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Short communication

Variations in growth responses of 23 wild sugarcane (*Saccharum spontaneum* L.) clones to enhanced ultraviolet-B radiation under field conditions in Kunming, China

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Abstract

Field studies were conducted at Kunming (China) to determine the sensitivity of 23 wild sugarcane (*Saccharum spontaneum* L.) clones to enhanced ultraviolet-B radiation (UV-B, 280 to 315 nm). The clones sourced from different sites (altitude 0 to1860 m and latitude 18 to 37°N) were evaluated in the field during 2003 and 2004, both with and without supplemental UV-B radiation of 5.0 kJ m^{-2}. Significant effects of UV-B radiation on plant height, leaf area index, number of tillers, and shoot biomass were observed, besides their significant inter-correlations. Based on the response index, it was deduced that intraspecific sensitivities of wild sugarcane clones to UV-B radiation are profound. Six most sensitive wild sugarcane clones had negative response index lower than –165 in 2003 and –110 in 2004, and six other most tolerant clones had positive response index higher than 150 in 2003 and 110 in 2004. Clones originating from regions with high ambient UV-B were not necessarily more tolerant to enhanced UV-B levels, implying the need to introduce tolerant strains from elsewhere to such locations. UV-B tolerant wild sugarcane clones identified and evaluated in this study might as well be useful as donors in sugarcane breeding programme.

Keywords: Intraspecific variations, Response index, Sugarcane improvement.

During last few decades, numerous investigations were conducted on the impact of rising levels of UV-B radiation on different plant species (see review by Kakani et al., 2003). Results of these studies generally indicate that most plants are adversely affected by increasing levels of atmospheric UV radiation. The common symptoms exhibited are stunting and reductions in tiller number, leaf area, biomass, and grain yield. Sensitivity to UV-B radiation, however, varies considerably both within and between plant species (Hidema and Kumagai, 2006). It is also probable that in certain cases, the reported responses to UV-B radiation may be exaggerated because of the limitations of short-term experiments in crop growth chambers and greenhouses (Zu et al., 2004), which in turn, necessitates long term field experimentation to evaluate the impact of increased solar UV-B resulting from ozone reduction (Li et al., 2002). Yet another limitation in this respect is that responses of wild plants to rising atmospheric UV levels have been seldom evaluated, which again is thought to be strain dependent. Hence a field study was conducted to assess the variations in growth responses of wild sugarcane (*Saccharum spontaneum* L.) clones to enhanced UV-B radiation under field conditions. Wild sugarcane is a perennial herb and one of the progenitors of cultivated sugarcane (*Saccharum officinarum*) and it has potential to be used for fodder production in the tropics. Although it grows in the tropical and subtropical regions with higher UV-B radiation levels, the intraspecific variations in responses were seldom evaluated.

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We chose 23 wild sugarcane clones that came from sites situated at different latitudes (18 to 37°N) and altitudes (0 to1860 m) in China (Table 1). The clones were grown under ambient and supplemental levels of UV-B radiation for two consecutive years. Seedlings were planted at 0.4 m apart at a density of 15 seedlings m^{-2} in 138 plots of 2 x 1 m on 14 March 2003. The experimental design was randomized complete block with UV-B treatment and control having three replications. At 45 days after planting, the plants were uniformly thinned to 10 shoots per m^{-2}. Supplemental UV-B radiation (280 to 315 nm) was provided by 30 W sunlamps (Gucun Instrument Factory, Shanghai, China). Lamps were filtered with either 0.13 mm thick cellulose diacetate (transmission down to 290 nm) for supplemental UV-B radiation or 0.13 mm polyester plastic films (absorbs all radiation below 320 nm) as control (Sullivan and Teramura, 1990). The spectral irradiance from the lamps was determined with a spectroradiometer (Optronics Model 742, Optronics Laboratories Inc., Orlando, USA). The supplemental level (5.0 effective kJ m^{-2}) was similar to that is normally experienced at Kunming (25°N, 1950 m) with a 20% stratospheric ozone reduction during a clear day on the summer solstice (10.0 kJ m^{-2} $UV–B_{BE}$; Madronich et al., 1995). Plants were irradiated for 7 h daily from thinning (April 30, 2003 and 2004) to ripening, around solar noon (during early April 2004, new shoots of wild sugarcane clones grew from the stubbles). Fifteen plants per plot were used to measure plant height (at ripening stage). Plants in two subplots of 0.5 x 0.5 m each were harvested (per plot) to determine the number of tillers and leaf area index (LAI) on 15 August in both years. Total leaves and a subsample of 15 leaves per subplot were collected, and LA (area per leaf) of the subsample measured using a Li-Cor 3100 Area Meter (Li-Cor, Inc., Lincoln, NE, USA). All leaves were oven dried at 60°C for 68 h and weighed. A regression equation linking leaf weight and leaf area ($r = 0.70$, $p < 0.01$) was used to estimate total LA per subplot, based on which the LAI was computed. Total shoot biomass per subplot at ripening was determined after oven drying the same at 60°C for 68 h. Response index (RI; Li et al., 2002) to evaluate the overall response of 23 wild sugarcane clones to enhanced UV-B radiation was calculated as follows:

$$RI = \left(\frac{PHt - PHc}{PHc} + \frac{LAIt - LAIc}{LAIc} + \frac{NTt - NTc}{NTc} + \frac{SBt - SBc}{SBc}\right) \times 100\%$$

Where PH = plant height, LAI = leaf area index, NT = number of tillers and SB = shoot biomass under *t* (UV-B radiation) and *c* (control). Statistical differences between control and UV-B radiation treatment within the same clone were determined by *t* test at $p<0.05$ or $p<0.01$ level. Relationships between parameters (% change of any measured indicators, latitude and altitude) were estimated using the SPSS package ($p < 0.05$ or $p < 0.01$ level; n=23).

A perusal of the data in Table 1 suggests that exposure to UV-B radiation exerts obvious positive or negative effects on plant height, LAI, number of tillers, and shoot biomass. Consequently, in 2003, RI ranged from –232 (II91-81) to 726 (I91-48). Whilst in 2004, it varied from –231 (II91-81) to 859 (I91-48). RI of II91-81 was most adversely affected, and that of I91-48 was most positively influenced both in 2003 and 2004. Across all clones tested, six clones had negative RI less than –165 in 2003 and –110 in 2004; the six most sensitive clones were II91-81, II91-126, II91-93, 90-22, II91-5 and I91-37. Conversely, the six most tolerant clones were I91-48, 92-11, 90-15, II91-99, I91-13, and I91-91 with RI greater than 150 in 2003 and 110 in 2004.

To our knowledge this is the first report to suggest intraspecific variations in growth of wild sugarcane clones to enhanced ultraviolet-B radiation under field conditions. However, experiments under controlled conditions have earlier reported that UV-B radiation significantly dwarfed wild sugarcane, primarily due to shorter internodes rather than node number (Zu et al., 2007). UV-B radiation may directly affect cell division and some intrinsic growth characteristics, which may be associated with many of the changes observed following UV-B exposure, such as changes in the leaf area dynamics and number of tillers. This is consistent with the observation of Li et al. (1998). Furthermore, even subtle UV-B induced effects on the physiological processes could accumulate and manifest as significant effects on biomass (Table 1).

Table 1. Intraspecific sensitivity in plant height, leaf area index (LAI), number of tillers, and shoot biomass of 23 wild sugarcane (*Saccharum spontaneum* L.) clones to UV-B radiation under field conditions at Kunming (China) in 2003 and 2004.

Clones	Origin	Altitude (m)	Latitude (°N)	Percentage change (between treated and untreated plants within a clone) 2003 Plant height	LAI	Number of tillers	Shoot biomass	RI	2004 Plant height	LAI	Number of tillers	Shoot biomass	RI
I91–48	Lianzhong, Sichuan	350	37	36.1*	179.7**	74.1*	435.1**	726	24.5**	378.8**	86.8**	418.2*	859
92–11	Yacheng, Hainan	12	18	3.8	274.5*	98.8*	50.0*	428	12.6**	161.8**	57.5*	65.0*	297
90–15	Cayu, Xizang	1460	28	23.2	227.3**	63.0*	106.3**	420	19.7	23.5	50.4*	39.2*	213
II91–99	Luoding, Guandong	80	23	52.3*	114.8**	25.4	31.6*	224.	28.3*	72.8*	63.6*	48.6*	133
II91–13	Liuba, Shanxi	600	34	52.3*	114.8**	17.0	–12.0	172	13.3**	87.6**	19.9	–7.9	113
I91–91	Zizhong, Sichuan	250	30	23.3	61.4*	1.4	67.7*	154	24.7*	48.5*	0.3	39.3*	113
83–193	Yiliang, Yunnan	780	25	–45.1*	160.3**	–2.4	0.0	113	8.2	–17.4	–14.6	9.1	89
I91–38	Ziyan, Sichuan	450	30	–43.9**	77.5*	50.6*	8.7	93	7.2	37.8*	37.3*	5.7	–59
92–4	Tongshi, Hainan	310	18	31.6*	14.0	–21.0	–0.9	24	3.8	12.5	–27.2	–2.5	–14
90–8	Cayu, Xizang	1860	28	23.6	–26.3	–23.7	–8.7	–35	–18.6*	–18.6	–14.9	–7.5	–15
92–36	Haikou, Hainan	3.6	20	3.6	–20.6	–27.5	6.5	–38	–21.1**	–22.7	–21.5	–17.0	–48
II91–98	Gaoyao, Guandong	0	22	–19.9	12.2	–29.7	–14.8	–52	–39.0*	10.5	–6.2	–13.3	–60
92–26	Zhanzhou, Hainan	200	20	–6.0	–53.7*	–31.1	–45.1*	–136	–14.4	–34.0*	–16.9	–23.6	–72
II91–89	Haifen, Guandong	40	23	–17.2*	–49.0*	–22.2	–49.4*	–138	–38.6**	–19.6	68.2*	–15.4	–82
II91–72	Xianyou, Fujian	30	26	–14.7	–38.5*	–22.1	–65.3*	–141	–7.9	–31.3*	–13.9	–38.5*	–89
II91–116	Linming, Guanxi	200	23	–39.4*	–29.3	–40.5*	–42.6*	–152	–5.6	–26.4	–54.0*	–27.3	–92
93–25	Chahe, Hainan	100	20	–9.7	–52.4*	–43.8*	–61.4*	–167	–17.8**	33.8*	–55.0*	–32.5*	–113
I91–37	Jianyan, Sichuan	550	30	–58.1**	–46.9*	–29.1	–35.0*	–169	–26.9*	–38.8*	–37.4*	–67.4*	–133
II91–5	Chenggu, Shanxi	500	34	–2.4	–78.0**	–32.4*	–74.3*	–187	–11.4	–42.1*	–37.8*	–48.7*	–133
90–22	Cayu, Xizang	1650	28	–20.7	–71.3*	–26.2	–72.4*	–191	–4.1	–44.2*	–59.1*	–26.0	–135
II91–93	Huizhou, Guandong	20	23	–35.2*	–41.9*	–62.7*	–66.8*	–207	–19.8**	–48.8*	–33.0*	–33.5*	–140
II91–126	Tianyang, Guanxi	100	23	–46.8*	–53.7*	–47.8*	–63.5*	–217	–17.7**	–38.3*	–34.1*	–43.0*	–170
II91–81	Zhaoan, Fujian	60	26	–43.7*	–76.1**	–24.6	–87.2*	–232	–37.3**	–82.8**	–40.2*	–71.2*	–232

** and *, Significant difference between control and UV-B radiation at $p<0.01$ or $p<0.05$ level according to *t* - test. Response index (RI) is based on percentage change in plant height (cm), leaf area index (LAI), number of tillers (per m^2), and shoot biomass ($g\ m^{-2}$).

Our results also show that RI is significantly correlated ($p<0.05$) with plant height, LAI, number of tillers and shoot biomass under field conditions for two consecutive years. It is assumed that crop cultivars from near the equator or higher altitude regions are generally more tolerant to UV-B radiation (Sullivan et al., 2002). In this study, however, the correlations between latitude and altitude with plant height, LAI, number of tillers, shoot biomass, and RI were not significant ($p> 0.05$). Implicit in this is that wild sugarcane clones native to regions with high ambient UV-B (lower latitude or high elevation) are not necessarily tolerant to enhanced UV-B radiation. However, further long term research covering local climate modulations and physiological mechanisms are required to arrive at definitive conclusions. Such analysis would also improve our understanding of the responses of wild sugarcane to UV-B radiation and our ability to more realistically assess intraspecific differences of this wild plant to increased levels of UV-B radiation.

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