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Differential responses of two *Stellaria longipes* ecotypes to ultraviolet-B radiation and drought stress

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Abstract

Enhanced ultraviolet-B (UVB) radiation and water deficit affect plant growth and development. We determined the effects of UVB and drought stress on growth parameters and chemical attributes of two ecotypes (alpine and prairie) of *Stellaria longipes* under controlled-environment conditions. Clonal ramets of these ecotypes were grown under three UVB levels (0, 5, and 10 kJ m^{-2} d^{-1}) and exposed to two watering regimes (well watered and drought stressed) for 21 days. Compared to the alpine, the prairie ecotype was taller, had higher number of nodes, and greater leaf area and specific leaf weight (leaf dry weight: leaf area), which resulted in increased dry matter in this ecotype. Overall, 'prairie' was higher in total chlorophyll (Chl), but lower in Chl*a:b* ratio, flavonoids, and ethylene, than 'alpine'. In both ecotypes, UVB and drought stress reduced growth and dry matter, whereas UVB increased carotenoids and flavonoids. Drought stress decreased ethylene evolution. These characteristics were also determined in plants growing in the field. In the field-growing plants, 'prairie' had higher growth and dry matter, but lower Chl*a:b* ratio and flavonoids, than 'alpine'. The two ecotypes responded differentially to UVB and watering regime, as 'prairie' appeared to be more sensitive to UVB and drought stress than 'alpine'.

Keywords: Alpine; Drought stress; Ecotype; Prairie; *Stellaria longipes*; Ultraviolet-B radiation

Introduction

Previous studies have reported that ultraviolet-B (UVB) radiation can have a wide range of effects on plant growth, ranging from inhibition (Krizek et al., 1997), no effect (Hakala et al., 2002), to promotion (Al-Oudat et al., 1998). The observed UVB effect seems to be species dependent (Kakani et al., 2003). Ecotypic differences in response to UVB radiation were also exhibited by various plant species (Kalbina and Strid, 2006; Sullivan et al., 1992).

Plant responses to UVB radiation are dependent on the interaction between UVB and other environmental factors, including temperature, water, nutrients, and light (Caldwell et al., 2003). Allen et al. (1998) reported that photosynthetic parameters often show little sensitivity to UVB. This may depend on water availability. UVB radiation reduced photosynthetic pigments in some species (Gao et al., 2004; Qaderi and Reid, 2005), increased them in others (Chaturvedi et al.,

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1998), but had no effect on some others (Ranèelienë et al., 2005).

Plants employ various mechanisms to overcome different stresses, such as UVB radiation or drought stress. The key protective mechanism of plants against UVB radiation is accumulation of phenolic compounds. Flavonoids are important phenolics that act as UVB screen (Smith and Markham, 1998; Karioti et al., 2008). Additive combined effects of UVB and drought stress have been reported (Teramura et al., 1984). Adaptation to drought stress contributes to decreased UVB sensitivity and can cause tolerance to UVB radiation (Hofmann et al., 2003). Hence flavonoids play an adaptive role in water stress regulation (Gitz and Liu-Gitz, 2003). UVB radiation can also affect wax biosynthesis (Gordon and Percy, 1999) and ethylene evolution (A.-H.-Mackerness, 2000), which differ with species, plant age, and environmental cues, such as humidity, temperature, light quality and quantity.

Stellaria longipes Goldie (Caryophyllaceae) is a herbaceous perennial. It exhibits circumpolar distribution and grows in diverse habitats, including arctic, alpine, montane, prairie, and sand dune sites (Chinnappa et al., 2005). Our previous work with the alpine ecotype (normally found at around 2450 m) and prairie ecotype (found at around 1300 m) of *S. longipes* showed differential responses to various environmental factors, such as wind stress (Emery et al., 1994), light quality, and irradiance (Kurepin et al., 2006). The conditions normally experienced by the alpine ecotype are very different from those experienced by the prairie ecotype. For example, alpine plants experience higher UVB radiation (McKenzie et al., 2007) and drier atmospheric conditions and, in turn, higher transpiration (Chinnappa et al., 2005), which have not been studied in *S. longipes*. It was therefore important to explore the responses of these two ecotypes to UVB and drought stress. We hypothesized that the alpine ecotype is less sensitive to UVB radiation and drought stress than the prairie ecotype. The objective of this study was to investigate separate and combined effects of UVB and drought stress on the two ecotypes of *S. longipes*.

Material and methods

Plant material and growth conditions

In 2006, two ecotypes of *S. longipes* with different genetic and geographical background were selected, genotype 1D representing the alpine habitat, and genotype 7B representing the prairie habitat. Clonal ramets of each genotype were planted in 10 cm-diameter pots containing peat moss, sand, and Terragreen (2:1:1), and maintained in controlled-environment growth chambers (Conviron, Winnipeg, Canada) at the University of Calgary. To stimulate the winter cycle requirement (Macdonald et al., 1988), plants were exposed to short-day cold condition (8 °C for 8 h light, 4 °C for 16 h dark) for 90 days and then transferred to a controlled-environment growth chamber (Enconaire, Winnipeg, Manitoba) set to 22 °C for 16 h light and 16 °C for 8 h dark.

Inside the controlled-environment growth chamber, light was provided by a mix of cool white fluorescent tubes (Philips F72T12/CW/VHO, Philips Lighting Co., Somerset, NJ, USA) and Philips 60 W incandescent lamps (Philips Electronics Ltd., Markham, ON, Canada). Relative humidity was between 60% and 70%. Photosynthetically active radiation (PAR), measured at the apex of the plants with a Quantum L1-185B radiometer/photometer (LI-COR, Inc., Lincoln, NE), was 270 μmol photons $m^{-2} s^{-1}$. Light irradiance was kept constant by adjusting the distance between shoot apices of the plants and lights.

UVB irradiation and drought stress treatments

The UVB radiation was supplied by fluorescent tubes (UVB 313EL, Q-Panel, Cleveland, OH, USA), which were fixed on the top of a wooden frame within the controlled-environment growth chamber. The frame was transversely divided into three sections. One compartment was supplied with 0 kJ $m^{-2} d^{-1}$ of UVB (no UVB), another with 5 kJ $m^{-2} d^{-1}$ of UVB, and the third one with 10 kJ $m^{-2} d^{-1}$ of UVB radiation. The biologically effective UVB radiation (UVB_{BE}) of 5 kJ $m^{-2} d^{-1}$ was chosen as a control because this level is within the range of natural solar UVB radiation measured in the summer for Calgary, Canada (M. Qaderi, pers. obs.). Details of UVB treatments and UVB_{BE} measurement and estimation can be found in Qaderi et al. (2008). As measured on 30 August 2007, the average levels of UVB radiation (for 9.5 h) for the original sites of the prairie and alpine ecotypes were 4.97 and 5.94 kJ $m^{-2} d^{-1}$, respectively (M. Qaderi, pers. obs.). In the controlled-environment chamber, plants were irradiated with UVB for 9.5 h each day from 8.00 to 17.30, for the whole period of the experiment. To minimize positional effects, plants were rotated twice a week within the particular compartment.

Plants were subjected to six treatments with the following combinations: ecotypes: alpine and prairie, UVB levels: 0, 5, and 10 kJ $m^{-2} d^{-1}$, and watering regimes: well watered and drought stressed. Well-watered plants were watered every other day, whereas drought-stressed plants were watered whenever they showed sign of wilting.

Each treatment had three replications, each in one pot. From each replication, five ramets were marked for