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Discrimination of Environmental Factors Affecting Strawberry Yield[1]

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Abstract. This paper investigates the importance of various environmental factors that have a strong influence on strawberry yields grown in greenhouse using various pattern recognition methods. The environmental factors influencing the production of strawberries were six factors such as average inside temperature, average inside humidity, average CO2 level, average soil temperature, cumulative solar irradiance, and average illumination. The results of analyzing the observed data using Dynamic Time Warping (DTW) showed that the most significant factor influencing the strawberry production was average inside humidity, while it was found that average illumination was the lowest influential environmental variable. In addition, an increase in the level of co2 significantly affects the decrease in strawberry yield. Therefore, in order to increase the harvest of strawberries cultivated in the farms, it is necessary to manage the environmental factors such as thoroughly controlling the humidity and maintaining the concentration of CO2 constantly by ventilation of the greenhouse.

Keywords. Strawberry yields, environmental factors, graphic analysis method, dynamic time warping, inside humanity, CO2 level

1. Introduction

Strawberry is an important fruit crop in the Korea, and is a highly nutritious and very popular food source. In addition, strawberry is a fruit that can be utilized in various aspects such as cake making, dessert menu and juice making, so it is very high value added fruit. This trend is increasing the demand for strawberry. Therefore, strawberry cultivation has become a value-added business for farmers, and more attention has been paid to high-quality, high-yielding cultivation techniques.

For this reason, famers are therefore very interested in developing smart farming technology that can improve strawberry yields by combining agriculture and internet of things (IoT) technology. Utilizing the IoT technology, we measure the growth of crops and environment information from various observation sensors in real time. In addition,

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by using the extracted information, an optimal growth management system is constructed, technologies that can increase the productivity and the quality of the crops by automatically managing the crops are developed dramatically.

Previous studies related to these technologies until now are given as follows. Using a generalized randomized block design, Estrada-Oritz at al. [1] evaluated the effect of different percentages of phosphite added to the nutrient solution on the concentration of total P in leaves and the activation of the antioxidant system, which determines the concentration of anthocyanin, yield, pH, electrical conductivity, and strawberry fruit size. They suggest that supplying 20% phosphite in the nutrient solution improved strawberry fruit performance and that supplying 30% phosphite activated dense mechanisms in the plants, which increased the concentration of anthocyanins and improved fruit quality.

Letourneau et al. [2] had performed a field-scale experiment to simultaneously evaluate the impacts of three irrigation management scales and a pulsed water application method on strawberry yield and water use efficiency. The results of their experiment showed that spatial variability of the soil properties at the experimental site was important but most likely not enough to influence the crop response to irrigation practices.

Boyer et al. [3] carried out studies to investigate whether arbuscular mycorrhizal fungi (AMF) could improve strawberry production in coir under low nitrogen input and regulated deficit irrigation. Application of AMF led to an appreciable increase in the size and number of class 1 fruit, especially under either deficient irrigation or low nitrogen input condition.

Fan et al. [4] had evaluated the effects of plastic mulch (PM) and plastic mulch with row covers (PMRC) versus the conventional MRS, on total yield, yield per plant, average fruit weight, soluble solids content, treatable acidity, firmness, fruit postharvest quality, total phenolic content, total antioxidant content, oxygen radical absorbance capacity and phenolic composition analyzed by high-performance liquid chromatography in strawberry selection ‘SJ8976-1’ at different harvest times during the growing season.

Therefore, based on previous studies, we proposed a method to identify the various environmental factors affecting strawberry production using various pattern recognition methods. First, the relationship between production volume and environmental factors will be roughly examined through various graphs. Second, we will use the dynamic time warping method (DTW) to determine the interrelation between strawberry yield and environmental factors. Finally, based on the results of the analysis, a new cultivation method will be proposed to increase the strawberry production.

2. Dataset and Methods

2.1. Dataset

The data used in this study were based on data observed from three farms grown in the Gyeongbuk area in South Korea. The observed data consist largely of both the production of strawberries and the measurements of six environmental factors, respectively, given at the three farmhouses. These six environmental factors are average inside temperature, average inside humidity, average CO2 level, average soil temperature, cumulative solar irradiance, and average illumination.

The observation period was 38 observations from the first week of September, 2016 to the third week of May, 2017. Therefore, the data used in the analysis consist of both 7 variables including the yield, six environmental factors, and 38 observations. The specific variable names and units of measurement used in the analysis are given in Table 1 below.

Table 1. The list of variable names and measurement unit

Response and Environmental factors	Variable name	Measurement unit
Response factor		
The weekly cumulative yield	y	kg/m^2
Environmental factors		
Average CO2 level	X_1	ppm
Average inside temperature	X_2	℃
Average inside humidity	X_3	%
Average illumination	X_4	lx
Cumulative solar irradiance	X_5	mW/㎠
Average soil temperature	X_6	℃

2.2. Methods

First, the Dynamic Time Warping algorithm (DTW) has earned its popularity by being extremely efficient as the time-series similarity measure which minimizes the effects of shifting and distortion in time by allowing elastic transformation of time series in order to detect similar shapes with different phases [5]. Given two time series $X = (x_1, \cdots, x_N)$, $N \in \mathbb{N}$ and $Y = (y_1, \cdots, y_M)$, $M \in \mathbb{N}$ respectively by the sequences of values DTW yields optimal solution in the $O(MN)$ time which could be improved further through different techniques such as multi-scaling. The only restriction placed on the data sequences is that they should be sampled at equidistant points in time.

If sequences are taking values from some feature space Φ than in order to compare two different sequences $X, Y \in \Phi$ one needs to use the local distance measure which is defined to be a function:

$$d : \Phi \times \Phi \to \mathbb{R} \geq 0. \tag{1}$$

Intuitively d has a small value when sequences are similar and large value if they are different. Since the Dynamic Programming algorithm lies in the core of DTW it is common to call this distance function as the cost function and the task of optimal alignment of the sequences becoming the task of arranging all sequence points by minimizing the cost function.

Algorithm starts by building the distance matrix $C \in \mathbb{R}^{N \times M}$ representing all pairwise distances between X and Y . This distance matrix called the local cost matrix for the alignment of two sequences X and Y :

$$C_l \in \mathbb{R}^{N \times M} : c_{i,j} = \| x_i - y_j \|, i \in [1:N], j \in [1:M] \tag{2}$$

Once the local cost matrix built, the algorithm finds the alignment path which runs through the low-cost areas – valleys on the cost matrix. This alignment path (or warping path, or warping function) defines the correspondence of an element $x_i \in X$ to $y_j \in Y$ following the boundary condition which assign first and last elements of X and Y to each other, Figure 1.

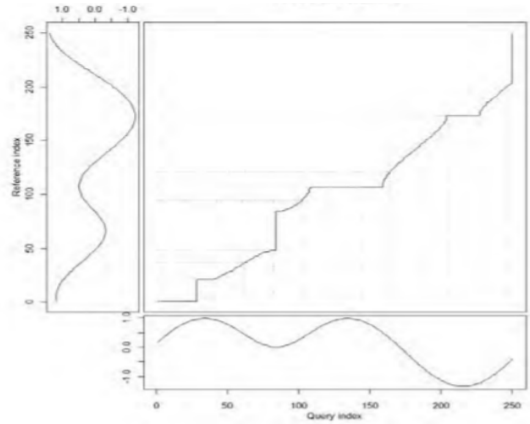


Figure 1. The optimal warping path alignment time series.

3. Experimental Results

First, Figure 2 and Figure 3 below are line graphs to roughly determine how the strawberry yields produced in the three farms A, B, and C are affected by the six environmental variables. From Figure 2 we can see that the yields of farms B and C are similar, while the yield of farm A is different from that of the other two farms.

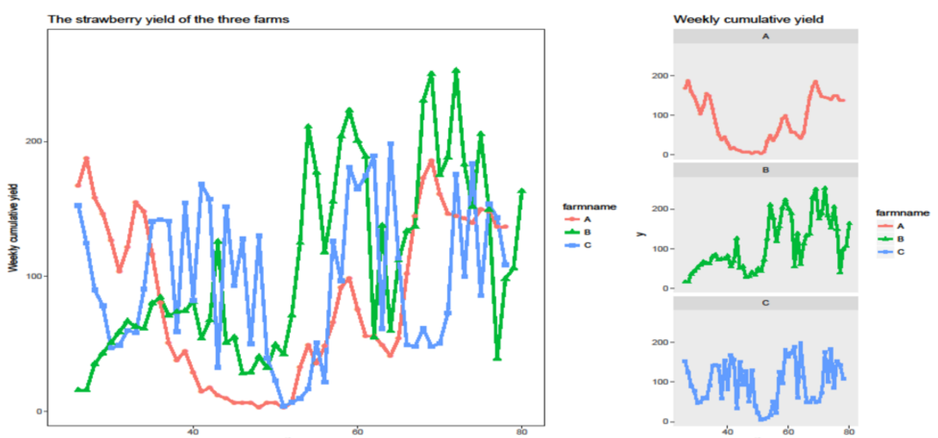


Figure 2. Strawberry production in three farms A, B, C

Also, from Figure 3 for six environmental variables, we can see that the level of CO_2 in farm B is very different from that in other farms, and that farm A has a remarkable difference from two farms with different cumulative solar irradiance.

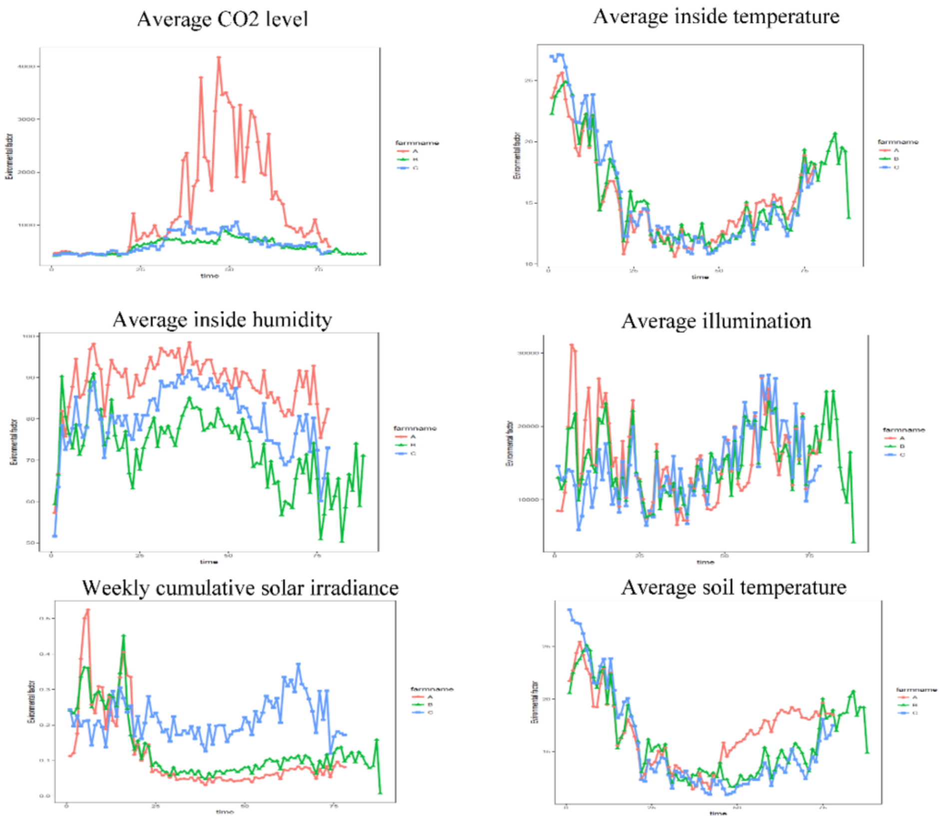
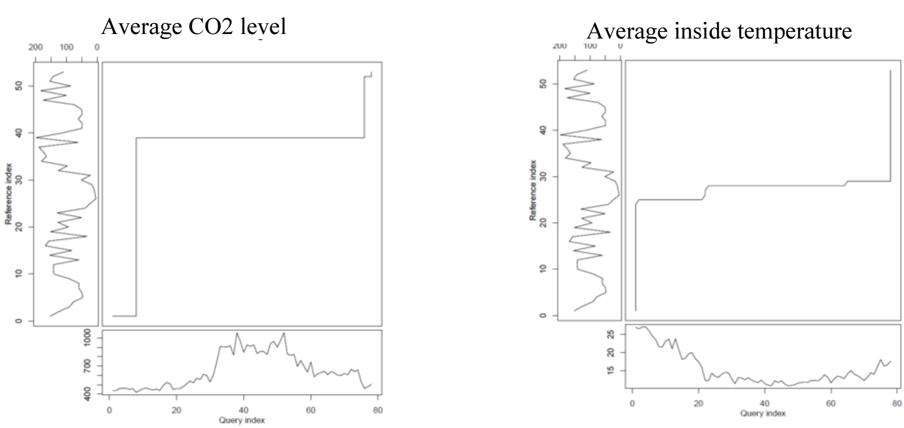


Figure 3. Measured values of six environmental variables.

Next, the results of applying the dynamic time warping method to obtain the relationship between the yields of strawberries produced in farms A, B and C and the six environmental variables are given as in Figure 4, 5 and 6.



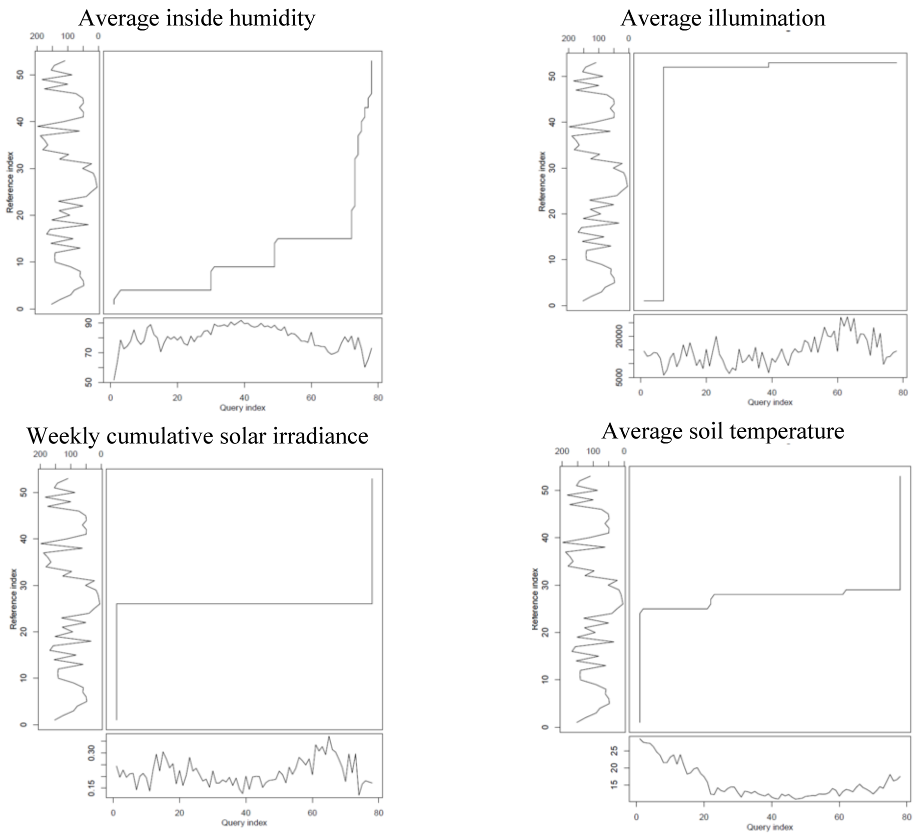
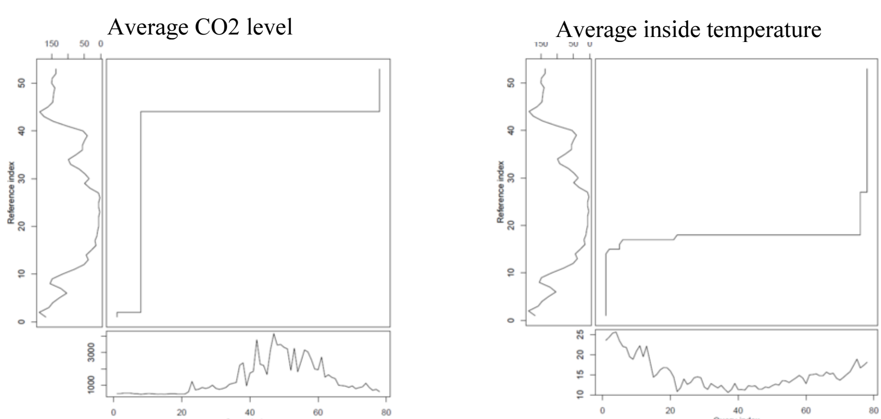


Figure 4. Effect of environmental variables on farm A

From the results in Figure 4, the most relevant environmental variables of yields of farm A were average inside humidity (x3), cumulative solar irradiance (x5), average inside temperature (x2) and average soil temperature (x6).



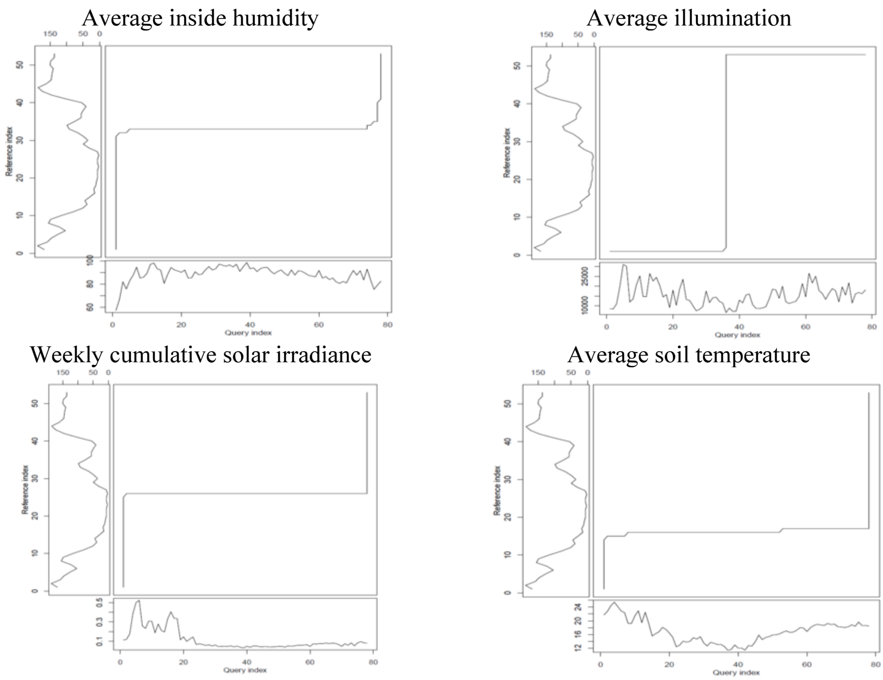
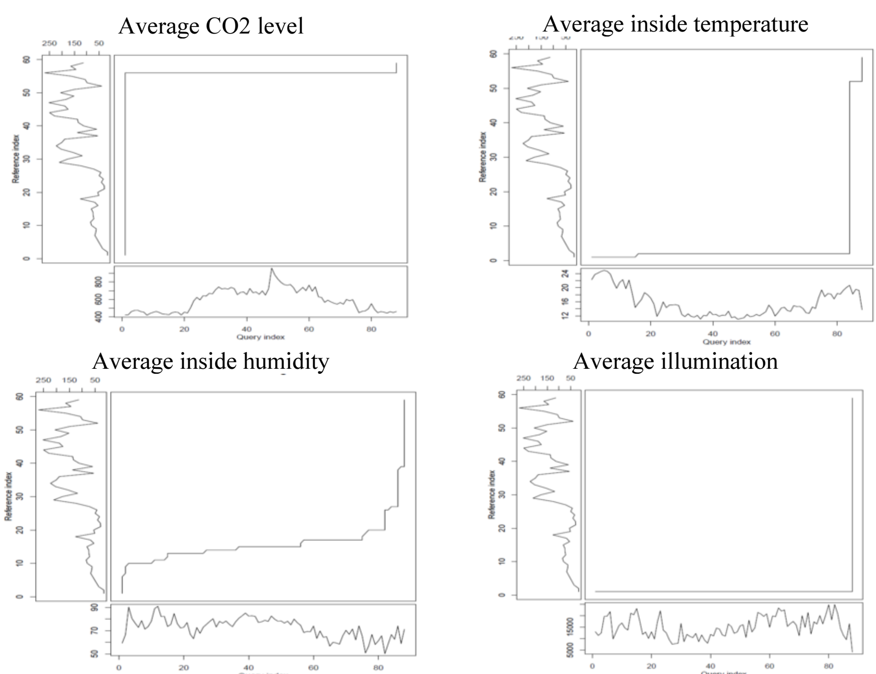


Figure 5. Effect of environmental variables on farm B

From the results in Figure 5, the most relevant environmental variables of yields of farm B were average humidity (x3), cumulative irradiance (x5), average soil temperature (x6) and average inside temperature (x2).



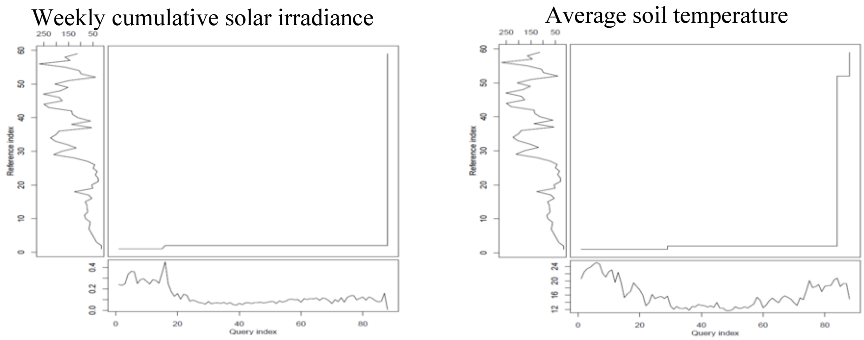


Figure 6. Effect of environmental variables on farm C.

From the results in Figure 6, the most relevant environmental variables of yields of farm C were cumulative solar irradiance (x5), average inside humidity (x3), average inside temperature (x2), and average soil temperature (x6). Therefore, when we compare the six environmental variables that affect the yield of the three farm, the average inside humidity is the most important environmental variable, while the least influential environmental variable is the average illumination.

4. Conclusion

In this paper, we analyzed the effects of six environmental variables affecting strawberry yields using real data collected from the three farms. The facts from the experimental results are as follows. First, the environmental variables that have the greatest influence on the strawberry yield are average inside humidity, average inside temperature, and cumulative solar irradiation. Second, average CO2 level greatly influence the increase and decrease of yield. Third, from the experimental results by comparing the strawberry yields in three farms, it is proper environmental variable management methods to maintain the concentration of CO2 constantly by ventilating the vinyl house thoroughly, and to thoroughly control the humidity in order to improve the strawberry yield of the greenhouse.

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