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ORIGINAL ARTICLE

Analysis and Monitoring of Environmental Parameters in a Single-span Greenhouse during Strawberry Cultivation

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Abstract

In this study, strawberry cultivation environment in a greenhouse located in Jeonju was monitored and internal environmental parameters were analyzed. Temperature, humidity, RAD, and PPF sensors were installed to monitor environmental conditions in the test greenhouse. Data were collected every 10 minutes during four winter months from sensors placed across the greenhouse to assess its permeability and environmental uniformity. Temperature and humidity inside the greenhouse were relatively uniform with negligible deviations among the center, south, and north; however, it was judged that further analysis of gradients of these parameters from the east to the west of the greenhouse would be needed. Both RAD (Total solar radiation) and PPF (Photosynthetic photon flux) had high values on the south and were low on the north and the reduction rate of these parameters was 54% and 61%, respectively, indicating that a significant amount of light could not be transmitted. This implied a significant decrease in the amount of light entering the greenhouse during winter. Therefore, it is concluded that environmental control devices and auxiliary lighting are needed to achieve uniform greenhouse environment for efficient strawberry cultivation.

Key words : Single-span greenhouse, Strawberry, Environment, Monitoring

1. Introduction

Climate change and increased frequency of extreme weather events have become a social issue placed at the center of environmental problems worldwide. The Intergovernmental Panel on Climate Change (IPCC) anticipated that the average temperature of Earth will rise by about 2.8℃ over the next 100 years and reported that Korea has also experienced a temperature rise of about 0.5℃ over the past 10 years. In addition, extreme phenomena such as increased precipitation in summer, increased number of days with torrential rain, and extremely high temperatures are caused by climate change (Jeong et al., 2018). Such unusual weather conditions may cause many problems in agriculture, especially in environments unsuitable for crops that are reflected in low rate of photosynthesis, which can diminish crop quality and yield and disrupt agricultural management (Shin et al., 2008; Kim et al., 2009; Kim, 2013; Koung, 2014; Choi et al., 2015 Choe et al., 2016; Kim et al., 2017).

Environmental factors that mainly affect crop

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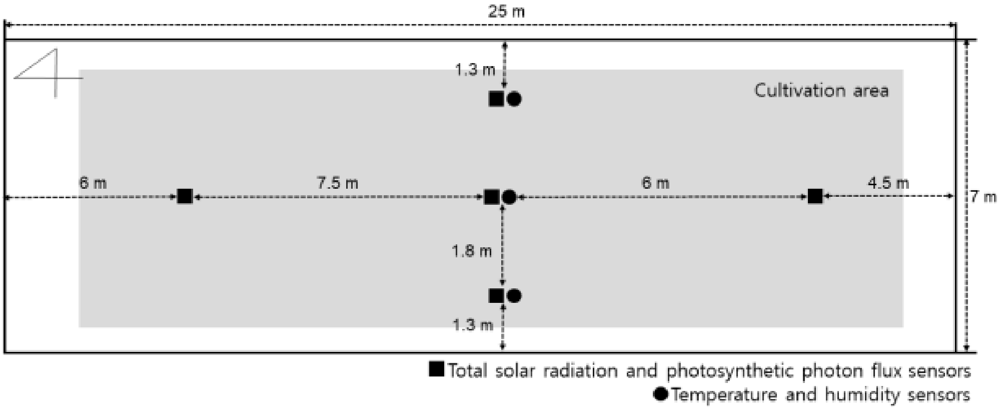

Fig. 1. Sensor installation locations.

growth are: light, temperature, humidity, carbon dioxide concentration in the atmosphere, and watering (Von Amin et al., 1996; Cha et al., 2006; Kang et al., 2010; Jung, 2012). Among them, temperature, humidity, and light play major roles in the photosynthesis and affect crop production (Zhong and Kato, 1988; Sin et al., 1991; El-Gizawy et al., 1993; Masuda and Shimada, 1993; Chung et al., 1998). Under inadequate temperatures and in humidity and light-deprived environments, crops are reported to be susceptible to physiological disturbances and diseases and to have reduced yield and quality due to poor absorption of nutrients (Kang et al., 2008; An et al., 2011). In particular, strawberries have been reported to catch gray mold disease due to abnormalities caused by the lack of sunlight and to abort flowers due to changes in humidity in their environment (Lee et al., 2017). Crops such as strawberries, grown in greenhouses during winter and spring, have available lower average amounts of sunlight than summer crops (Choi et al., 2019), which results in lower growth rates (Lee et al., 2020).

According to the previously stated facts, it is important to measure and analyze temperature, humidity, total solar radiation (RAD), and Photosynthetic Photon Flux (PPF) in greenhouses to effectively learn the most suitable internal environment for strawberry cultivation. This study was aimed at monitoring the internal environment of a strawberry-growing greenhouse in Jeonju during winter by assessing the uniformity of environmental parameters recorded in different locations inside the greenhouse.

2. Materials and methods

2.1. Test greenhouse and data measurement

The type of a test greenhouse used in this study for data collection was a single-walled vinyl house with the measures: 7 m × 25 m × 1.7 m (W × L × H). The greenhouse was built on a north-facing slope, facing east, and was covered with polyethylene cover (0.1 mm thick). Temperature and humidity sensors (U23, Onset Computer, USA), total solar radiation sensors (S-Llb-M003, Onset Computer, USA), and photosynthetic photon flux sensors (S-Llx, Onset Computer, USA) were used to measure temperature, humidity, total solar radiation (RAD), and PPF changes in the greenhouse. Temperature and humidity sensors were installed in the center, north, and south of the greenhouse near the level of the crop, while total solar radiation sensors and photosynthetic photon flux

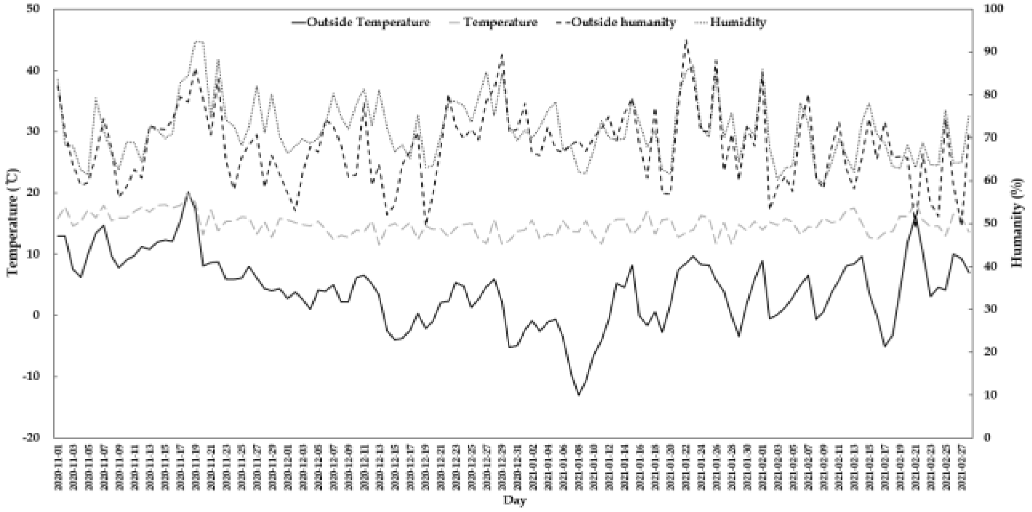

Fig. 2. Temperatures and humidity inside and outside the greenhouse presented monthly.

sensors were placed 1.35 m high and installed in the east, west, north, south, and central points (Fig. 1). As far as possible, sensors were placed to be unaffected by the greenhouse structure, particularly by the shadows of elements such as pipes that would affect the environmental parameters inside the greenhouse. The study was conducted during four winter months, from November 1, 2020 to February 28, 2021 and data were collected every 10 minutes.

3. Results and Discussion

3.1. Temperature and humidity analysis inside and outside the single-span greenhouse

Fig. 2 shows the distribution of internal and external temperatures as well as humidity in the described greenhouse located in Jeonju during winter. During the strawberry cultivation period, the average outside temperature was 4.3℃, the lowest temperature was -13.1℃ recorded in January, and the highest temperature was 20.2℃ recorded in November. Humidity averaged 88.4% (85.2~92.9%) and no significant fluctuations were observed during the cultivation period. Regarding the greenhouse interior, the average temperature was maintained at 14.9℃ (13.9℃~16.3℃) and the average humidity at 71.8% (67.8~73.9%). This was accomplished by a thermal effect using facilities such as multi-layered thermal insulation materials and heating devices to optimize crop growth. In addition, as a result of analyzing temperature and humidity distribution among the center, south, and north of the greenhouse, the obtained temperature deviation was 0.1~1.7℃ and the humidity deviation was 0.2~7.7%, indicating uniform distribution between the center, south, and north.

3.2. Analysis of total solar radiation inside and outside the single-span greenhouse

Fig. 3 shows the results of total solar radiation amount in the studied single-span greenhouse during winter. The average total solar radiation inside the greenhouse was 169.2 W/㎡ and values recorded in December and January were lower than in other two months. The average solar radiation measured during the experimental period was 177.4 W/㎡ on the east of the greenhouse, 173.7 W/㎡ on the west, 214.6 W/㎡ on the south, 103.8 W/㎡ on the north, and 176.6 W/㎡ at the center of the greenhouse. Total solar radiation at

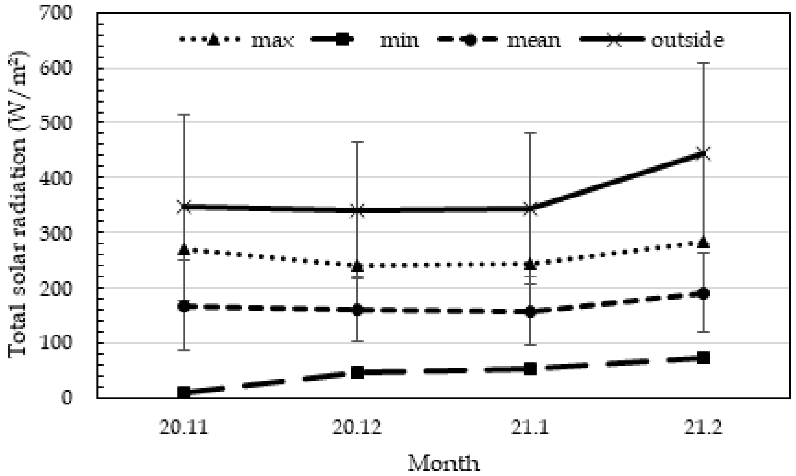

Fig. 3. Total solar radiation trend inside and outside the greenhouse presented monthly.

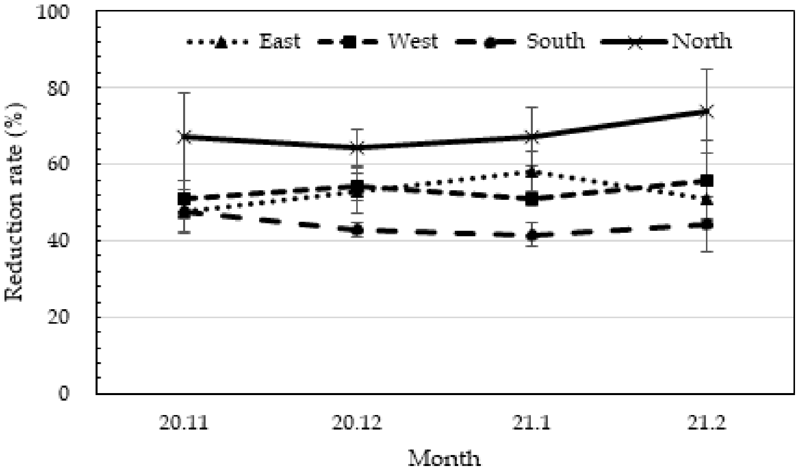

Fig. 4. Total solar radiation reduction rate by location inside the greenhouse presented monthly.

the center an on the east and west of the greenhouse slightly differed and the highest and the lowest values were recorded on the south and north, respectively, indicating that this parameter was unevenly distributed along the north-south direction. Fig. 4 shows reduction in the rate of total solar radiation through the greenhouse cladding based on the amount of solar radiation measured inside the greenhouse during the experimental period. The average total solar radiation reduction rate measured inside the greenhouse was 52.4% (36.5~75.9%) on the east, 53.0% (40.0~84.1%) on the west, 42.2% (26.8~66.2%) on the south, 68.1% (44.9~85.7%) on the north, and 52.7% (40.1~66.8%) at the center. Due to the direction of sunlight movement and the structure and materials used in the central part of the greenhouse, the reduction rate on both the north and the west sides of the greenhouse was high.

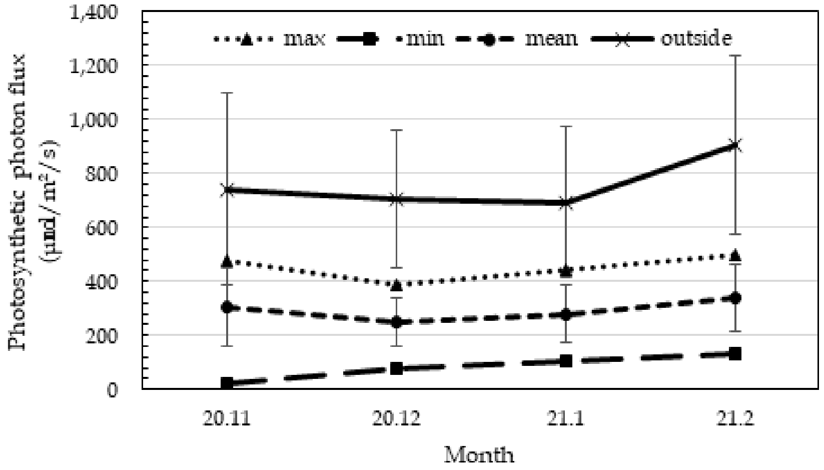

Fig. 5. Photosynthetic photon flux trend inside and outside the greenhouse presented monthly.

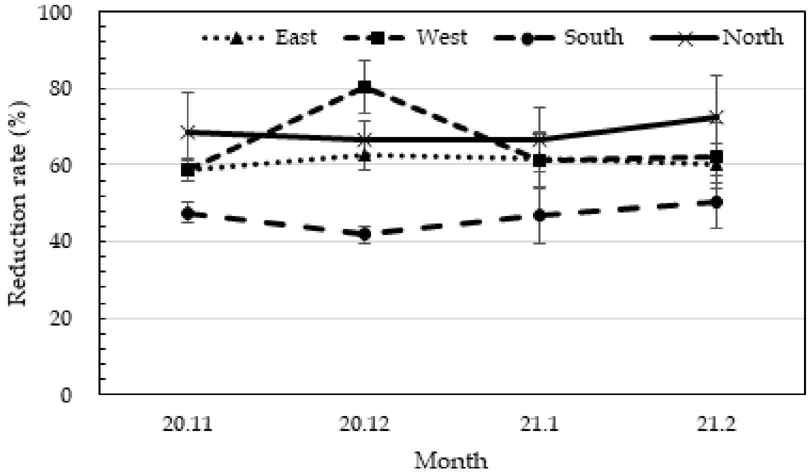

Fig. 6. Photosynthetic photon flux reduction rate by location inside the greenhouse presented monthly.

3.3. Analysis of photosynthetic photon flux inside and outside the single-span greenhouse

It is extremely important to measure the number of photons, because the photosynthesis of crops is not photogenic but photochemical reactions of photons. Photon count is termed PPF and is represented by the amount of micromoles of photons hitting a square meter per second. The results of analyzing winter PPF values in the strawberry-cultivated greenhouse are presented in Fig. 5. The internal average PPF value during the experimental period was 294.4 W/㎡ and monthly average value was the lowest in December, tending to gradually increase over time. Several differences among the locations inside the single-span greenhouse were found. During the experimental period, the average value of PPF was 298.7 μmol/m/s on the east, 266.7 μmol/m/s on the west, 387.6 μmol/m/s on the south, 211.9 μmol/m/s on the north, and 307.1 μmol/m/s at the center. In November, PPF values were below the light compensation point for strawberries due to weather conditions. In all measuring periods, PPF values below the light saturation point (800 μmol/ms/s) were measured, indicating that the amount of light needed for crop photosynthesis was insufficient during the winter. The percentage of PPF reduction was 60.9% (33.4~79.5%) on the west, 65.6% (34.3~90.5%) on the east, 48.6% (11.1~68.7%) on the south, 68.6% (46.3~84.8%) on the north, and 59.5% (33.2~71.6%) at the center (Fig. 6).

4. Conclusions

Climate change such as abnormal weather and extreme high temperature phenomena that are difficult to predict have a direct impact on agriculture. Changes in seasonal extreme temperatures and luminosity, resulted from abnormal weather, hinder crop growth and affect their yield.

In this study, the environment in a strawberry -cultivated greenhouse located in Jeonju was monitored and analyzed to collect basic data that would aid in responding to climate change. Temperature, humidity, RDA, and PPF sensors were installed inside the greenhouse to collect environmental data. Measurements of environmental parameters were carried out every 10 minutes from November 1, 2020 to February 28, 2021. Regarding temperature and humidity, measurements between the center, north, and south were uniform, but it was concluded that further analysis along the east-west direction would be necessary. RAD and PPF values were reduced as the light passed through greenhouse cladding and structures and this reduction was 54% and 61%, respectively, indicating a significant decrease in the amount of light entering the greenhouse. In addition, differences in these values among the east side, west side, south side, north side, and the center of the greenhouse were large, indicating that these parameters were not uniformly distributed. The observed uneven distribution of environmental gradients measured during the winter season inside this strawberry -cultivated greenhouse is expected to affect growth disorders and diminish production as they do not satisfy the environmental needs required for optimal crop growth. Based on these results, active control of environmental parameters and securing auxiliary light sources are necessary to improve strawberry quality and production during winter. The results of this study are expected to be used as basic data for strawberry cultivation in winter facility houses.

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REFERENCES

An, C. G., Hwang, Y. H., An, J. U., Yoon, H. S., Chang, Y. H., Shon, G. M., Hwang, S. J., 2011, Effect of LEDs (Light Emitting Diodes) Irradiation on growth of paprika (*Capsicum annuum Cupra*), J. Bio-Env. Con., 20(4), 253-257.

Cha, I. S., Cho, K. C., 2006, Study on characteristics of seed cultivation using artificial light source, The Korean Institute of Power Electronics, 178-180.

Choe, M. E., Kim, J. I., Jung, T. W., Kwak, D. Y., Kim, K. Y., Ko, J. Y., Woo, K. S. Song, S. B., Jung, K. Y., Oh, I. S., 2016, Waxy sorghum (*Sorghum bicolor* L.) variety 'Nampungchal' with lodging resistant and high yield, Korean J. Breed Sci., 48(2), 192-197.

Choi, D. W., Kim, D. C., Lee, J. E., 2015, Technologies relationships change analysis due to extension of anti-disaster greenhouses in oriental melon, J. Bio-Env. Con., 361-362.

Choi, H. G., Jeong, H. J., 2019, Effects of supplemental LEDs on the fruit quality of two strawberry (*Fragaria x Ananassa Duch.*) cultivars due to ripening level, Protected Horticulture and Plant Factory, 28(4), 302-310.

Chung, D. G., Young, S. J., Choi, Y. J., 1998, The effect of $CaCl_2$ foliar application on inhibition of abnormally fermented fruits and chemical composition of oriental melon (*Cucumis melo* L. Var. *makuwa Mak*), Journal of Korean Society for Horticultural Science, 16(2), 215-218.

El-Gizawy, A. M., Abdallah, M. M. F., Gomaa, H. M., Mohamed, S. S., 1993, Effect of different shading levels on tomato plants. 2 Yield and Fruit Quality, ISHS Acta Horticulture, 323, 349-354.

Jeong, J. W., Kim, S., Lee, I. K., So, N., Ko, H. S., 2018, Negative effect of abnormal climate on the fruits productivity - focusing on the special weather report-, Journal of Korean Agricultural and Forest Meteorology. 20(4), 305-312.

Jung, H. S., 2012, Characteristics of strawberries and seedling raising-method, Agricultural and Horticulture, 44-51.

Kang, I. G., Jeong, W. J., Lee, J. T., Myoung, G. E., Kang, B. Y., Kim, K. Y., Han, T. H., Lee, J. H., 2008, Effect of light levels on fruit quality and characteristics of strawberry, J. Bio-Env. Con., 17(1), 538-540.

Kang, Y. I., Kwon, J. K., Park, K. S., Yu, I. H., Lee, S. Y., Cho, M. W., Kang, N. J., 2010, Changes in growths of tomato and grafted watermelon seedlings and allometric relationship among growth parameters as affected by shading during summer, J. Bio-Env. Con., 19(4), 275-283.

Kim, Y. K., Back, S. B. Kim, J. G., Lee, M. J., Kim, M. J., Kim, H. S., Park, J. C., Hyun, J. N., Suh, S. J., Kim, S. J., Kim, J. C., Jeung, J. H., Choi, J. S., 2009, Anew six rowed and covered barley cultivar, “Hyedang” with lodging tolerance and high-yield, Korean J. Breed Sci., 41(4), 630-634.

Kim, Y. J., 2013, Abnormal climate’s effect on crop yield and its volatility - A case study of onions, Master Degree Dissertation, Seoul National University, Seoul, South Korea.

Kim, D. K., Choi, J. K., Kim, K. J., Kwan, O. D. Park, H. G. Seo, M. J., Lee, Y. H., 2017, Mungbean cultivar, ‘Suhyeon’ with short stem length, disasters resistance and high yielding, Journal of Korean Agricultural and Forest Meteorology, 16(4), 274-284.

Koung, C. P., 2014, The influence of abnormally temperatures on growth and yield of hot pepper (*Capsicum annum* L.), Master Degree Dissertation, Pusan National University, Busan, South Korea.

Lee, G. B., Choe, Y. U., Park, E. J., Park, Y. h., Choi, Y. W., Kang, N. J., Kang, J. S., 2017, Effect of removing corolla and calyx lobes on fruit shape and quality of strawberry, J. Environ. Sci. Int., 26(1), 87-96.

Lee, G. B., Lee, J. E., Je, B. I., Lee, Y. J., Park, Y. H., Choi, Y. W., Son, B. G., Kang, N. J., Kang, J. S., 2020, Effect of low-light intensity on growth, yield and quality of strawberries, J. Environ. Sci. Int., 29(2), 167-175.

Masuda, M., Shimada, Y., 1993, Diurnal changes in mineral concentrations of xylem exudate in tomato plants and their concentrations as affected by sunlight intensity and plant ages, Journal of Japanese Society for Horticultural Science, 61(4), 839-845.

Shin, K. M., Kim, G. Y., Roh, K. A., Jeong, H. C., Lee, D. B., 2008, Evaluation of agro-climatic indices under climate change, Korean Journal of Agricultural and Forest Meteorology, 10(4), 113-120.

Sin, G. Y., Jeong, C. S., Yoo, K. C., 1991, Effects of temperature, light intensity and fruit setting position on sugar accumulation and fermentation in oriental melon, Journal of Korean Society for Horticultural Science, 32(4), 440-446.

Von Amim, A., Deng, X. W., 1996, Light control of seedling development, Annual review of plant physiology and plant molecular biology, 47, 215-243.

Zhong, L. F., Kato, T., 1998, The effect of sunlight intensity on growth, yield and chemical composition of xylem exudate in solanaceous fruits, Kochi University, Japan.

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