Scientia Horticulturae 178 (2014) 184–191

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Effects of UV radiation on growth and postharvest characteristics of three pot rose cultivars grown at different altitudes

Meseret Tesema Terfa, Amsalu Gobena Roro, Jorunn Elisabeth Olsen, Sissel Torre*

Norwegian University of Life Sciences, Department of Plant Sciences, P. Box 5003, 1432 Ås, Norway

ARTICLE INFO

Article history:
Received 4 April 2014
Received in revised form 17 August 2014
Accepted 19 August 2014
Available online 16 September 2014

Keywords:
Altitude
Growth
Postharvest life
UV radiation
Water usage

ABSTRACT

The ultra violet (UV) radiation reaching the ground is classified as UV-B (315–280) and UV-A (315–400 nm) and the levels vary with altitude and latitude. Numerous studies have shown that UV-B has various effects on morphology, biochemical composition and molecular responses of different species. It is well known that the climate conditions during growth also affect how plants behave after harvest. However, less is known about the effect of UV radiation during growth on postharvest characteristics of ornamentals, and especially the role of UV-B. In this study we investigated the effect of natural levels of UV radiation at different altitudes (2794 m a.s.l. (high altitude) and 1700 m a.s.l. (low altitude)) on growth responses like morphology and flowering, postharvest water usage and shelf life of three pot rose cultivars ('Cygein', 'Snow White', 'Tom Tom'). Plants were grown under UV-transmitting or UV-blocking films at different altitudes. The results showed that UV radiation significantly reduced growth at both altitudes; however the effect was more prominent at lower altitude. Besides, higher level of solar UV radiation also delayed flowering by 7–10 days. Postharvest life and water usage were not significantly affected by UV radiation but rather by the altitude and plants produced at high altitude had a better control of water loss and a longer postharvest life compared to lower altitude-grown plants. In conclusion, UV radiation mainly affected morphology and development of the plants. However, stomata conductance, postharvest water usage and characteristics were rather affected by altitude differences than UV radiation.

1. Introduction

Ultraviolet radiation (UV) is a part of the non-ionizing region of the electromagnetic spectrum and comprises approximately 8–9% of the total solar radiation (Hollosy, 2002). UV is traditionally divided into three wavelength ranges: UV-C (200–280 nm) is extremely harmful to organisms, but not relevant under natural conditions of solar irradiation since it does not reach the ground due to efficient filtration by stratospheric ozone layers; UV-B (280–315 nm) represents only approximately 1.5% of the total spectrum, but is of particular interest since it can induce a variety of effects in plants; UV-A (315–400 nm) represents approximately 6.3% of the incoming solar radiation and is the least hazardous part of UV radiation (Hollosy, 2002).

UV-B has various effects on morphology, biochemical composition and molecular responses of different species. However, the responses depend on species, cultivar, experimental conditions, levels of UV-B and the interaction with other climate factors like temperature and photosynthetically active radiation (PAR) (Frohnmeyer and Staiger, 2003; Reddy et al., 2004; Brown et al., 2005; Berli et al., 2012). Even though UV-B effects on vegetative growth and morphology of plants are variable, reductions in shoot length and leaf expansion were found to be the most common effects (Mark et al., 1996; Caldwell et al., 2003; Zhao et al., 2003). Besides, extended exposure of plants to UV-B radiation results in higher accumulation of phenolic compound to absorb UV-B and reduce its penetration and cellular damage (Lois, 1994; Jansen et al., 1998; Caldwell et al., 2003). Accumulation of such secondary metabolites and reduction in leaf area are part of the strategy by which plants adapt and escape from harmful UV-B radiation, through reduction in its transmittance (Jansen et al., 1998).

Furthermore, there are many reports showing significant reduction in total plant biomass and photosynthetic capacity due to damages to the photosynthetic pigments and chloroplast structure (Teramura and Sullivan, 1994; Kakani et al., 2003), as well as inhibition of photosystem II (Ziska et al., 1993; Allen et al., 1997). Additionally, photosynthesis could be indirectly affected through reductions in stomata conductance (gs) (Day and Demchik (1996); Zeuthen et al., 1997). There have been contradictory results on the responses of UV-B regarding gs and stomata characteristics.

* Corresponding author. Tel.: +47 6496 5628.
E-mail addresses: sissel.torre@nmbu.no, mesitesema@gmail.com (S. Torre).

http://dx.doi.org/10.1016/j.scienta.2014.08.021
0304-4238/

It has been indicated that elevated levels of UV-B radiation might decrease gas exchange through enhancement of stomata closure (Dai et al., 1995; Keiller and Holmes, 2001; Berli et al., 2012) but in some plants UV-B has also been shown to induce stomata opening (Musil and Wand, 1993).

Pre-harvest environmental conditions have an enormous effect on the shelf life of ornamentals like cut flowers, bedding plants and pot plants. Ornamentals are mainly grown in protected cultivation systems and the environmental conditions during growth such as light (Mortensen and Gislerød, 1999; Fjeld et al., 1994), day and night temperatures (Moe, 1975; Hamrick, 2003), carbon dioxide levels (Dole and Wilkins, 2005) and relative air humidity (Torre et al., 2001; Pettersen et al., 2007; Fanourakis et al., 2012) are all shown to affect the postharvest shelf life (for review see, Halevy and Mayak, 1979a, 1979b). Stomatal behavior and water relations are one of the main factors determining the potential postharvest life, especially for cut flowers, but also for some pot and bedding plants (Torre and Fjeld, 2001; van Doorn, 1997; Waterland et al., 2010a, 2010b). Studies have shown that the stomatal behavior in response to conditions of the cultivation environment, such as relative air humidity (Torre and Fjeld, 2001; Fanourakis et al., 2012), light quality (Terfa et al., 2012), and photoperiod (Mortensen and Gislerød, 1999), will persist also after harvest. Thus, the postharvest water relation might be dependent on the environment during growth.

UV-B can induce a range of specific plant responses, some of which are particularly desirable from a horticultural perspective. However, less is known about the effect of UV radiation during growth on postharvest characteristics of ornamentals, and especially the role of UV-B (280–315 nm). Although UV-B was earlier mainly considered a plant stressor and a potential source for damage, currently an ambient or ecological dose of UV-B is believed to be an important signal for plants rather than a stressor (Jansen et al., 1998; Searles et al., 2001; Jordan, 2002; Jenkins, 2009; Jansen et al., 2012). Novel technologies to manipulate UV levels are emerging. For example, by using different selective plastic films, either UV-blocking or UV-transparent, specific parts of the UV spectrum can be manipulated. This provides new opportunities in protected crop cultivation (Jansen et al., 2012).

Since UV-B at ground level varies with altitude and latitude, UV-B exposure of plants will depend on the specific growing site. Close to the equator commercial plant cultivation is possible also at high altitudes. For example, in Ethiopia highland areas have a mild climate for ornamental and other crops production. Ethiopia, is currently the second largest exporter of cut flowers in Africa (Gebreeyesus and Iizuka, 2012), and roses are produced in protected cultivation systems under plastic coverings but without heating. The two main locations where the commercial rose productions are intensively under way in Ethiopia are highlands (2400–2600 m a.s.l) around the capital, Addis Ababa, where the climate is characterized by high daily temperatures and cool nights, and Ziway (mainly characterized as lowland; 1100–1800 m a.s.l) where the temperatures are higher (25 °C in average). The UV radiation reaching the highland region of Ethiopia is higher compared to lowland due to the increase in solar UV radiation with altitude (Sullivan et al., 1992; Schmucki and Philipona, 2002). Obviously, there is also a huge difference in daily mean temperature and day and night temperatures between highland and lowland. However, the expected difference in UV-B at the two altitudes may also have a role in postharvest behavior either directly or indirectly by affecting stomata function and eventually postharvest water usage. In other postharvest study we have observed that there is a huge difference in postharvest life of different cultivars of roses grown at different altitudes, where plants grown at high altitude showed better postharvest characteristics as compared to low altitude grown ones (Terfa et al., unpublished result). Thus, the aim of this study was to test the role of natural levels of UV radiation at different altitudes in Ethiopia on growth responses like morphology and flowering, postharvest water usage and shelf life of different cultivars of pot-roses. These pot roses were grown under UV-transmitting and UV-blocking films at different altitudes.

2. Materials and methods

2.1. Study area and planting material

Field experiments covered with different plastic films (see below; Fig. 1) were carried out in the southern part of Ethiopia at two different locations commonly described as highland (Hagereselam) and lowland (Hawassa). Hawassa (7°3′N 38°28′ E) is located at an altitude of 1700 m a.s.l and Hagereselam (6°27′N 38°27′ E) at an altitude of 2794 m a.s.l. During the experiments climatic parameters at the experimental sites were recorded every hour by a thermo hygrometer data logger (Testo 174H, Testo comfort software basic, Version 5.0.2564.18771, Lenzkirch, Germany) hanged on the top of the plant canopy (Table 1). Three pot rose (*Rosa* × *hybrida*) cultivars collected from a commercial rose grower near Addis Ababa (Ethio Plants PLC, Alemgena, Ethiopia) were used in the experiments; 'Snow white' (white petals), 'Tom-Tom' (pink petals) and 'Cygein' (red petals).

2.2. Pre-cultivation and growth condition

Plants from the three pot rose cultivars were grown from a single node stem segment with one mature leaf. Cuttings were made from the middle and lower position of fully developed stems with open flowers and rooted in pots with coconut peat rooting medium (Galuku Lankaexport PVt. Ltd., Kurunegala, Sri Lanka) for 3 weeks. During the rooting the plants were kept under plastic cover to keep the air humidity high. After rooting the plants were transferred to a 15 cm new pot with fertilized coconut peat (Nitrogen–Phosphorus–Potassium (NPK) 12–7.5–28 ppm) and kept in shade house in Hawassa for about 10–12 days. The climate under the shade house was 20 °C ± 5 temperature, 70% relative humidity and 12/12 h of light/dark. Natural light was used during the experimental period. When the plants had 1–2 cm long shoots they were transferred to a structure made of UV-blocking plastic covers (selectively cut-off UV-B below 350 nm radiation; Solar EVA-5 High Diffuse opaque polyethylene film with 0.20 mm thick and 3 m wide, Revora plastic, The Netherlands), and UV-transmitting white polyethylene sheet (transmits all solar spectrum beyond 250 nm; 0.2 mm polyethylene sheet, Addis Ababa, Ethiopian) (Fig. 1).

The structure was 3 m × 3 m wide and 2 m high with the bottom and top sides (15 cm above ground and 15 cm below roof) left open to allow air ventilation. It was constructed in the North–South direction over the treatment plot to ensure the solar radiation reaching the plants only after passing through the filter as the sun moves from East to West. The main climate factors recorded inside the structure during growth were temperature, relative air humidity (RH), and UV-B distribution (Table 1 and Fig. 2). The photosynthetically active radiation (PAR) passing through the UV-blocking and UV-transmitting films was about 80% and 75%, respectively, compared with unfiltered radiation (Fig. 2). Hereafter plants growing under plastic film blocking UV-B and short UV-A radiation will be referred to as minus UV (−UV), and those grown under white transparent plastic film transmitting UV-B and UV-A radiation will be referred to as plus UV (+UV). The solar irradiance was measured using a PAR quantum sensor (Skye quantum sensor, Skye Instruments Ltd., Llandrindod Wells, UK), in (μmol m^{-2} s^{-1}). The amount of UV-A and UV-B were quantified by a UV-A and