Effect of Serial Irradiation of Low Dose Gamma Rays on the Growth and Photosynthesis of Red Pepper (*Capsicum annuum* L.) Plants

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1. Introduction

Ionizing radiation at several grays can induce growth stimulation in plants. This phenomenon has been called 'radiation hormesis'. Low dose radiation also modulates photosynthesis. Although an alteration in photosynthesis has been thought to involve in the growth stimulation of irradiated plants, no reports did clarify their relationship yet. In the present study, we attempted to reveal a possible relationship between them by comparing the effects of serial gamma-irradiation on the growth and photosynthesis of red pepper. Furthermore, something beyond the dose effect of ionizing radiation is discussed by this new experimental approach.

2. Materials and Methods

2.1 Plant Material and Gamma-irradiation

Red pepper (*Capsicum annuum* L. cv. Taeyang) plants were irradiated with low doses of gamma-radiation (0.5, 1, 2, 3, and 4 Gy) at 28, 31, and 34 days after sowing (DAS). The gamma-radiation was generated by a gamma irradiator (^{60}Co, *ca.* 150 TBq of capacity, AECL) in Korea Atomic Energy Research Institute. Before and after the irradiation, plants were grown in a growth chamber with photosynthetic photon flux density (PPFD) at pot level of 330 μmol m^{-2} s^{-1} supplied by two natrium and six fluorescence lamps. The growth chamber was maintained at 28/20°C (D/N) with a 14 h photoperiod.

2.2 Growth Test

Plant growth was evaluated by the stem length, leaf length & width, and fresh weight measured at 27, 29, 32, 35, and 39 DAS.

2.3 Chlorophyll Fluorescence Analysis

Chlorophyll (Chl) fluorescence was measured using a Chl fluorometer (IMAGING-PAM, Walz, Germany) as described in the operation manual. Readings were taken after the samples were dark-adapted for 15 min at room temperature. Finally, the parameters, Fo, Fm, Fv/Fm [1], qP [2,3], qN, NPQ [2], and ETR [4], were obtained.

3. Results and Discussion

3.1 Effect of Serial Gamma-irradiation on the Growth of Red Pepper Seedlings

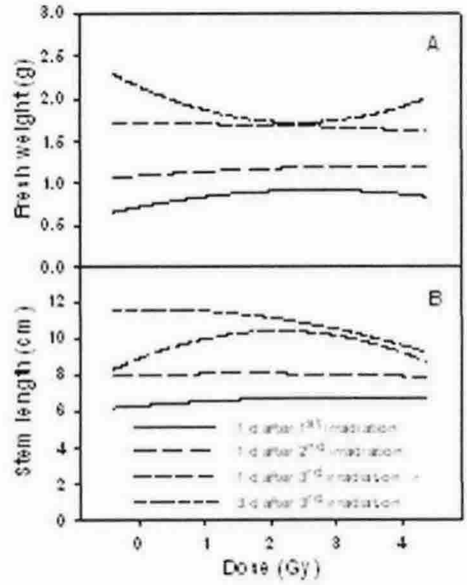

Figure 1. Changes in the fresh weight and stem length of red pepper seedlings by the serial irradiation of different doses of gamma rays.

As shown in Figure 1, the gamma-irradiation could stimulate the plant growth at low doses up to 4 Gy, but it rather inhibited the growth in all irradiation groups at 3 d after the 3rd irradiation. Therefore, the dose effect of the incident radiation couldn't be correlated with the early growth stimulation of red pepper seedlings. For instance, the total incident dose of three irradiations at 1 Gy was 3 Gy, but this cumulative dose inhibited an increase in the fresh weight opposite to the same dose of single irradiation.

3.2 Modulation of Photosynthetic Activity in Red Pepper Leaves by Serial Gamma-irradiation

The values of Fv/Fm, the maximum photochemical efficiency of photosystem II (PSII), were not different between the control and irradiation groups until 1 d after the 3rd irradiation (Figure 2A). However, the irradiation groups except 0.5 Gy showed higher Fv/Fm values at 3 d after the 3rd irradiation than the control one. In contrast, after the 3rd irradiation, the photochemical use of

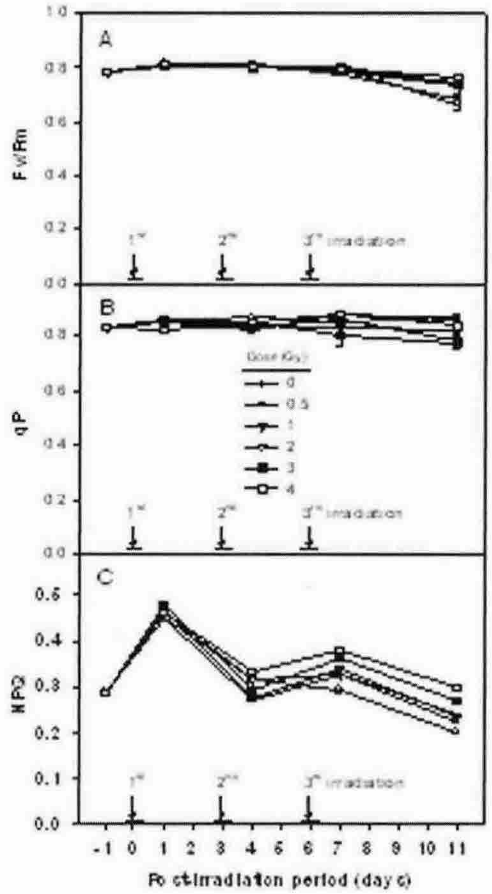

Figure 2. Changes in the Chl fluorescence parameters of red pepper leaves by the serial irradiation of different doses of gamma rays. Fv/Fm, the maximum photochemical efficiency of photosystem II; qP and NPQ, the photochemical and non-photochemical quenching.

absorbed light energy, qP, appeared to be a little lower in the 3 Gy and 4 Gy groups than in the other ones. Interestingly, the non-photochemical dissipation of the light energy was overall lower in the irradiation groups after the 2nd irradiation than in the control one. These results may imply that the 2nd irradiation started to behave as a stress factor almost regardless of the incident dose. Moreover, the growth inhibition of the irradiation groups at 3 d after the 3rd irradiation as shown in Figure 1 can be partly explained by this possibility. Nevertheless, according to Figure 2A, any possible stress caused by the serial irradiation doesn't seem to be related to the maximum photochemical efficiency of PSII.

The light response of the irradiation groups was distinguishable from that of the control one. The apparent rate of photosynthetic electron transport, ETR, decreased in the control group during the irradiation period, while it remained constant in the 4-Gy one (Figure 3). The ETR was the highest in the control group at 1 d after the 1st irradiation, but at 3 d after the 3rd irradiation, it became higher in all irradiation groups than in the control one (Figure 3, data not shown for the irradiation groups except 4 Gy). These results are somewhat in good agreement with the higher Fv/Fm values in the irradiation groups at 3 d after the 3rd irradiation (Figure 2A). Therefore, it's possibly suggested that the serial gamma-irradiation should protect a reduction in the photosynthetic activity by the natural leaf senescence.

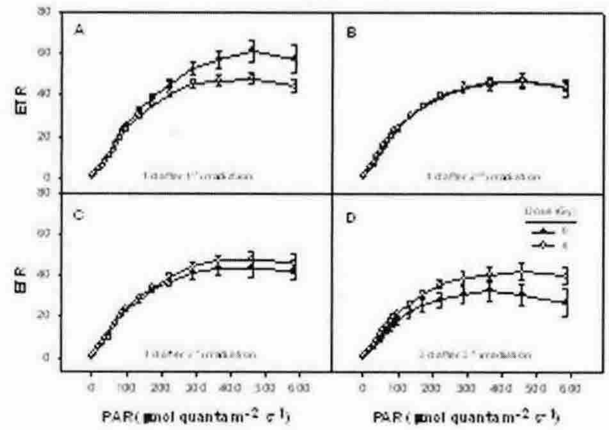

Figure 3. Difference in the light response pattern between the control and irradiated red pepper leaves during the serial gamma-irradiation. The ETR represents the apparent rate of photosynthetic electron transport. PAR, photosynthetically active radiation.

4. Conclusion

Base on the results obtained, we concluded that the effect of ionizing radiation to stimulate the plant growth was determined by the single radiation dose rather than by the cumulative one. However, the plant growth stimulation induced by low dose radiation could not be correlated with an alteration in the photosynthetic activity. In stead, we propose a possibility that ionizing radiation may delay the natural senescence of leaves or plants themselves.

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