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PHENOTYPING OF LOW TEMPERATURE STRESSED PLANT SEEDLINGS USING INFRARED THERMOGRAPHY

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ABSTRACT

This study evaluated the feasibility of an infrared thermography technique for the phenotype analysis of pepper seedlings which exposed to low temperature environment. We employed an active thermography technique to evaluate the thermal response of pepper seedlings which exposed to a low temperature stress. After pepper seedling samples were planted under a low temperature environment at a temperature of 5°C and relative humidity of 50% during four periods (6, 12, 24, and 48 h), the temperature of pepper seedling leaves was measured in the room temperature surroundings at a temperature of 23°C and relative humidity of 70% using infrared camera shortly after they were taken out from the low temperature environment. In addition, we also have measured the visible images of pepper seedling samples which are exposed to low temperature stress to estimate the appearance changes of them. The largest appearance change was observed at the low temperature stressed pepper seedlings which are planted for 12 h, and the temperature from pepper seedling leaves which exposed to low temperature environment for 12 h was the highest among all samples. In addition, the thermal image of low temperature stressed pepper seedlings for 6 h showed the lowest temperature than others. We demonstrated that the leaf withering state due to the water deficiency which happened under a low temperature conditions can induce an increasing temperature from plant leaves by using infrared thermography technique. These results suggest that the time-resolved and averaged thermal signals or temperatures of plants can be significantly associated to the physiological or biochemical characteristics of plants which are exposed to low temperature stress.

KEYWORDS: Phenotype analysis, Infrared thermography, Low temperature stress, Exothermic response

1. INTRODUCTION

In situations where the Earth's climate is gradually changing, it is needed to develop the plants or seeds which are robust to environmental stresses such as low temperature and water deficiency. Plants can be easily exposed to various environmental stresses, and it is commonly known that a low temperature is one of key factors which can influence plant growth and productivity. During low temperature stress and subsequent recovery periods, plants may develop several mechanisms to minimize potential damages. In addition, their response for low temperature will be highly complex process that involves any physiological and biochemical modifications. It was reported that the plant responses to low temperature are widely different from species to species. However, a common mechanism of plants to low temperature is changes in membrane lipid composition to protect their membrane stability and integrity [1]. In addition, the reasons of the change of membrane lipid composition were observed as the increase in the unsaturation of fatty acids when plants are exposed to low temperature [2, 3]. An increase was observed in the level of unsaturation when the plants were grown at 4°C, and it was also demonstrated that a desaturation played a major role in the low temperature tolerance mechanism of membrane lipids by revealing the tolerant plants showed a very fast accumulation in unsaturated acids compared to the low temperature sensitive plants [2]. In this study, we constructed an infrared signal measurement system consisting of a far-infrared (7.5-14 μm) camera and computer system for the phenotype analysis of pepper plant under low temperature stress and subsequent recovery process. Pepper seedlings are planted under a low temperature environment (5°C and RH of 50%) during four periods (6, 12, 24, and 48 h), and then infrared thermal signals of them were measured using an infrared camera, and the thermal image processing methods were developed to analyze the temperature distribution of pepper seedling leaves.

2. MATERIALS AND METHODS

2.1 MEASUREMENTS OF INFRARED THERMAL IMAGES

Temperatures from pepper seedling leaves were measured using an infrared camera (VarioCAM, InfraTec GmbH, Germany) that has a 640 × 512 pixel resolution and the sensitivity of 7.5-14 μm spectral range as shown in Figure 2. The detector in the scanner unit was micro bolometer, and the temperature sensitivity was 30 mK. The digitized thermal signals from pepper seedling leaves transferred to the computer, and were registered in a disk memory using commercial software (IRBIS3, InfraTec GmbH, Germany). In this study, we employed an active thermography technique to evaluate the thermal response of pepper seedlings which planted in a low temperature environment. In an active approach, an external stimulus is required to generate relevant temperature differences not present otherwise. The temperatures of pepper seedling leaves which planted in a low temperature conditions environment at a temperature of 5°C and relative humidity of 50% during four periods (6, 12, 24, and 48 h) were measured under controlled laboratory conditions at a temperature of 23°C and relative humidity of 70% shortly after pepper seedling samples were taken out from the low temperature condition.

3. CONCLUSIONS

Consequently, we demonstrated that the leaf withering state due to the water deficiency which happened under a low temperature conditions can induce an increasing temperature from plant leaves by using infrared thermogaphy technique. These results suggest that the time-resolved and averaged thermal signals or temperatures of plants can be significantly associated to the physiological or biochemical characteristics of plants which are exposed to low temperature stress. We expect that this infrared thermography technique including the thermal image measurement system and infrared image analysis software can potentially be used in the phenotype analysis of biological and agriculture industry.

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