Lettuce Growth and Production under Plastic Shading as a Response to different Microclimate Condition: A Preliminary Study of Climate Change Factors Impact on Crops

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Abstract— *Crop production is vulnerable to climate variability, especially when it associated with increasing temperature. Results from global and local scale research with different methods consistently showed negative temperature impacts on crop yield especially vegetables. One reason of lacking research in quantifying the impacts of climate change on crops is difficult to modify the air temperature and climate change marked by global temperature increase happened on regional and sub-regional scales. Therefore, this primary research tried to overcome this problem with planting highland crops on lowland area which has higher temperature area and study what changes experienced in crops growth and production. Lettuce is chosen in this experiment since lettuce is a wild plant native to temperate regions then vulnerable to climate change and as leafy crops, lettuce is representative in examining temperature effects on crop, leaf area is the main determining factor affecting light interception by crop and lead to biomass production. The experiments were conducted under UV polyethylene sheet to reduce the incoming solar radiation, and measured microclimate factors along with lettuce growth and production. Numbers of leaves for both lettuce plants inside the shading were significantly lower and as the consequences the fresh weight was still lower. Direct full sunshine with lower intensity combined with low temperature is the characteristic of highland area, the habitat of lettuce in Tropical area. In open and under shading condition of the experiment, the incoming radiation was still in the range of recommended light intensity for lettuce production. However, the air temperature seemed too high for lettuce cultivation in lowland area. In the nature it is possible that if the earth temperature keeps rising more crops will inhibit higher altitude.*

Keywords— ***Microclimate, lettuce, radiation, climate changes, shading.***

I. INTRODUCTION

Crop production is vulnerable to climate variability, especially when it associated with increasing temperature. Results from global and local scale research with different methods consistently showed negative temperature impacts on crop yield especially vegetables. All of studies find that crops are sensitive to changes in temperature (IPCC, 2007; Mendelsohn, 2014). The consistency of these findings suggested that crops are potentially vulnerable to climate change.

Environmental extremes that recently magnified by climate change affected several physiological and biochemical process such as photosynthetic activity, metabolism and enzymatic activity (Ayyogari, Sidhya and Pandit, 2014). Even moderate increase of average day or night temperatures could affect the yield and quality of vegetables like spinach, potato, broccoli, and lettuce (Turner and Meyer, 2011). Initially, high temperature reduced leaf area, which reduced radiation intercepted and eventually reduced the biomass. On the other hand, high temperature speeded up phonological development and shortened the period from emergence to flowering and from flowering to maturity; this often turned out to have undesirable traits. Smaller Tomato fruits in size with higher dry matter content and uneven heads with over-sized flower buds in broccoli occurred even at temperatures of only 25^{o}C (Bisbis, Gruda and Blanke, 2019)

Indonesia is a tropical country in the region of Southeast Asia. By the end of the century IPCC scenarios projected that both temperature and precipitations will change; the temperature may rise from 0.72 to 3.92°C while precipitation may decrease by two percent or increase by up to twelve percent (Cruz et al., 2007). Downscaled modeling specific for Indonesia projected that the temperature will rise relatively uniform across all of Indonesia from about 0.1 to 0.3°C per decade for the next 100 years; and other study suggested that the rate of temperature rising for Indonesia will be slightly greater from 0.2 to 0.3°C per decade (Boer and Faqih, 2004).

Indonesia depends much on agriculture productions; both food crops like rice as the staple food and horticulture products are important. While food crops are sensitive to water availability, horticulture products are sensitive to air temperature and humidity. One of the consequences of climate change in a tropical country will be a shift in the areas of cropping; and as crops could invade mountainous area in searching for cooler air it eventually lead to soil erosion and landslides. New crops could be invaded particular area that are currently marginal for cropping because the temperatures were so low, while some previous productive area could become bare soil (Iizumi and Ramankutty, 2015). In long term it will change the land use and endanger the environment. One reason of lacking research in quantifying the impacts of climate change on crops is it needs detailed information on physiological responses of the crops, climate factors effect on crops growth, development, quality and productivity and it is difficult to modify the air temperature (Malhotra, 2017). Moreover, climate change marked by global temperature increase happened on regional and sub-regional scales. For that reason, it is difficult to generalize the impact on vegetable and fruits crop, for growth and development of these crops are influenced by different environmental factors and numerous type with wide diversity makes it even difficult to summarize the potential effects of climate change on growth and yield. For that reason, few studies on the impact of climate change on vegetables have been carried out (Nelson et al., 2010). Therefore, this primary research tried to overcome this problem with planting highland crops on lowland area which has higher temperature area and study what changes experienced in crops growth and production.

Lettuce is chosen in this experiment since lettuce is a wild plant native to temperate regions then vulnerable to climate change. Some problems that might happen if the temperatures higher than 30^{o}C are: seedling malformation, low germination potential, decline in plant size, latex accumulation making leaves bitter and rigid, also loss of apical meristem and browned edges. Higher temperatures can also be associated with stem cleft resulting from deficiency of calcium and boron (Mattos et al., 2014). Lettuce seems to be a model crop well studied for light quality and temperature response, since beside temperature lettuce production also depends on light quality and light intensity. In high latitude area, lettuce production may be limited during late spring and summer months because of unfavorable temperatures which exceeding 30/16 °C day/night that increase the risk of bolting (forming of non-desirable flower stalks), tip burn, rib discoloration and leaf bitterness (Ilić et al., 2017). Lettuce was also chosen because as leafy crops, lettuce is representative in examining temperature effects on crop. Leaf area is the main determining factor affecting light interception by crop and lead to biomass production. Therefore, any reduction of leaf expansion rate is usually associated with reduction of photosynthesis and consequent decrease in above-ground biomass, grain yield and quality. We proposed a hypothesis that changing in crops microclimate would affect crop growth and production.

II. METHODOLOGY

2.1 Experimental and Shading Set-Up

The experiments were conducted under UV polyethylene sheet in form of tunnel shelter with floor area of 1.5 × 2 m2 and 2 m height, oriented in a north–south direction at private land in TelukBetung, Bandar Lampung, Indonesia (5^0 26'07" S and 105^0 15' 32" E, 10 m asl). Red lettuce (Lactuca sativa L. var. lollorosa), Romaine lettuce (Lactuca sativa L. var. longifolia) were planted inside the tunnel and in open space (without shading) as the control on dry hot season from May to June 2019.

2.2 Measuring the Required Parameters

The microclimate parameters: incoming radiation intensity (watt/m^2) measured with Skye instrument pyranometer, above ground temperature (^{0}C) and humidity (%) inside and outside the shading tunnel were measured using Flush USB humidity and temperature data logger E3845 type at noon time. Plants parameters were measured at harvest time including number of leaves, leaves maximum length and width, stem length, root dry weight and crops fresh weight. Means differences were analyzed statistically using T test.

III. RESULTS AND DISCUSSIONS

3.1 Microclimate Condition of Experiment

Average of incoming solar radiation intensity, above ground temperature and humidity inside and outside the polyethylene tunnel shading were presented in Table 1 and daily difference of those measurements between outside and inside the shading were presented in Fig. 1-3.

TABLE 1
AVERAGE OF INCOMING SOLAR RADIATION INTENSITY

Micro Climate measurements	Outside the shading	Inside the shading
Incoming solar radiation (watt/m^2)	673.95 (58.23 MJ/m2/day)	473.11 (40.88 MJ/m2/day) s
Above ground temperature (^oC)	35.61	34.66 ns
Above ground humidity (%)	53.26	56.18 ns

T test with 95% confidence interval

The incoming solar radiation flux is the sum of the diffused (the incoming shortwave in the shade) and direct radiations incident on the earth's surface in the form of shortwave radiation. This is the energy that drives the hydrological cycle and determines the total amount of energy that is available at the earth's surface for life-giving processes including photosynthesis. The diurnal range of the incoming solar radiation at a Tropical station, Ile-Ife (7.53^0N; 4.54^0E), Nigeria during the dry months was 700.7±105.2 Wm-2 (Soneye, et al., 2019). Photosynthesis use part of the incoming solar radiation called PAR (Photosynthetic Active radiation). The use of simple PA R irradiance ratio values is an average of 0.44 (±0.01) in January to an average of 0.48 (±0.01) in July (Biyun and Cho, 2006).

The polyethylene shield consistently reduced the radiation intensity in average to about 200.51 watt/ m2 (statistically significant 14% reduced), it also could be said that the transmittance was about 70%. White shading had highest in direct and diffuse PAR transmittance 0.5-0.6 all day at all angles, reflectance 0.3-0.5 and lowest in absorbance 0-0.1 (Al-Helal and Abdel-Ghany, 2019). Transmitted solar radiation is the main source of energy in shading and released as sensible and latent heat while contribution of thermal radiation to the total energy in the greenhouse is low. More than 70% of the transmitted solar radiation is transformed to sensible heat used to increase the air temperature (Abdel-Ghany et al., 2019). At a plant density corresponding to a leaf area index (LAI) of 3, about 54% of the integrated solar radiation that was utilized by the greenhouse was converted to sensible heat and about 46% converted to latent heat via evapotranspiration (Abdel-Ghany, 2011).

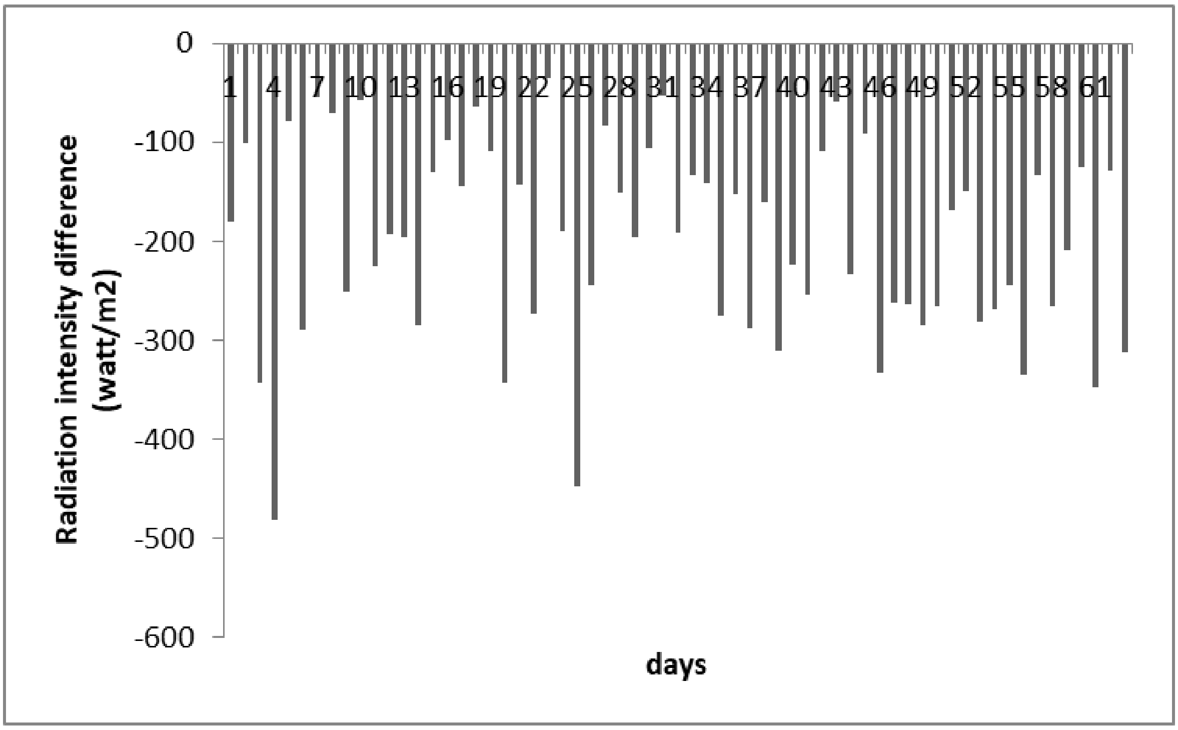

FIGURE 1: Incoming radiation intensity difference inside and outside the plastic shading

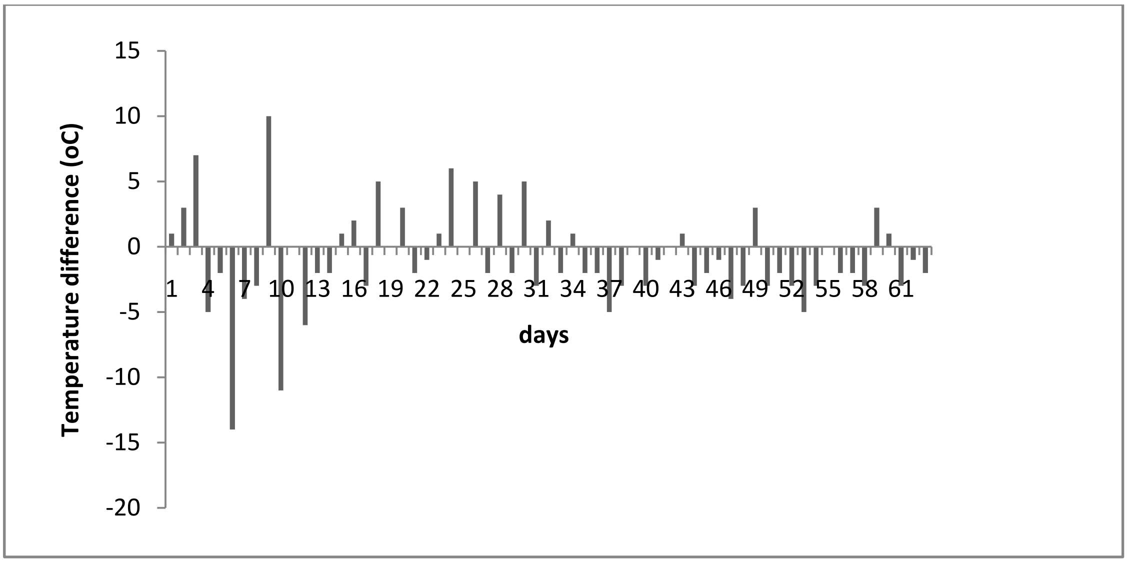

FIGURE 2: Above ground temperature difference inside and outside the plastic shading

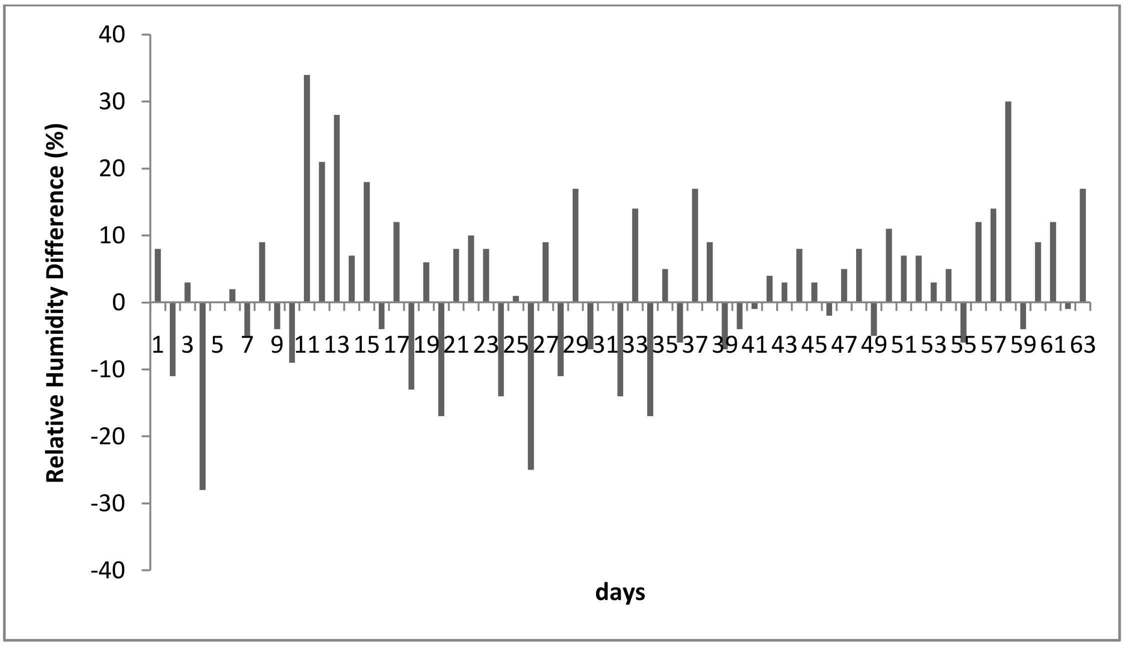

FIGURE 3: Relative humidity difference inside and outside the plastic shading

The above ground temperature inside the shading was not constantly lower compare to the open space even though in average, it was still reduced in about 0,92 ^{0}C. As explained above source for air temperature inside shading is sensible heat converted from the transmitted radiation, so that with little advection the temperature would not reduce much it even might be increased. Some research results noted that shading color had a predominant effect on the transmittance, reflectance and absorbance values. Plastic shading in hot and sunny regions slightly reduce average daily temperature 28.90 °C to 27.81 °C, white plastic shading was significantly lower temperature at night compare of the control. (Chen et al, 2019), 28.4°C to 29.1°C (Rigakis et al, 2012).

Air humidity was mostly higher inside the shade even though with just small differences (3%). While change of air temperature inside greenhouses is a function of the transmitted solar radiation, the ventilation, and the size of the greenhouse; the variation of RH inside greenhouses depends on temperature and air circulation. The higher the temperature, the lower relative humidity and the more intense the air circulation the lower the relative humidity (Holcman and Sentelhas, 2012). The humidity also showed that the transpiration rate was slightly higher under shading and open field conditions. It could be attributed to a possible increase in crop stomata conductance since temperature and air humidity is the variables with the greatest effect on stomatal conductance and transpiration rate (Shaban et al., 2016).

3.2 Lettuce Growth and Production

In general, growth and yield of crops are related to the amount of solar radiation received during the growing period. However, solar radiation could not be used as a single factor to estimate the performance of crops. Other interactions with other climatic variables, especially air temperature, must also be considered. Although air temperatures are related to solar radiation, this relationship is not constant, and may show variations in different seasons and/or locations (Sandri et al., 2003)

Since the temperature and humidity in this experiment could considered similar inside and outside the shield, it can be assumed that radiation difference was the main microclimate factor that effect the plant growth and yield difference of these types of the lettuce as shown in Table 2.

TABLE 2
LETTUCES GROWTH AND YIELD ON SHADING TREATMENTS

Variable	Treatments	Red lettuce	Romaine
Number of leaves	Open space	14.03	34.14
	Under shading	10.52 s	24.90 s
Leaves length (cm)	Open space	12.24	19.81
	Under shading	12.63 ns	19.86 ns
Leaves width (cm)	Open space	10.02	12.02
	Under shading	10.05 ns	11.13 s
Leaves area (cm^2)	Open space	41.41	89.94
	Under shading	40.55 ns	85.36 s
Stem Length (cm)	Open space	11.69	18.59
	Under shading	11.53 ns	23.56 s
Fresh Weight (gram)	Open space	46.50	228.00
	Under shading	35.39 s	123.97 s
Root Dry weight (gram)	Open space	0.54	3.91
	Under shading	0.47 ns	1.26 s

T test with 95% confidence interval

Numbers of leaves for both lettuce plants inside the shading were significantly lower. Leaves length and width and as consequences leaves area as well as stem length in Red lettuce were just similar in open and shading condition. Therefore, lower fresh weight was the results of fewer leaves. For Romaine lettuce even though leaves length was not significantly difference but the leaves width was lower and as consequences the leaves area was lower, and even though stem was longer but the fresh weight was still lower. Similar with the red lettuce lower number of leaves result in lower lettuce fresh weight. One research in Indonesia also showed that planted lettuce in open direct sunshine resulted in much better crops growth and development showed in all variables (Nurdianna, Putri and Harjoko, 2018). Full and direct sun radiation is important in lettuce cultivation and in general photosynthetic performance in greenhouse intensive production can be limited due to reduced distribution of the intercepted solar light along the canopy profile, which can reach levels of about 35%. If all factors to improve the efficiency of radiation use and the efficiency of crop light interception were optimized simultaneously, crop productivity could be improved by 36%–64% (Sandri et al., 2003).

Direct full sunshine with lower intensity combined with low temperature is the characteristic of highland area, the habitat of lettuce in Tropical area. The range of PAR 400 $\mu mol/m^2/s$ to 600 $\mu mol/m^2/s$ is a recommendable light intensity for lettuce production (Fu et al, 2012). With the conversion of solar radiation (Rs) Wm^{-2} to photosynthetically active radiation (PAR) is about ~ 2.02 (dos Reis and Ribero, 2020), then PAR in this experiment site was 673.95x0.48x2.02 =653.46 to 473.11x0.48x 2.02= 458.73 $\mu mol/m^2/s$ which was still in the range of recommended light intensity for lettuce production. However, the air temperature seemed too high for lettuce cultivation in lowland area.

IV. CONCLUSION

As this study aimed to understand whether highland crops could adapt to the lowland environment condition as a premiere study of the impact of climate change on crops, it can be concluded that radiation intensity might not be the problem as long as the temperature would not rise. Shading especially with polyethylene sheet may not be the solving method since it could raise the temperature inside the shading. In the nature it is possible that if the earth temperature keeps rising more crops will inhibit higher altitude.

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