$$W = exp(a_0 + a_1 t + a_2 t^2 + \cdots) \qquad (2.1)$$

The parameter that researcher used is the amount of rice tillers (A) through the planting season, so Equation 2.1 can be rewritten as below

$$A = exp(a_0 + a_1 t + a_2 t^2 + \cdots) \qquad (2.2)$$

The equation above can derived further by extracting the natural logarithmic (ln) into Equation 2.3

$$ln\ A = a_0 + a_1 t + a_2 t^2 \qquad (2.3)$$

Equation 2.3 is equivalent to a polynomial function hence we can the numbers of ln A on the y axis and time (t) on the x axis. Those graphs will help to find the mathematical model's constant parameters (a_0, a_1, a_2).

Rice Plant Height

If we put plants' height growth data into a graph of time series, the result will be the same as monomolecular function [12]. The monomolecular function can be expressed as below

$$W = W_f - (W_f - W_0)\exp(-kt) \qquad (2.4)$$

W = dry-weight of plant

W_f = final dry-weight of plant

W_0 = intial dry-weight of plant

t = time

k = constant

Equation 2.4 could be derived further and we could substitute the dry-weight into the plant's height (T) thus we can get equation 2.5

$$\ln\left(\frac{T_f - T_0}{T_f - T}\right) = kt \qquad (2.5)$$

T_0 = Initial height of plant

T_f = Final height of plant

T = Height of plant on certain time

We can make a graphic where the value of $ln\left(\frac{T_f - T_0}{T_f - T}\right)$ on the y axis and the time series will be on the x axis. The value of k is the gradient of the graph.

Model Validation

Model validation with simple linear regression on the rice tillers and the plant height is performed to obtain the coefficient parameter that will help oversee the accuracy of the predicted value from the mathematical model compared to the actual value from the observation. After that, the observed values are plotted in a graph with the predicted values that have been previously calculated. The graph will show the coefficient of determination R^2 can prove a correlation between the observed value and the predicted value.

3. RESULT AND DISCUSSION

3.1. Climate Classification

This research used rainfall data of East Sumba from year of 2011 to 2020 to classify the type of climate using the Oldeman system.

After find the average of the consecutive wet and dry month through 2011-2020 from the data, East Sumba region can be classified with an E4 type. The dry climate on East Sumba region is caused by the monsoonal climate pattern, which one of the sign is that the rain would be concentrated on a short time or it could be defined as the unimodal rainfall pattern [13].

On the year 2011-2020, East Sumba region has really low wet month, moreover from 2014-2016 there is not even a single wet month. This could be correlated to the El Nino that was peaked on 2015. Based on Nino 3.4. Index, the 2015 El Nino classified as strong nino, it passed 1.5°C on the index [14].

This dry climate condition is not necessarily suitable for rice cultivation. Therefore, it need some modification on the resource compliance.

3.2. Daily Microclimate

This study review the microclimate of the rice field land and turn it into daily data through the planting season.

Each element of climate very fluctuant through the planting season. The total of rainfall through the planting season s 59 mm. This is a small number but if we compare with the rainfall data in East Sumba year 2011-2020 on the same month range, is quite a increase. This study was conducted on May-August, where the rainfall usually low in Indonesia generally.

Table 2. Rainfall data of East Sumba in 10 years (2011-2020).

Month	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Jan	216	199	243	50	158	155	188	286	273	169
Feb	316	182	249	183	142	68	232	231	100	262
Mar	272	253	76	120	169	199	138	174	195	127
Apr	154	64	93	81	127	34	73	19	83	104
May	10	78	62	0	3	89	3	0	1	134
Jun	0	0	92	0	0	63	3	0	0	2
Jul	0	0	9	0	0	20	0	0	0	0
Aug	0	0	0	0	0	11	1	8	0	0
Sep	0	2	0	0	0	9	0	0	0	0
Oct	2	0	0	0	0	12	13	6	0	2
Nov	40	47	103	13	0	7	203	129	33	19
Dec	78	176	258	101	166	64	189	58	24	142
Wet Month	3	1	3	0	0	0	2	2	1	1
Dry Month	9	11	9	12	12	12	10	10	11	11

(Source: BMKG, 2021)

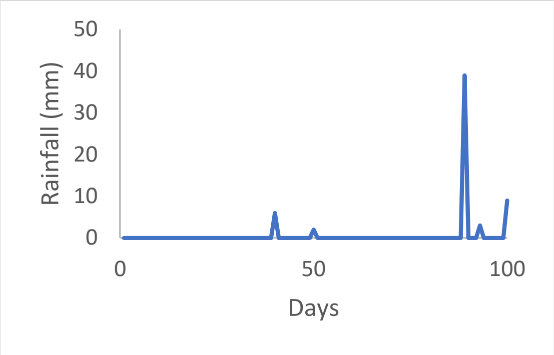

Figure 1 Rainfall rate through the planting season.

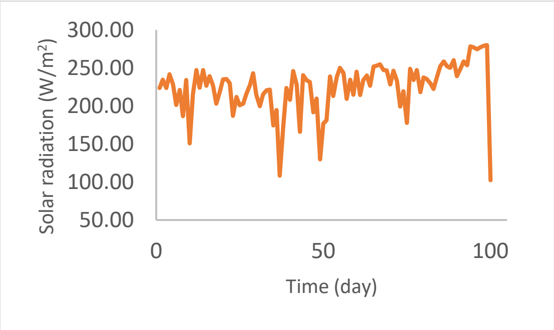

Figure 2 Solar radiation through the planting season.

Figure 2 shows the fluctuant of the solar radiation on the research location. The average of solar radiation during the cropping period is 224,90 W/m^2. Solar radiation is the main energy source for rice plant to do photosynthesis. Solar radiation also affect the evapotranspiration process that correspond with the water balance system.

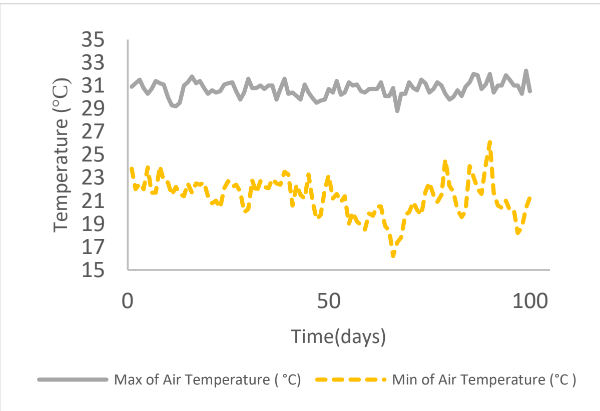

Figure 3 Maximum and minimum temperature through the planting season

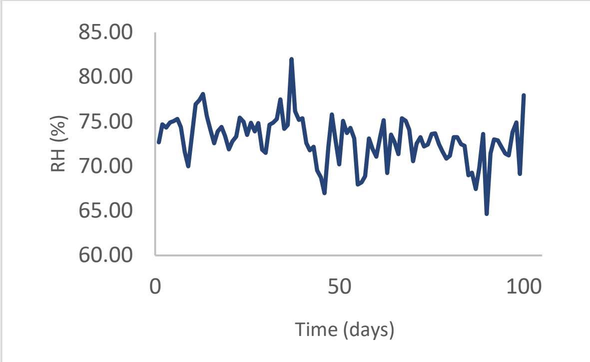

Figure 4 Relative humidity through the planting season.

Figure 3 shows us the maximum and the minimum temperature in the location of this study. The result is that the average of daily temperature through cropping period is 26,02°C which is suitable for rice cultivation in general.

We can oversee the shift of the relative humidity during the planting season on **Figure 4.** It has average value of 72,98%. Relative humidity impacts many aspects of plant growth. It could affect the growth of the plant size in general [15]. Humidity also takes effect on leaf development, leaf size, and the rooting of the plants [16].

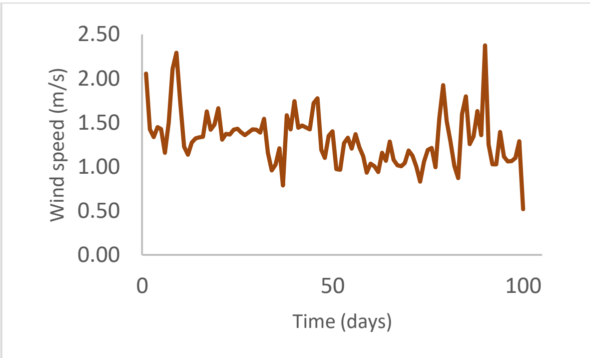

Figure 5 Wind speed through the planting season.

Figure 5 shows the altering wind speed during the cropping period on the location. The result of the measurement is that the average of wind speed is 1.31 m/s. Wind helps to enhance the turbulence in the air itself and make the availability of the CO_2 increased. As a result the photosynthesis rate may heighten as well. But on the other side, the wind that becomes too strong could damage the crop plants, lodge the plants or even uproot them [17].

3.3. Rice Plant Growth

Rice Tiller Growth

The graph of the rice tiller growth over time is similar to the polynomial exponential function. The growth rate rapidly increases on the first third of planting season as and then reach the highest number between day 50-60. After that, as it goes to the end of planting season the growth is slower and eventually the amount of the rice tiller is a bit decreasing. The fluctuation of growth rate on rice tiller is in line with the rice plant growth stages, it entered the vegetative stage in the first half where the growth rate is fast, and then getting slower as it enters the next stage, generative stages. The unproductive rice tiller would die one by one on this stage.

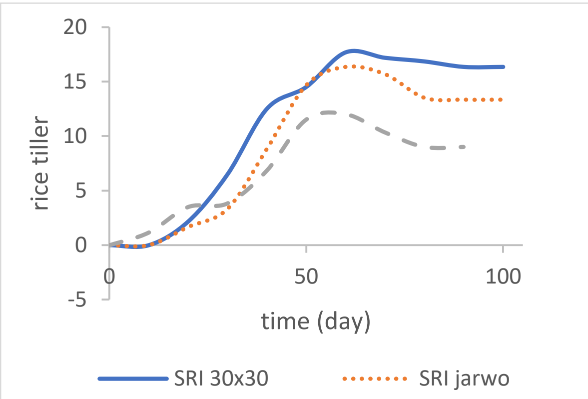

Figure 6 Rice tiller growth graph.

Table 3. Polynomial exponential function of rice tiller growth.

Treatment	a_0	a_1	a_2	R^2
SRI 30x30	-0,0006	0,087	-0,3778	0,93
SRI Jarwo	-0,0005	0,082	-0,474	0,87
Conventional	-0,0006	0,076	-0,2173	0,94

Table 3 shows the constant parameters of the polynomial exponential equation from the rice tiller growth. The mathematical models can describe the rice tiller growth well as seen on the number of the R^2 correlation, which comes up to 1.

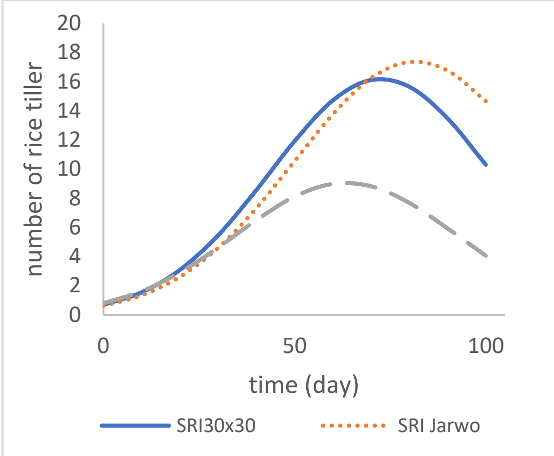

Figure 7 Predicted rice tiller growth.

The amount of rice tiller on the plot of land that use SRI method, is higher than the conventional one. This could happen because on SRI method the planting only use one seedling in each hole while the conventional one used 3-5 seedlings. Less seedling means more space and less competition on getting the necessary nutrient. It is also shown in **Figure 7** that the rice tiller on all of the plots of land had the same growth rate until day 20 and then the rice tiller of SRI 30x30 and SRI Jarwo surpassed the growth of the conventional one.

Plant Height

The graph of plant height should have been similar to the monomolecular function where the height growth rate rapid on the early planting time were slowly decreasing and finally got into its peak and then going stagnant. But as seen in **Figure 8**, the plant height growth rate rather slow at the early stage. This could've been caused by the pests and diseases that attacked the rice plant before planting. They were blast disease, the yellow stem borer (*Scirpophaga incertulas*), and the leafroller (*Cnaphalocrocis medinalis*). The pests and disease damage the plants so some of the plant died and need to be replanted with new seedling. The farmer immediately applied some pesticide and luckily it controlled well. The rice plant reached its maximum height between day 70-80.

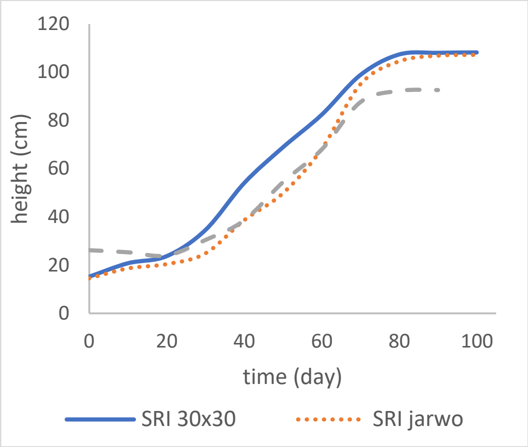

Figure 8 Rice plant height graph.

At first, the conventional method had higher plant height because it used older seedling, 21-days old whereas the other two plots used 14-days old seedling. The SRI plot of land excels on the plant height between days 30-40. This is possibly caused by using one seedling each hole so each plant could obtain the nutrient easier and less competitively.

4. CONCLUSION

The result of this research as listed below

1. East Sumba is classified as E4 type by Oldeman System which mean doesn't necessarily suitable for rice cultivation due to its low water availability.

2. During the cropping period, the rainfall on the land is generally low the whole time while the other element of climate, temperature, solar radiation, relative humidity, and wind speed are constantly fluctuate.

3. Rice tiller growth graph is equivalent to the second order of polynomial function which shows rapid increase on early stages and will slow down and finally there is a little bit drop as some of the unproductive tillers died.

4. Plant height growth graph is not corresponding the monomolecular function due to the disturb from pests and disease on the early stage of cropping.

ACKNOWLEDGMENTS

We are thankful to the Directorate of the Research University of Gadjah Mada for supporting this study through the 2021 Final Paper Recognition Scheme. We also thank the Department of Agriculture of East Sumba and Kambaniru Dam Operation and Maintenance Unit that assisted with this research.

REFERENCES

[1] Badan Pusat Statistik, 2018. Kajian Konsumsi Bahan Pokok Tahun 2017. Jakarta: Badan Pusat Statistik.

[2] Subagio, H. & Aqil, M., 2013. Pemetaan Pengembangan Varietas Unggul Jagung di Lahan Kering Iklim Kering. Seminar Nasional Serealia, pp. 11-19

[3] Purba, J. H., 2009. Penghematan Air dan Peningkatan Produksi Melalui Budidaya Padi Metode SRI (System of Rice Intensification). Widyatech: Jurnal Sains dan Teknologi, 9(2), pp. 28-46.

[4] Yoshida, S., 1978. Tropical Climate and Its Influence on Rice. IRRI Research Paper Series, Volume 20, pp. 1-28.

[5] Winarno, G. D., Harianto, S. P. & Santoso, R., 2019. Klimatologi Pertanian. Bandarlampung: Pusaka Media.

[6] Dewi, N. K., 2005. Kesesuaian Iklim terhadap Pertumbuhan Tanaman. Jurnal Biologi Universitas Negeri Semarang, 1(2), pp. 1-15.

[7] Nugroho, B. D. A., 2021. Penerapan Klimatologi dalam Pertanian 4.0. Yogyakarta: Penerbit Deepublish.

[8] Chirkov, Y. I., 1979. Microclimate and Phytoclimate. In: Agrometeorology. New York: Springer-Verlag Berlin Heidelberg, pp. 139-144.

[9] Koesmaryono, Y. & Askari, M., 2014. Pengertian dan Ruang Lingkup Klimatologi Pertanian, dan Pengaruh Atmosfer terhadap Kehidupan dan Pertanian. In: M. A. Yonny Koesmaryono, ed. Klimatologi Pertanian. Tangerang Selatan: Universitas Terbuka, pp. 1-24.

[10] Rozen, N. & Kasim, M., 2018. Teknik Budidaya Tanaman Padi Metode SRI (System of Rice Intensification). Depok: Rajagrafindo Persada.

[11] Hasan, M. & Sato, S., 2007. Water Saving for Paddy Cultivation Under the System of Rice Intensification (SRI) in Eastern Indonesia. Jurnal Tanah dan Lingkungan, 9(2), pp. 57-62.

[12] Murtiningrum, W. A. Purba, S. D. Lubis, W. Wardana. 2012. Mathematical models of rice crop height growth of rice cultivated with SRI method. J. Agrotek, 5(2), pp. 60-70

[13] Kaho, N. P. L. B. R., 2016. Mengapa NTT Kering? Apakah Hanya Karena Musim Hujan yang Kurang?: Menelaah Lebih Jauh Beberapa Penyebab dan

Solusi Praktis untuk Mengatasinya, Kupang: Fakultas Pertanian UNDANA.

[14] Yuda, I. W. A., Prasetia, R., Nursa'idah & Wiratmaja, M. D., 2020. Perbandingan Dampak El Nino Kuat 2015/16 dan 1997/98 terhadap Curah Hujan di Provinsi Bali - Indonesia. Megasains, Volume 11, pp. 28-35.

[15] Codarin, S., Galopin, G. & Chasseriaux, G., 2006. Effect of Air Humidity on the Growth and Morphology of Hydrangea macrophylla L.. Science Horticulturae, Volume 108, pp. 303-309.

[16] Hirai, G.-i.et al., 2000. Studies on the Effect of the Relative Humidity of the Atmosphere on the Growth and Physiology of Rice Plants. Plant Production Science, 3(2), pp. 129-133.

[17] Tamil Nadu Agriculutural University, 2009. Arometeorology: Wind and Plant Growth. [Online] Available at: agritech.tnau.ac.id [Accessed 29 July 2021].