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Protecting grapevines from rainfall in rainy conditions reduces disease severity and enhances profitability

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ABSTRACT

The growing season of grapes is often associated with high levels of rainfall in the Chinese rainy regions, which leads to serious grape diseases. In this study, we sheltered grapevines from rainfall for the purpose of disease management. Experimentally (2007 and 2008), it was found that rain shelter could block the rainfall and clearly reduced the average daily leaf wetness duration and the relative humidity in the canopy compared with open field cultivation. The average severities of grape ripe rot, white rot, downy mildew, grey mould, and brown spot on the Red Globe cultivar were reduced by 85, 73, 81, 54, and 68% compared with fungicide sprays. The average severities of grape ripe rot, white rot, grey mould, and brown spot on the Shuijing cultivar were reduced by 84, 65, 100, and 73% compared with fungicide sprays. Rain shelter increased grape yields by an average of 110–176% and increased farmers' income by an average of 80–193% compared to fungicide sprays. Large-scale field monitoring from 2009 through 2012 unequivocally confirmed that rain shelter could effectively and stably control the main grape diseases. Although powdery mildew infections were more severe in plants under rain shelter cultivation than in plants under open field cultivation, this disease could be effectively controlled by one application of prochloraz and one application of difenoconazole during the growing season in vineyard trials under rain shelter from 2011 through 2013. These results demonstrated that protecting grapevines from rainfall is an efficient disease management technique with extensive application prospects in rainy regions.

1. Introduction

Table grapes are widely produced and consumed in China. The grape planting area and yield in China ranked first in the world in recent years (OIV, 2012; Li, 2001). Especially in southern China, the grape planting area has increased rapidly in the past decades due to early ripe time and high market value. However, the grape growing season in southern China coincides with rainfall during the berry maturation period, which results in severe disease outbreaks and epidemics (Wang et al., 2005; Meng et al., 2013). In the vineyards of southern China, outbreaks of the most economically important diseases, such as downy mildew [*Plasmopara viticola* (Berk. & Curtis.) Berl. & de Toni], ripe rot (*Colletotrichum gloeosporioides*), white rot (*C. petrakii* B. Sutton), black rot (*Guignardia bidwellii* f. *muscadinii*), brown spot [*Pseudocercospora vitis* (Lev) Speg], and grey mould (*Botrytis cinerea* Persoon), occur easily due to rainfall (Su et al., 1999; Wang et al., 2005). Losses may range from 40 to 90% depending on the inoculum level, weather, and cultivar susceptibility (Wang et al., 2005). Reductions in fruit quality and yield cause significant economic losses to the grape industry and make grape production difficult in southern China (Wang et al., 2005). Developing a disease management program that successfully controls the main grape diseases would therefore increase the profitability of grape production in southern China.

Various methods for grape disease management, such as cultural practices, use of resistant cultivars, and fungicide application, have been employed over the past three decades (Su et al., 1999; Wang et al., 2005). However, the most important strategies for grape disease management are still based on the routine application of fungicides (Su et al., 1999; Wang et al., 2005; Bettiga, 2013).

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These scheduled fungicide spray programmes are in turn based on grape growth stages rather than on forecasting models based on disease and weather conditions. Furthermore, the effectiveness with which grape diseases can be controlled by fungicides has been hampered by excessive rain wash and pathogen resistance (De Waard et al., 1993; Su et al., 1999; Gullino et al., 2000). Thus, grape diseases have not been effectively controlled by fungicides in the vineyards of southern China.

In recent years, a simple method has been used to avoid the damaging effects of rainfall in southern China; essentially, grape leaves and fruits are covered by a plastic film during the rainy season. This method effectively overcomes rain problems, improves fruit quality, and achieves satisfactory economic and social benefits (Sun et al., 2006; Meng et al., 2013). However, few studies have examined the effect of vine canopy sheltering on the occurrence and development of table grapes diseases in the southern region of China.

In this study, we selected the vineyards in Yunan province, a typical table grapes production region in southern China, to (1) evaluate the effect of a rain shelter on grape disease development, the canopy microclimate, grape yield, and grape quality in vineyard trials; (2) monitor the development of grape disease in plants under the rain shelter in six different table grapes planting regions in Yunnan Province; and (3) explore the use of rain shelter combined with fungicides to manage grape powdery mildew.

2. Materials and methods

2.1. Effects of rain shelter on disease development, canopy microclimate, and berry quality in vineyard trials

2.1.1. Experimental plots

In 2007, 2008, two vineyards in Yunnan Province were selected as experimental plots. One vineyard, which was planted with the local grape cultivar Shuijing for 5 years, was located in Mile County (24° 24′ 14.49″ N; 103° 26′ 54.30″ E, 1426 m a.s.l). The other vineyard, planted with the cultivar Red Globe for 4 years, was located in Shilin County (24°48′ 31.87″ N; 103° 24′ 1.25″ E, 1915 m a.s.l). These two counties are the main grape plantations in Yunnan. In Shilin vineyard (Fig. 1, A), the vines were grown with 1.0-m spacing within rows and 2.2-m spacing between rows. The Y-type trellis was adopted in this vineyard. In Mile vineyard (Fig. 1, C), the vines were grown with 2.0-m spacing within rows and 3.0-m spacing between rows. The T-type, horizontal trellis was adopted in this vineyard. All rows were oriented from north to south in both vineyards. The mean annual temperatures were 18.5 °C and 17.2 °C and the mean annual rainfall levels were 860 mm and 900 mm in Mile and Shilin, respectively, with the majority of this rainfall occurring between June and September each year.

2.1.2. Experimental design

Three treatments, including rain shelter without fungicide spray, no rain shelter with 10 applications of fungicide, and a control with neither rain shelter nor fungicide application, were designed for each vineyard. Rain shelter was used in the vineyard trials from mid-May to the end of September in 2007 and 2008. The rain shelter consisted of a 150-μm thick, low-density vinyl house structure without sidewalls. This structure could block rainfall effects and provide a moderately humid environment. The width and height of the rain shelter were designed in accordance with the trellises of the grapevines. For the Red Globe vineyard in Shilin County, the width of the rain shelter was 2.0 m and its height was 2.5 m above the ground. Rain falling upon on the shelter flowed into the drainage between the two rows (Fig. 1, B). For the Shuijing vineyard in Mile County, the width of the rain shelter was 3 m and its height was 2.8 m above the ground (Fig. 1, D). No fungicides were applied to the sheltered vines during the growing season. For the non-fungicide treatment, no fungicide was applied at any time during the growing season. For fungicide treatment, fungicides were applied according to the specific grape diseases in each vineyard. In the Shilin vineyard, fungicides were sprayed 10 times to control the main diseases downy mildew, anthracnose, and white rot (Table 1S). In the Mile vineyard, anthracnose and white rot were the main diseases. Fungicides were sprayed 10 times following the spraying program in Table 1S. Each experimental site consisted of three treatments, and three replicates for each treatment. Nine plots were selected for each site in the same vineyard according to a randomised block design. The plot areas were 160 m^2 and 300 m^2 in the Shilin and Mile experimental sites, respectively. Vineyard management with respect to pruning, fertilisers, weed control, and insect pest control was uniform for each plot.

2.1.3. Grape disease assessment

The main grape diseases in each plot were surveyed at the ripening stage. The survey methods for downy mildew [*P. viticola* (Berk. & Curtis.) Berl. & de Toni] and brown spot [*P. vitis* (Lev) Speg] were based on the DB34/T 576-2005, P.R. China (Ministry of Agriculture of the People's Republic of China, 2005a); the survey method for ripe rot (*C. gloeosporioides*) was based on the DB34/T 577-2005, P.R. China (Ministry of Agriculture of the People's Republic of China, 2005b); the survey method for white rot [*Coniella petrakii* B. Sutton] was based on the DB34/T 575-2005, P.R. China (Ministry of Agriculture of the People's Republic of China, 2005c); the survey method for grey mould (*B. cinerea* Persoon) followed the method of English et al. (1989); and the survey method for powdery mildew [*Uncinula necator* (Schw.) Burr.] followed the method of Reuveni and Reuveni (1993). All investigated diseases were assessed at five sampling points in each plot and distributed in a uniform pattern. Disease severity was summarised within each plot as $\{[(n1 \times 1) + (n2 \times 2) + (n3 \times 3) + \ldots + (nN \times N)]/N \times (n1 + n2 + n3 + \ldots + nN)\} \times 100$, where $n1 \ldots nN$ are the number of leaves or grape bunches in each of the respective disease categories and N is the highest score for the disease.

2.1.4. Canopy microclimate data monitoring

Canopy microclimate data were collected from the canopies of the rain shelter treatment, no rain shelter treatment, and no rain shelter with fungicide treatment from both the Mile and Shilin County sites using electronic sensors during the grape growing seasons in 2007 and 2008. Temperature, relative humidity, and light intensity were recorded using a portable micrologger (HOBO H8 Pro, Onset Computer Corp., Pocasset, MA, USA). Leaf wetness duration data were monitored with leaf wetness loggers (WatchDog, 3610TWD, Spectrum, USA). Microclimate measurements were made throughout the season until harvest, and sensors were programmed to record each microclimate variable once per hour. Four monitoring points were selected in each plot. All monitoring sensors were placed at cluster height within the canopy halves in all treatments. The data presented for each treatment are an average of the diurnal microclimatic conditions at 12 different points. Rainfall was recorded using a siphoning type raingauge (DSJ2, Tianjin, China).

2.1.5. Yields and monetary value surveys

Yield was determined based on weight of grape bunches harvested from whole plots in 2007 and 2008. Grape values were based on market prices. The detail price for each cultivar is shown in Table 1. Farmers' income was calculated by the equation: total value (US$/$hm^2$) = grape yield (Mg/$hm^2$) × grape market price (US$/kg) × 1000. Income increment was calculated by the total value substract the annual input value for disease control.