3 - 44  Effects of Germination, Survival and Plant Growth on Wheat Seeds Induced by $^{12}$C$^{+}$

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Heavy ion beams are characteristic of energy deposition effect and Bragg peak. Compared with low-LET ionizing radiation, including γ rays, X-rays and electrons, they have higher linear energy transfer (LET) and higher relative biological effectiveness (RBE). These characters made them become a novel and efficient mutagens. It has been reported that heavy ion beams could induce growth suppression, and lethality in plants after radiation.

![Graph showing germination rates of wheat seeds irradiated by $^{12}$C$^{+}$](image1)

**Fig. 1** Germination rates of wheat seeds irradiated by $^{12}$C$^{+}$. I S.E. * statistical significance, * $p<0.05$, ** $p<0.01$.

In the present study, the effects of germination, survival and plant growth on wheat seeds irradiated by $^{12}$C$^{+}$ were investigated. The values of energy and mean LET used were 76.4 MeV/u and 35.6 keV/μm respectively. As Fig. 1 shown, the germination rates were 98.9% and 97.7% in 10 and 20 Gy, and the control was 96.67%, which rates were higher than the control. However, the germination rates decreased gradually from 60 to 200 Gy, but the lowest rate was still 84.4%. The survival rate was higher in 10 Gy than the control, but when the dose was up to 20 Gy, the curve showed a decreasing trend (Fig. 2). From 30 to 200 Gy, the survival rates dropped significantly. After radiation of the highest dose, it was merely 2.2%. The median lethal dose ($LD_{50}$) for carbon ion radiation was 55 Gy. At the same time, the root length and plant height of the seedling were investigated 3 and 7 d after seedling (Figs. 3 and 4). The dose-response curves of root length showed the same trend with these of plant height measured on 3rd and 7th day, respectively. On 3rd day, the root growth and plant height had no difference among 10, 20 Gy and the control. But they grew slowly after radiation range from 30 to 200 Gy. On 7th day, the root length was longer after 10 and 20 Gy than in control, whereas the root growth was suppressed obviously by higher doses. Especially, after 150 and 200 Gy irradiation, the root length was 14.76 and 17.59 mm on 3rd day, 13.6 and 16.52 mm on 7th day, respectively, which suggested that the root growth almost ceased until they died. The whole plant growth was affected by root growth, and it varied from the root growth.

![Graph showing survival rates of wheat seeds irradiated by $^{12}$C$^{+}$](image2)

**Fig. 2** Survival rates of wheat seeds irradiated by $^{12}$C$^{+}$. I S.E. * statistical significance, * $p<0.05$, ** $p<0.01$.

The above results suggested that the germination and survival rate had the different sensitivity to $^{12}$C$^{+}$ irradiation. Meanwhile, $^{12}$C$^{+}$ irradiation had a smaller impact on germination than on survival. Most importantly, $^{12}$C$^{+}$ radiation of lower doses had a stimulation effect on the seed germination and plant growth in lower doses, while higher doses radiation played an inhibition role, which resulted in the survival decreasing.