Yield Loss and Quality Degradation of Strawberry Fruits Cultivated Under the Deficient Insolation Conditions by Shading

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Abstract. Deficient insolation conditions (DICs) frequently occur during the winter and early spring season in Korea and negatively affect crop growth. This study was conducted to investigate changes in the yields and qualities of strawberry fruits under DICs that result from an insufficient input of sunlight. To induce DIC, strawberry plants were treated with 40 or 70% shading by covering the plants with curtains during growth in a plastic greenhouse. The shaded plants were cultivated from March to May of 2012. When the strawberry plants were subjected to the shading treatments, their photosynthesis and fruit yields were significantly reduced. Although the mineral element and organic acid contents of the fruits were not affected by the shading treatments, the total nitrogen (T-N) of the stems and roots were noticeably reduced. Furthermore, the shading treatments of the plants also resulted in reductions in the sugar contents and total phenolics of the fruits. In parallel with these observations, the shading treatments were also found to decrease the antioxidant activities of the fruits as measured with the DPPH assay. We suggest that the DIC-induced losses of strawberry fruit yield resulted from the reduced photosynthetic performances of the plants that were caused by insufficient sunlight.

Additional key words: antioxidant, photosynthesis, sugar contents

Introduction

The elevation of the earth’s temperature due to the carbon dioxide produced by the ever increasing use of fossil fuels, has led to serious global warming problems. The abnormal climate changes in the Korean peninsula are also believed to have resulted in part from the rapid melting of the Arctic glaciers, which has been accelerated by global warming. The abnormal weather due to global warming has been reported to significantly affect the growth of crops (Wurr et al., 1996), including rice (Peng et al., 2004) and potato (Hijmans, 2003).

In the greenhouse horticulture industry of Korea, vegetable shipment is performed primarily in the winter and early spring season; therefore, the weather at the season is important in this local region. Deficient insolation conditions (DICs) caused by continuously cloudy weather during the season are believed to be detrimental to the cultivation environments of greenhouse facilities. Leaves illuminated with light of intensities above 2,000 lux exhibit much higher efficiencies in terms of photosynthetic quantum conversion compared to leaves under shade (Lichtenhailer et al., 1981). Moreover, lowlight intensities have been found to be responsible for reductions in the biomass of lettuce plants (Fu et al., 2012). It is apparent that the frequent occurrence of cloudy days during the season constitutes one of the primary causes of reductions in the temperatures of greenhouses and depresses the photosynthetic efficiencies of crops.

Strawberry plant (Fragaria × ananassa Duch.) is a member of the perennial rose family and represent one of the major horticultural crops of Korea. The ‘Daewang’ cultivar of the strawberry plant is popular among Korean farmers because this cultivar is noted for its high levels of fruit hardness. The strawberry production value in Korea of 2010 was reported...
more than 1 billion dollars according to the statistics of Ministry of Agriculture, Food and Rural Affairs (MAFRA), which ranks next to the earning from pepper production in Korea. Strawberry planting in greenhouses is performed in September, and the harvest usually begins between November and May of the following year. During the season, external environmental factors affecting cultivation strongly influence both the yield and quality of strawberry fruits.

Strawberries contain high levels of antioxidants, such as phenolics, flavonoids, and anthocyanins, which have been reported to correlate with decreased risks for chronic diseases (Meyers et al., 2003). The total phenolics and anthocyanins produced by strawberries have also been implicated in the health benefits of phytochemicals (Ordidge et al., 2010). These phytochemicals have functional roles in plant growth and metabolism and are also essential for the nutritional and organoleptic qualities of the fruits (Tulipani et al., 2008). Eventually, phytochemical levels were adopted as important criteria for the evaluation of fruit quality. Several methods are frequently employed to estimate the antioxidant capacities of fresh fruits for clinical studies, including the 2,2-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) and 2,2-diphenyl-1-picryl-hydrazyl (DPPH) assays (Thaipong et al., 2006). Antioxidant activity is another important criterion that can be to evaluate fruit quality.

Little is known about how the imposition of DICs on strawberry plants during cultivation, affects the production of fruits in terms of yield or quality. In this study, we attempted to investigate the extents of yield loss and quality degradation in strawberry fruits subjected to DICs.

Material and Methods

Plant Materials and Cultivation

This study was carried out at the protected horticulture research station near Busan city in Korea (located in Busan city of Korea, 35°13′N, 129°10′E). Strawberry (Fragaria × ananassa Duch. cv. Daewang) seedlings were planted onto high-bench beds filled with coir medium located inside a plastic greenhouse at the October 10, 2011 and nutrient solutions were supplied through drip irrigation system. Fruits were normally harvested until February and then all remaining were fruit thinned. Our study treatments were began at March and fruits harvest was restarted at April and continued until May of 2012. For the DIC treatments, the plants were allowed to receive daily sunlight levels that corresponded to 40 or 70% of the intensity of the natural light via covering the ceiling of the plastic greenhouse with curtains. A non-shaded condition was used as the control. Nutrient solution (Research Station for Floriculture and Glasshouse Vegetables, Aalsmeer, The Netherlands) was given to plants for one minute as many as five times a day at a concentration of EC 1.2 dS·m⁻¹. Solar radiation and photosynthesis were measured using a portable spectroradiometer (LI-1800, LI-COR, Lincoln, NE, USA) and portable photosynthesis equipment (LI-6400, LI-COR, Lincoln, NE, USA), respectively, in the greenhouse on the April 26 (a sunny day, from 13:00 to during 2 hours) of 2012. The solar radiation was measured at 1 m from ground and measuring photosynthesis part of leaf was point upper one-third point of the 15-day-old leaves.

Determination of the Mineral Concentrations of the Plants

Samples of stems, leaves, roots and fruits were harvested on the April 25, 2012 and used in mineral analysis. Briefly, the samples were dried at 70°C in an oven for two days and carefully ground to powder with a pestle and mortar. The total nitrogen (T-N) contents were determined according to Kjeldahl method (Kjeldahl, 1883), and phosphorus (P) contents were determined by the chloro-stannous-reduced molybdophosphoric blue-color method (Jackson, 1973). The concentrations of calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) were also determined by atomic-absorption spectroscopy (Integra XM2, GBC Co., Sydney, Australia).

Preparation of Plant Extracts

To determine the sugars, organic acid, and phytochemicals contents and antioxidant activities of the fruits, fully matured strawberry fruits were harvested on the April 25, 2012. Samples of 50 g of fresh fruits were macerated in a homogenizer (PT-3100, Kinematica AG Co., Lucerne, Switzerland) and centrifuged (64R Centrifuge, Beckman Coulter Inc., CA, USA) at 16,000 g for 30 min at 4°C. The extracts were passed through filter papers (Whatman No. 2) and rapidly frozen at -70°C.

Analysis of Sugars and Organic Acids

After the frozen samples were thawed and subsequently filtered through 0.45-μm-membrane filters, the filtrates were diluted with distilled water. Sugar content tests were performed using HPLC on a high-pressure liquid chromatography (YL9100, Younglin, Anyang, Korea) equipped with a SugarPak (4.6 mm × 250 mm, Supelco, PA, USA) column and an RI detector. The separation was conducted at 30°C with a mobile phase of acetonitrile and water (75:25 ratio, v/v) at a flow rate of 1 mL·min⁻¹. The identification of the sugars in the fruits was performed by comparing reference retention times of the individual sugars to those of the tested solutions. The quantitative assays were performed for fructose, glucose, and sucrose. The contents of carbohydrates were calculated.