S8-040

Stimulating effect of low dose gamma-ray radiation on the growth and physiological activities of Chinese cabbage cultivars

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Keywords: Chinese cabbage, gamma-ray, low dose radiation, growth stimulation, physiological activity, photosynthesis, chlorophyll fluorescence

Introduction

The most remarkable aspect in the hormesis law is that low dose of harmful agent can produce effects that are diametically opposite to the effect found with high doses of the same agent. Radiation hormesis was predictable from the thesis and provides an important concept for the present controversy regarding the usefulness of radioactive atoms. Accelerated germination, sprouting, development, growth, blooming and ripening, and increased crop yield in higher plants grown from seeds irradiated with low dose radiation were observed (Luckey, 1980). There are ample reports for the appearance of hormesis in many crops and vegetables with respect to various aspects such as photosynthesis of carrot (Vlasyuk, 1964), respiration, catalase activity and nitrogen contents of Indian colza (Garg *et al*., 1972). In this study, we evaluated the stimulating effects of low dose gamma-ray radiation on the growth of cultivars, storage periods, physiological activities and photosynthetic responses of Chinese cabbage cultivars.

Materials and Methods

Gamma-ray Irradiation and cultivation

Dry seeds of Chinese cabbage (*Brassica campestris* L. cv. Hanyoreum, cv. Tropic emperor and cv. Sulim eockari) were irradiated at the various doses from 0 to 20 Gy by gamma-ray irradiator (^{60}Co, ca.150 TBq of capacity, AECL). After irradiation, seeds were grown in the green house and experimental field. Dose rate was measured by Fricke dosimeter (Holm and Berry, 1970)

Analysis of antioxidant enzyme activity and Chl fluorescence yields

The peroxidase (POD) and catalase (CAT) activity was assayed according to the method of Yun *et al*. (1998). Fluorescence parameters (Fo, Fv, Fm, Fv/Fm) were measured with PAM fluorometer at room temperature. The quenching parameters were calculated by Schreiber *et al*. (1994).

Results and Discussio

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Seedling development was significantly increased by low dose gamma radiation. In case of Hanyoreum cultivar, the fresh weight of 8 Gy and 12 Gy irradiated group increased 61% (p<0.01) and 37% (p<0.01) compared with the non-irradiated group, respectively. The seedling height of Tropic emperor cultivar was very high as 19% (p<0.01), 17% (p<0.05) and 15% at 12 Gy-, 1 Gy- and 2 Gy-irradiated group, respectively. The yield components of Tropic emperor cultivar showed the stimulating effects in 4 Gy-, 0.5 Gy- and 8 Gy-irradiated group (Table 1). These results suggest that there could be significant difference in effects of low dose gamma-ray radiation on the growth patterns of cultivar seeds.

Table 1. Growth response of two Chinese cabbage cultivars developed from seeds irradiated with different doses of gamma- ray radiation

Dose	Germination		Seedling height (cm)		Fresh weight (g)		Plant height (cm)		Diameter (cm)	
	H	T	H	T	H	T	H	T	H	T
0	88	72	7.7	7.2	0.54	0.50	40.8	37.8	21.3	19.8
0.5	90	65	7.4	7.5	0.47	0.50	39.8	39.1	18.7	21.2
1	78	85	7.7	8.4*	0.59	0.61	40.4	37.9	20.2	21.2
2	65	87	8.6	8.3	0.65	0.57	40.8	36.9	19.9	20.5
4	80	78	8.3	8.0	0.63	0.56	39.1	40.7	19.0	20.9
8	53	75	9.1	7.5	0.87**	0.47	39.6	37.2	18.2	22.3*
12	62	68	9.4*	8.6**	0.74**	0.63*	41.7	39.0	18.6	21.5
16	63	73	9.7	6.8	0.71	0.41	41.1	36.8	21.4	19.5
20	62	52	8.5	6.8	0.68	0.41	39.4	37.3	19.5	20.3

H ; Hanyoreum cultivar, T ; Tropic emperor cultivar. *, ** ; p<0.05 and p< 0.01, respectively.

Effects of low dose gamma-ray radiation on the seed viability and seedling evelopment

The stimulating effect of low dose gamma radiation on the seeds stored for longer periods was investigated. The germination rate and seedling height of old seeds increased positively in the green house, but were different from each other depending on their storage period. For example, the germination rate of 1 - 2 Gy irradiated group in 4-years old seeds increased about 20% and the seedling height of 3-years old seeds were stimulated 17% (p<0.05) at 0.5 Gy irradiated group (Table 2).

Table 2. Germination rate and seedling height of Chinese cabbage developed from old seeds irradiated with different doses of gamma-ray radiation

Dose	5 years		4 years		3 years		2 years		1 year	
	GR	SH	GR	SH	GR	SH	GR	SH	GR	SH
0	68	7.8	72	7.2	77	7.8	87	8.7	98	8.3
0.5	73	7.8	65	7.5	85	9.1*	77	8.8	73	9.0
1	75	7.6	85	8.4*	77	8.1	87	8.2	90	9.3
2	73	7.0	87	8.3	87	7.3	90	8.1	95	8.6
4	75	8.3	78	8.0	82	7.5	90	8.7	88	9.4*
8	60	7.0	75	7.5	77	8.7	83	8.8	88	8.7
12	55	7.3	68	8.6**	82	8.3	75	8.2	95	8.9
16	62	7.8	73	6.8	57	8.1	73	9.0	92	9.0
20	53	7.2	52	6.8	52	7.5	70	8.4	82	8.5

GR ; Germination rate (%), SH ; Seedling height ( ). *, ** ; $p<0.05$ and $p< 0.01$, respectively.

S*timulating effects of radiation on the physiological activities*

Contrary to the stimulating effects on two cultivars, it was hardly shown any stimulating effect in Sulim eockari cultivar with respect to the germination and early growth at the optimum dose at 1 – 2 Gy (Table 3). Interestingly, some antioxidant enzyme activities were significantly increased by low dose radiation in Sulim eockari: for example, activities of peroxidase catalase of 10 days old seedlings increased by 45% and 85 % at 2 Gy irradiated group, respectively (Fig.1).

Table 3. Early growth of Chinese cabbage grown from seeds (produced in 1994, cv. Sulim eockari) irradiated with different doses of gamma-ray radiation

Dose (Gy)	Germ (%)	10 DAS			20 DAS		
		Cotyledon width (cm)	Leaf width (cm)	Leaf length (cm)	Leaf width (cm)	Leaf length (cm)	Fresh weight (g)
0	85	2.18†	2.35	3.97	4.24	7.96	2.29
0.5	85	2.27**	2.42	4.25**	4.57***	8.51***	2.51
1	86	2.25*	2.55***	4.55***	4.68***	9.08***	2.66***
2	89	2.27*	2.57***	4.67***	4.68***	8.97***	2.53**
4	85	2.21	2.50**	4.52***	4.44*	8.56***	2.43
8	84	2.21	2.61***	4.65***	4.43*	8.46**	2.41
12	86	2.13	2.42	4.30**	4.62***	8.66***	2.64***
16	87	2.13	2.47**	4.43***	4.35	8.42**	2.31
20	87	2.02	2.15	3.85	4.03	7.68	1.92

DAS ; days after sowing. *, **, *** ; $p<0.05$, $p<0.01$ and $p< 0.001$, respectively.

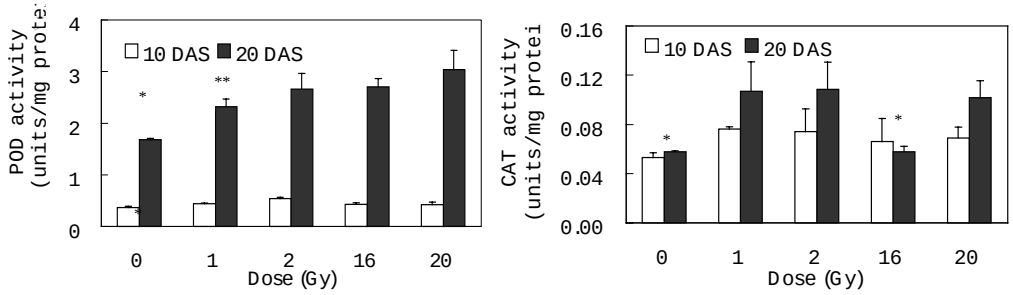

Fig. 1. Antioxidant enzyme activity of Chinese cabbage grown from seeds (produced in 1994, cv. Sulim eockari) irradiated with different doses of gamma-ray radiation. DAS ; days after sowing. *, ** ; $p<0.05$ and $p<0.01$, respectively.

Effect of low dose gamma-ray radiation on photosynthesis

As shown in Figs. 2 and 3, Fv/Fm was not changed by the low dose gamma-ray radiation compared with the control, indicating that there was no stimulating effect of gamma-ray radiation on PSII functionality in leaves. Contrastingly, the effective quantum yield of PSII increased slightly by 10% at the dose of 2 Gy and 16 Gy, indicating that the photosynthetic electron transport to PS I from PS II was enhanced by the low dose gamma-ray irradiation. Additionally, qP increased by 10% at the dose of 16 Gy compared with the control, while NPQ did not change, meaning that electron transport represented by qP was enhanced by the low dose gamma-ray irradiation but the Δ pH formation through electron transport was not affected.

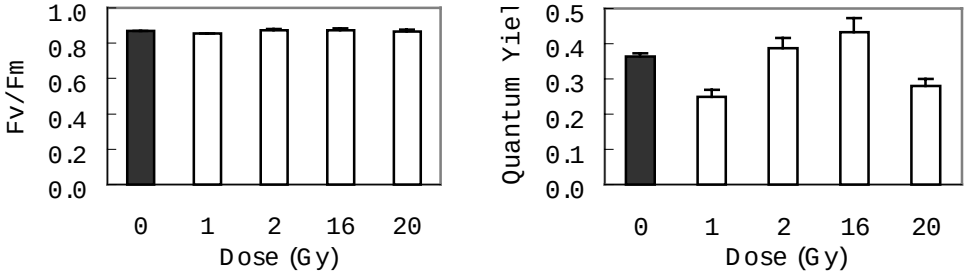

Fig. 2. Changes in the maximal photochemical efficiency of PSII (Fv/Fm) and the effective quantum yield of photochemical energy conversion at PSII reaction centers of Chinese cabbage grown from seeds (produced in 1994, cv. Sulim eockari) irradiated with different doses of gamma-ray radiation.

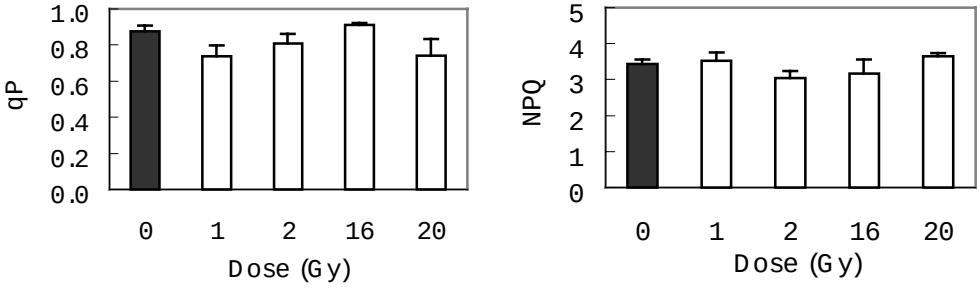

Fig. 3. Changes in the photochemical quenching (qP) and non-photochemical quenching of Chinese cabbage grown from seeds (produced in 1994, cv. Sulim eockari) irradiated with different doses of gamma-ray radiation.

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