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Research article

Assessment of microclimate conditions under artificial shades in a ginseng field

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ABSTRACT

Background: Knowledge on microclimate conditions under artificial shades in a ginseng field would facilitate climate-aware management of ginseng production.
Methods: Weather data were measured under the shade and outside the shade at two fields located in Gochang-gun and Jeongeup-si, Korea, in 2011 and 2012 seasons to assess temperature and humidity conditions under the shade. An empirical approach was developed and validated for the estimation of leaf wetness duration (LWD) using weather measurements outside the shade as inputs to the model.
Results: Air temperature and relative humidity were similar between under the shade and outside the shade. For example, temperature conditions favorable for ginseng growth, e.g., between 8°C and 27°C, occurred slightly less frequently in hours during night times under the shade (91%) than outside (92%). Humidity conditions favorable for development of a foliar disease, e.g., relative humidity > 70%, occurred slightly more frequently under the shade (84%) than outside (82%). Effectiveness of correction schemes to an empirical LWD model differed by rainfall conditions for the estimation of LWD under the shade using weather measurements outside the shade as inputs to the model. During dew eligible days, a correction scheme to an empirical LWD model was slightly effective (10%) in reducing estimation errors under the shade. However, another correction approach during rainfall eligible days reduced errors of LWD estimation by 17%.
Conclusion: Weather measurements outside the shade and LWD estimates derived from these measurements would be useful as inputs for decision support systems to predict ginseng growth and disease development.

1. Introduction

Panax ginseng Meyer is well grown under high levels of shade because it is adapted to shade conditions [1]. For example, the understory of a temperate forest is common habitat for wild ginseng. Artificial shades provide an ideal environment for growth of ginseng in a field.

The microclimate conditions of ginseng grown under shade structures would be different from those of other field crops. For example, most of direct beam solar radiation would be blocked by the shade, which would allow ginseng growth under a shade condition. Wind speed would be slower under the shade, which would limit evaporation of water droplets on leaves. These changes would create microclimate conditions favorable for the development of plant diseases [2,3] as well as ginseng growth. For example, yield of ginseng is often limited by outbreaks of foliar disease including *Alternaria panax* which causes considerable damage in ginseng production in Korea as well as North America [2].

Measurement of microclimate conditions under artificial shade would be helpful for the management of ginseng production because these conditions determine risks of foliar disease as well as growth of ginseng. Still, measurements of weather variables under the shade

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would require considerable labor and cost for installation and maintenance of electrical sensors. Alternatively, weather data could be obtained from national weather services for management of crop. For example, Korea Meteorological Administration provides digital forecast data at a township scale, which is about 5 km of spatial resolution. However, these data represent weather conditions in an open field.

Little effort has been made to assess and to estimate microclimate conditions under the shade in a ginseng field for application of a decision support system to ginseng management. Because microclimate is considered altering by artificial shades in a ginseng field, it is essential to examine if weather data obtained outside the shade could represent microclimate conditions for ginseng management or not. Furthermore, a model to estimate microclimate conditions under the shade could be developed using knowledge on the relationship between under the shade and outside the shade. For example, reasonable estimates of leaf wetness duration (LWD) under the shade, which is an important factor for the development of foliar diseases, could be obtained using weather measurements outside the shade as inputs to an LWD model.

The objectives of this study were: (1) to assess microclimate conditions between under the shade and outside the shade in a ginseng field; and (2) to develop correction schemes for improving the estimation of LWD under the shade using an existing LWD model. Reliable microclimate data at a ginseng field would facilitate the operation of a decision support system for effective and timely ginseng management, e.g., yield prediction model or disease warning system.

2. Materials and Methods

2.1. Shade settings at experiment sites

Microclimate variables including temperature, humidity, and LWD were analyzed at two commercial ginseng fields located in Gochang-gun (N 35° 25′ 07′, E 126° 39′ 45′) and Jeongeup-si (N 35° 34′ 23′, E126° 46′ 28′), Jeollabuk-do, Korea. Four-yr-old and 5-yr-old ginsengs were growing at Jeongeup and Gochang, respectively. Shade structure was a rear line link type at both sites. Two types of shade netting, i.e., single and double netting, were used depending on site and season. The double shading net used at the Gochang site had a two-layer black polyethylene (P.E.) net on top of three-layer black and blue P.E. net throughout the growing season in 2011. At the end of season in 2011, the two-layer P.E. net was removed on May 19, 2012. Later, the two-layer P.E. net was installed again until the end of the 2012 season. At the Jeongeup site, a single shade netting of three-layer black and blue P.E. net was installed at the beginning of 2011 season. From May 19, 2011 onwards, a two-layer black P.E. net was added and used throughout the 2011 season at the same site. In 2012, double shading nets were used throughout the growing season at the Jeongeup site.

2.2. Measurement and analysis of microclimate variables

A set of sensors was deployed to measure air temperature, relative humidity (RH), precipitation, and wind speed in ginseng fields (Table 1). A pair of sensors was used to measure air temperature and RH under the shade and outside the shade. An anemometer was installed at 3 m high to measure wind speed outside the shade. In 2011, measurements of weather variables were averaged for 60 min. In 2012, those measurements were averaged for 30 min. Because of sensor malfunctions, temperature and humidity at Gochang in 2012 were measured only from a single set of sensors under the shade.

Unpainted flat panel sensors were used to detect occurrence of wetness under the shade. Because unpainted sensors tended to detect less wetness duration when small water droplets were formed on the sensors [4], a pair of wetness sensors was installed [5,6]. It was assumed that wetness occurred when wetness was detected by at least one sensor. Hours with wetness occurrence was classified to a "wet" hour. Remaining hours were identified as a "dry" hour.

Table 1
List of sensors installed to assess microclimate in the ginseng field

Measurement type	Sensor
Air temperature and RH	HMP45, Vaisala, Helsinki, Finland
Wind speed	03001 wind sentry anemometer, Campbell Scientific, Logan, Utah, USA
Precipitation	TE525WS, Campbell Scientific, Logan, Utah, USA
Leaf wetness duration	Model 237, Campbell Scientific, Logan, Utah, USA
Data logger	CR10X, Campbell Scientific, Logan, Utah, USA

RH, relative humidity

To assess microclimate conditions altered by the shade, air temperature and RH measurements under the shade and outside the shade were compared. It was assumed that a temperature between 8°C and 27°C would represent a favorable condition for ginseng growth based on the Ecocrop database of the Food and Agriculture Organization (http://ecocrop.fao.org). Quayyum et al [7] reported that conidia of *A. panax* could geminate under temperature at 25°C and RH $>$ 70%. Thus, it was assumed that RH $>$ 70% would represent a humidity condition favorable for disease development. The frequencies of hours during which temperature and humidity conditions favorable for ginseng growth and disease development were met were compared between under the shade and outside the shade.

Occurrence of wetness on leaves would differ between days without rainfall, e.g., dew eligible days, and with rainfall, e.g., rainfall eligible days (Appendix 1). Daily data sets were classified into dew eligible days and rainfall eligible days depending on occurrence of rainfall ($>$ 0.25 mm/d) to analyze LWD. Because wetness would occur readily during night time, time period from 12:00 PM to 11:59 AM the next day was used to assess LWD in a 24 h period. In addition, hours from 18:00 PM to 8:00 AM the next day were defined as a night-time period.

2.3. Correction schemes for a model to estimate LWD under the shade

The empirical model suggested by Kim et al [8] was used to estimate LWD under the shade in ginseng fields. It was reported that the empirical model based on a fuzzy logic system had greater spatial portability than other LWD models [9]. This empirical model depends on net radiation, vapor pressure deficit, and wind speed at a sensor surface, which are derived from air temperature, RH, and wind speed measured in an open field [8]. Outputs of the empirical model can be adjusted to a specific condition on occurrence of wetness [10,11]. For example, a correction factor of the empirical model has been used to improve LWD under semiarid climate conditions [12].

Lee et al [13] suggested that errors of the empirical model could be reduced under the shade when a correction scheme would be applied to the model (Appendix 1). A set of correction schemes for the empirical model were applied to take into account microclimate conditions under the shade in estimation of LWD. Kim et al [14] suggested that the empirical model could be adjusted to unpainted sensors as follows:

$$F_U = f_U \cdot F \tag{1}$$

where F_U represents the corrected estimates of wetness occurrence to output value, F, of the empirical model for unpainted sensors. The