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Effect of UV Radiation on Early Growth of Korean Rice Cultivars (*Oryza sativa* L.)

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ABSTRACT

The concerns on the crop damage by ultraviolet (UV) radiations is increasing owing to the decrease of their absorbing stratospheric ozone in the tropospheric. Cultivar differences on early growth of UV radiation among five Korean rice cultivars, four japonica types and one Tongil type (indica-japonica cross hybrid), were studied. Pot-seeded rice plants were grown under four different radiation conditions, i.e., visible radiation only, visible radiation with supplemented with high or low dose of UV-B (280~320 nm in wavelength) and UV-C (less than 280 nm in wavelength). The inhibitory degree on plant height, shoot and root weight and length of leaf blade and leaf sheath were determined at 40 days after seeding. UV-C showed the most severe inhibitory effect on the degree of biomass gain and leaf growth in most cultivars examined, followed by high UV-B and low UV-B. Among the cultivars used, the Kuemobyeo was the most sensitive cultivar and had not repair or showed resistance ability to continued irradiation of UV radiation. However, Janganbyeo and Jaekeon showed different responses that the elongation of leaf blades was promoted on 2nd and 3rd leaves and inhibited on 4th and 5th leaves but this inhibitory degree was reduced on 6th and 7th leaves. Such tendency on leaf growth means that both cultivars had low sensitivity and most resistant ability to continued irradiation of UV radiation. While Tongil showed different response to enhanced UV radiation, i.e., low UV-B promoted leaf growth but the inhibitory was severely increased by continued irradiation of high UV-B and UV-C, which means that Tongil had high threshold of UV radiation for response as an inhibitory light of plant growth. The results of this study indicate that the differences on sensitivity or resistant to the effects of UV radiation were existed among Korean rice cultivars.

Keywords : growth, radiation, rice, ultraviolet, UV-B, UV-C.

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UV radiation from sun is electromagnetic wavelength with spectrum 190~400 nm which is classified into three regions of radiation spectrum, i.e. UV-A (320~400 nm), UV-B (280~320 nm) and UV-C (190~280 nm) (Krupa and Kickert, 1993). The UV is strongly absorbed by nucleic acids and proteins, thus causing influence to living organisms. The UV-C, below the region of spectrum 280 nm, can directly destroy the DNA and protein of organisms, and most of them do not reach the earth's surface by protective shield of ozone layer (Teramura, 1983). It has been concerned that the UV-B and UV-C in the tropospheric are increasing owing to the decrease of UV-Babsorbing stratospheric ozone, destroyed by complex chemistry involving mainly man-made chlorofluorocarbons (CFCs), by fossil fuel burning (Bornman, 1993). The influence of UV-B to crop plants varies in different ways depending on species and cultivars as well as on the growth conditions and the adaptable ability to enhanced levels of UV-B (Kim et al., 1998). Morphological changes such as differences in plant height, number of leaves and leaf length may occur by UV-B. Actually the increasing flux of UV-B radiation depress photosynthesis, which may be expressed in decreased rates of CO_2 assimilation or alterations in the partial reactions of the photosynthetic electron transport chain (Park et al., 1997). Reduced photosynthetic rates may be a reflection of several different processes such as stomatal closure, decrease in photosynthetic pigments, and altered rubisco activity, as well as impairment to PS II (Bornman, 1993; Kim, 1996; Strid et al., 1990; Teramura et al., 1990, 1991; Vu et al., 1981, 1984).

In general, C_3 plants and dicots are more sensitive to UV-B radiation than C_4 plants and monocots, respectively (Van et al., 1976). These differences between plant kinds are related with morphological and physiological differences of plant. And the differential sensitivity of crop species to UV-B also exists along latitudinal and altitudinal gradients plant, for example maize which originate from a latitude with high solar UV-B appear to be more tolerant than species such as wheat from areas with a lower natural UV-B level (Sullivarn et al., 1992; Rozema et al., 1991). In a crop species, varietal variation on sensitivity to UV radiation was founded in soybeans (Biggs, 1981; Teramura et al., 1990) and rice (Dai et al., 1994; Teranaka, 1975).

As rice is a major crop in Korea and Asia, the enhance of UV radiation at the surface may pose a threat to food production in this region. Several studies have shown the reduction of the growth and yield of rice by UV-B radiation (Teramura et al., 1991; Dai et al., 1992, 1994; Barnes et al., 1993).

Although numerous studies on effects of UV-radiation have been done in various physiological and biochemical processes in plants or crop species, the effects of enhanced UV radiation to Korean rice cultivars was not elucidated yet. In this study, we studied the effects of UV-B and UV-C on early growth of Korean rice cultivars, to know their resistance and sensitivity to increased UV radiation of respective spectrum regions.

MATERIALS AND METHODS

Plant culture

Five Korean rice (*Oryza sativa* L.) cultivars were used for this study, including four japonica type Jaekunbyeo, Mankuembyeo, Kuemobyeo and Janganbyeo, and a Tongil type (indica-japonica cross hybrid). Among them, Kuemobyeo and Tongil are early maturing type and others are mid-late maturing cultivars. Pre-germinated seeds were planted on plastic pots of 7 × 17 × 10 cm (L × W × H) filled with a mixture of commercial nursery soil (Mitsubishi Co. Ltd. Japan) and vermiculite compost (2 : 1, v/v). At 3 days after sowed containers were placed in an environment controlled phytotron (Koitotron Type KG, Japan) at University of Tohoku, Japan. Four plants were cultured per pot.

UV radiation treatments

The phytotron was divided into four independent sections with different irradiance of the UV radiation (one visible light, two levels of UV-B and one UV-C). The phytotron was set up at controlled photoperiod of 12 hours and temperature of 27/17℃ for light and dark period, respectively. The light sources and measurement of fluence were as follows: the white light was supplied by a combination of twenty-two 80-watt fluorescent lamps(Toshiba), nine 400 watt extra reflector lamps(Toshiba). Altogether, they provided about 9.8 W/m^{-2} at plant level.

Each monochromatic band of UV-A and UV-B supplementing the white light was provided by 20 watt tubes of BLB(Toshiba, 20S-BLB) and SE (Toshiba, 20-E). The fluence rate of each light in the region of UV-A(320~400 nm), UV-B(280~320 nm) and UV-C(250~280 nm) was 750, 33, and 4 mW/m^2 for the white light supplemented with BLB: and 755, 192 and 8 mw/m^2 for the white light supplemented with SE, respectively.

Fluence rate and spectral distribution were measured by a radiospectrometer with a multichannel detector (Hamamatsu Photonics Co.) and a CT-10C diffracting grating monochrometer (Japanese Spectroscopic Co.) devised by Japan Spectroscopic Co. (Tokyo), allowing measurement of the fluence of light between 250~800 nm with accuracy of 0.01mw $/m^2/mm$.

Measurements of growth

Four weeks after the start of UV-B irradiation, the plants were harvested for measurement of growth. Each plant was cutted at ground level and immediately measured for height and fresh weight. The plant height and the length of leaf blade and leaf sheath on each leaf of main stem were measured from 16 plants of 4 pots per each plot. After dividing into shoot and root, oven dried weight at 80℃ for 48 hours were measured. The inhibitory by UV radiation on length of leaf blade and leaf sheath compared with control were analysed by using an inhibitory index, which was calculated following the equation,

Inhibitory index = (Length of leaf blade under UV radiation / Length of leaf blade of control) - 1.

The value of the control was derived from that of the plant grown under visible radiation without supplemental UV radiation.

RESULTS AND DISCUSSION

Effect of UV radiation on growth

A signification varietal difference was found in the effect of continued UV radiations for four weeks on biomass measured as fresh weight and dry weight, number of tiller and plant height of rice were varied by cultivars and kinds of UV radiation. In general, the growth inhibition by UV irradiations was the most severe by UV-C and followed by high UV-B. In most cultivars, the UV-C radiation also caused the browning of the leaves, especially in older leaves (data not shown). Table 1 showed the inhibitory degree of UV radiation was UV-C or high UV-B was highest on Tongil, and followed in order of Kuemobyeo, Mankuembyeo, Janganbyeo and Jaekeon. However, Tongil showed little sensitive to low UV-B, although decreased on biomass by UV-C and high UV-B irradiation. Mankuembyeo and Kuemobyeo were very sensitive by high or low UV-B and UV-C, while Janganbyeo and Jaekeon were sensitive only by UV-C radiation. The tillering of Tongil, Mankuembyeo, and Keumobyeo were perfectively inhibited by UV-C radiation. But Janganbyeo and Jaekeon can formed their tillers about 15~20% in spite of UV-C radiation.

Table 1. Effects of irradiation of UV-B or UV-C on plant growth of Korean rice cultivars.

Cultivar	Treatment	Plant height	Fresh weight		Dry weight		Percent tillering	Degree of inhibition†
			Shoot	Root	Shoot	Root		
		--cm--	---------g/plant---------				--%--	
Tongil	low UV-B	37.9	1.87	0.52	0.26	0.05	100	-
	high UV-B	32.9	1.29	0.53	0.19	0.05	100	++
	UV-C	27.7	0.41	0.11	0.07	0.04	0	++++
	Control	39.4	2.04	0.80	0.28	0.07	100	-
Janganbyeo	low UV-B	49.1	1.60	0.50	0.24	0.06	100	-
	high UV-B	45.5	1.61	0.50	0.21	0.06	100	-
	UV-C	44.1	1.00	0.28	0.15	0.03	15	+++
	Control	49.7	1.86	0.50	0.25	0.07	100	-
Keumobyeo	low UV-B	54.2	1.81	0.36	0.18	0.05	85	++
	high UV-B	49.3	0.90	0.40	0.15	0.06	60	+++
	UV-C	44.8	0.60	0.15	0.10	0.02	0	++++
	Control	53.1	1.81	0.66	0.27	0.08	100	-
Jaekeon	low UV-B	47.4	1.29	0.29	0.20	0.03	100	-
	high UV-B	45.4	1.29	0.45	0.19	0.06	100	-
	UV-C	43.0	0.98	0.28	0.13	0.04	20	+++
	Control	47.7	1.61	0.49	0.23	0.05	100	-
Mankuembyeo	low UV-B	47.2	0.89	0.21	0.14	0.03	40	+++
	high UV-B	43.6	1.09	0.30	0.12	0.03	25	+++
	UV-C	39.5	0.79	0.18	0.12	0.02	0	++++
	Control	46.7	1.52	0.40	0.22	0.06	95	-

† -; no inhibition (high tolerance), +; low inhibition (tolerance), ++; medium inhibition, +++; high inhibition (sensitive), ++++; strong inhibition (high sensitive)

The tillering of most Korean cultivars, however, were not inhibited by UV-B radiation except Mankuembyeo which is a very sensitive cultivar to UV radiations (UV-B and UV-C). Above results indicated the inhibition degrees of UV radiation on the early growth of Korean rice cultivars. These results were similar to previously reported in japanese rice cultivars by Kumagai and Sato (1992) and Dai et al. (1992, 1994).

UV radiation effects on leaf length

The effects of UV radiations on length of leaf blades and sheathes from 2nd to 8th leaf of main stem were shown in Table 2. Fig.1 showed the inhibitory index of each leaf on main stem as an influence degree on leaf growth by UV radiation. The leaf blade were only shown leaf blade because the tendency was very similar between leaf blade and leaf sheath.

The inhibitory degree on leaf blade by UV radiation varied by cultivars and kinds of UV radiation. The elongation of leaf blade was inhibited the most in Kuemobyeo, in particular UV-C and high UV-B, that was gradually increased on upper leaves. Tongil was slightly inhibited or promoted by low UV-B, but severely inhibited by high UV-B and UV-C. Janganbyeo was showed promotive tendency on 2nd leaf and greater inhibitor on 4th leaf. In Jaekeon, the elongation of 2nd and 3rd leaves was promoted by both high or low UV-B, but that is inhibited on upper leaves of 4th. And the inhibitory index of Jaekeonbyeo was not only lower than other cultivars, but also higher high UV-B than UV-C. The elonga tion of leaf blade in Mankuembyeo was inhibited all UV radiation, especially greater on 4th and 7th leaves, and that was relatively greater by low UV-B irradiation compared with other cultivars.

Above results on leaf growth indicate that the Kuemobyeo was most sensitive cultivar and had not repair or resistance ability to continued irradiation of UV radiation. As the most resistant cultivars to UV radiation, Janganbyeo and Jaekeon can be selected, because the elongation of leaf blades on those cultivars was promoted on 2nd and 3rd leaves and inhibited 4th and 5th leaves but the inhibitory index reduced on 6th and 7th leaves. Such tendency on leaf growth means that not only both cultivars had low sensitivity and some resistant ability to continued the irradiation of UV radiation, but also the sensitivity or resistance are varied the plant growth stage as suggested by Kumagai and Sato (1992).

Table 2. Effects by irradiation of UV radiation on the length of leaf sheath and leaf blade of main stem of 4-week pot grown Korean rice cultvars.

Treatment	Leaf length (cm)													
	Sheath							Blade						
	2nd	3rd	4th	5th	6th	7th	8th	2nd	3rd	4th	5th	6th	7th	8th
								Tongil						
UV-B low	2.6	6.1	9.3	11.5	14.3	15.1	14.5	2.2	8.3	15.5	21.7	25.2	31.4	16.1
UV-B high	1.7	3.9	5.4	7.2	9.2	11.3	0	1.9	7.1	11.0	14.4	18.1	22.9	18.9
UV-C	2.5	5.0	6.6	7.2	7.9	7.3	0	2.1	7.1	12.3	15.9	17.2	15.6	0
Control	2.5	6.1	9.3	11.5	13.9	13.9	16.7	2.1	8.2	13.9	20.1	24.1	27.2	25.6
								Janganbyeo						
UV-B low	4.2	7.8	11.2	13.8	15.4	16.6	0	2.5	10.6	16.2	22.1	26.2	30.9	17.1
UV-B high	3.4	6.6	9.5	12.2	14.9	11.6	0	2.3	8.9	14.4	20.7	26.3	31.3	19.6
UV-C	3.6	7.5	11.3	14.0	15.8	16.0	0	2.3	8.7	15.2	23.5	28.5	30.7	0
Control	4.1	9.9	13.9	15.7	18.0	19.4	0	2.2	10.3	19.1	22.7	30.3	36.0	23.9
								Kuemobyeo						
UV-B low	3.7	8.1	12.5	14.7	13.4	13.0	0	2.1	8.8	17.3	26.0	30.9	26.6	0
UV-B high	3.0	6.5	9.1	10.5	9.1	9.0	0	1.6	8.2	16.9	19.3	23.0	20.3	9.3
UV-C	4.0	8.1	12.3	14.2	5.5	0	0	2.3	9.2	17.1	25.9	32.2	0	0
Control	4.0	9.5	13.8	16.5	17.1	17.9	0	2.1	9.3	18.5	28.4	34.0	37.7	23.5
								Jaekeon						
UV-B low	3.2	7.0	11.3	13.9	16.5	17.8	0	2.0	7.9	14.3	23.8	28.5	33.4	14.6
UV-B high	3.8	7.2	9.9	12.2	15.3	17.8	0	2.2	9.2	14.7	22.2	26.1	31.3	16.6
UV-C	3.4	7.5	11.4	14.0	16.7	17.0	0	1.9	7.6	14.7	23.6	28.7	32.6	0
Control	3.4	9.1	13.4	14.5	16.9	19.9	0	1.8	7.7	15.8	28.5	29.0	34.9	21.4
								Mankuembyeo						
UV-B low	3.5	6.5	9.6	12.7	15.5	16.0	0	2.3	8.2	13.9	20.8	26.6	25.8	0
UV-B high	3.9	7.0	10.3	13.0	16.2	14.5	0	2.6	9.6	15.1	22.0	27.0	29.8	0
UV-C	3.9	7.7	11.2	13.4	15.3	15.3	0	2.5	9.0	15.4	23.5	28.7	23.8	0
Control	4.6	9.6	12.9	16.0	19.3	19.3	0	2.6	10.4	20.1	25.8	31.7	36.9	7.5

While in Tongil the response on leaf growth to UV radiations was different among the spectrums of UV radiation, low UV-B promoted leaf growth but the inhibitory was increased severely by continued irradiation of high UV-B and UV-C. That means that Tongil had high threshold of enhanced UV radiation for responding as an inhibitory light of plant growth. Severe inhibitory in Kumobyeo and Tongil to high UV-B and UV-C may be related possibly with their early maturing habits. Those resistance or sensitivity on rice plant to UV radiation are related with gibberellin biosynthesis (Suge et al., 1991).

In conclusion, the results of this study indicate that the cultivar differences on inhibitory of early growth by UV radiation are existed among Korean cultivars. And these findings suggest that selection of rice cultivars with resistant to enhanced UV radiation can be done in a phytotron condition, although combined outdoor experiments are also needed.

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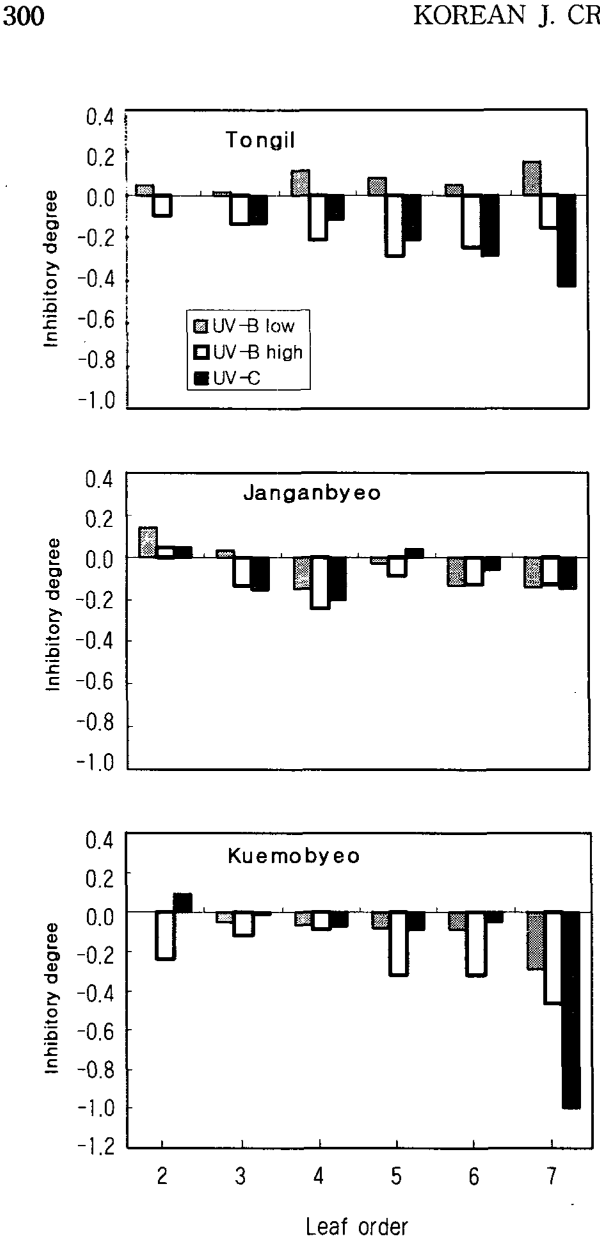

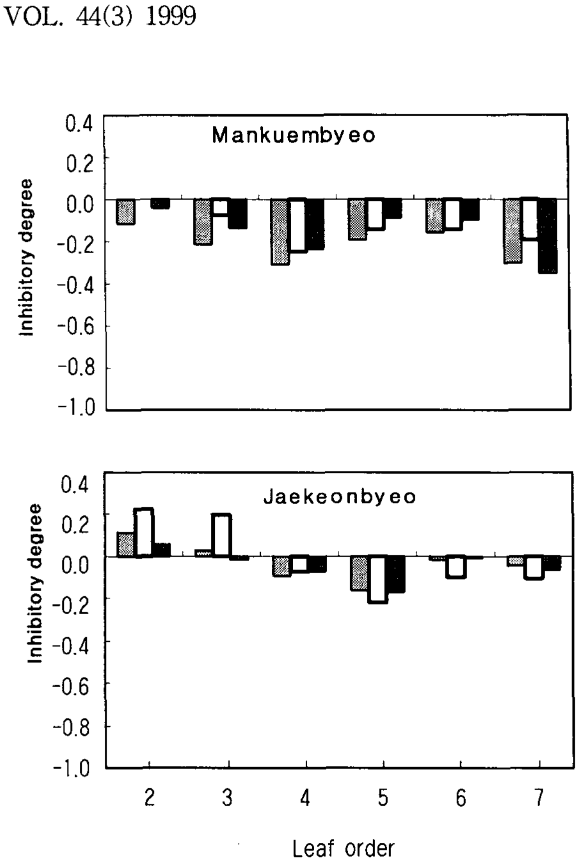

Fig. 1. The inhibitory index on elongation of leaf blade of Korean rice cultivars to UV radiation for 4 weeks after seeding. The plus and minus of inhibitory index represents promotion and inhibition of elongation of leaf blades to the control, respectively.

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