Low dose gamma radiation effects on seed germination and seedling growth of cucumber and okra

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Abstract. Cucumber and okra seeds were radiated by Co-60 gamma radiator for 50, 100, 150 and 200 Gy. Germination percentage and seedling growth were observed every day for 10 days. After 10 days of seedling growth, weight of fresh and dry seedling were measured. The result showed that the highest germination percentage of cucumber was 100% on the third day of 50 Gy gamma-radiated seeds. The highest germination percentage of okra was 100% on the fifth day of 50 Gy gamma-radiated seeds. The highest seedling lengths of cucumber and okra were 13.7 cm. and 9.4 cm. with 50 Gy and 200 Gy of gamma dose, respectively. Weight of fresh and dry seedlings showed no trend corresponding to the seedling growth. This study shows that the low dose gamma radiation may enhance the germination rate and the seedling growth during the early seedling state of some vegetable seeds.

1. Introduction
Gamma ray is an electromagnetic wave which causes ionizing radiation that induces biological effects such as inhibition, stimulation, mutation and cell death. The effect of gamma radiation on crop production has been reported by researchers around the world [1–5]. The low dose of gamma radiation can enhance germination percentage and seedling growth. Beyaz et al. reported the stimulatory effect of low gamma doses for germination and seedling growth [6]. Wiendl et al. found evidence that the use of low doses of gamma radiation can stimulate germination and plant production of tomato [7]. Hussain et al. reported that gamma radiation doses responded positively to radical length, plumule length, number of roots, seedling fresh weight, seedling dry weight, germination percentage and time of germination [8]. Marcu et al. confirmed that ionizing radiation stimulates physiological parameters of lettuce up to certain low doses [9]. Maity et al. described irradiations at low doses improve morphological traits like plant height, shoot number, panicle length and seed number per panicle [10].

Cucumber and okra seeds were used in this study because of their short mean germination time and ease to plant in a laboratory. The study focused on the determination of different gamma radiation dose effects on germination rate in the early stage of germination of cucumber and okra.

2. Materials and methods

2.1. Plant materials
Cucumber (Cucumis sativus) and okra (Abelmoschus esculentus) seeds from Chiang Mai, Thailand were used in the study. Seeds were sterilized by 95% ethanol and dried in an incubator at 25 °C for 24 h. Seeds were put into Petri dishes before irradiation. There were three replicates for each radiation dose and each replicate contained 10 seeds of each species.
2.2. Irradiation and planting
Gamma-cell 220 radiator at the Program in Applied Physics, Faculty of Science, Maejo University, Chiang Mai, Thailand was used for irradiation. Seeds were irradiated with gamma rays at a dose rate of 600 Gy h$^{-1}$. The irradiation exposure was 0, 50, 100, 150 and 200 Gy. After irradiation, seeds were immediately sowed in seed trays with sterilized soil. Seed trays were put into opened air laboratory. Water was applied daily to maintain soil moisture.

2.3. Observation
Seed germination and seedling length were determined daily for 10 days. After 10 days of germination, fresh weight and dry weight of seedling plant were determined by a 3-digit balance.

2.4. Calculation and statistical analysis
Final germination percentage (FGI), mean germination time (MGT), germination index (GI) and germination rate index (GRI) were used for seed germination assessment [11,12]. Recorded data were analyzed by SPSS software (version 25) for Microsoft Windows. Duncan’s multiple range test was used to determine the significant difference between groups.

3. Results and discussions
3.1. Seed germination
Daily seed germination percentage of cucumber and okra is shown in figure 1(a) and figure 1(b). Figure 1(a). shows the highest germination percentage of cucumber at 100% on the third day of 50 Gy gamma-radiated seeds. After the fourth day of observation, the germination percentage of cucumber was not significantly different. Figure 1b. shows the seed germination of okra of a 50 Gy gamma dose on the fifth day is 100%. After the fifth day of observation, the germination percentage of okra was not significantly different.

![Figure 1](image-url)

**Figure 1.** Effects of radiation doses on seed germination percentage of (a) cucumber and (b) okra. Data presented are mean ± standard error of measurement.

Seed germination parameters of cucumber and okra were shown in table 1. The final germination percentage (FGP) of cucumber was not significantly different among radiation doses. Mean germination time (MGT), germination index (GI) and germination rate index (GRI) were highest at a dose of 50 Gy. For okra, FGP and MGT were not significantly different among radiation doses. GI and GRI of okra were highest at a dose of 50 Gy.
Table 1. Effects of radiation doses on seed germination parameters of cucumber and okra.

| Seed germination parameters | Dose (Gy) | 0      | 50    | 100   | 150   | 200   |
|----------------------------|-----------|--------|-------|-------|-------|-------|
| Cucumber                   | FGP (%)   | 100a,b | 100a  | 90b   | 95a,b | 100a,b|
| MGT (days)                 |           | 3.22a  | 2.71b | 2.81b | 3.38a | 3.45a |
| GI                         |           | 50.8a  | 57.0b | 46.3a | 46.0a | 50.0a |
| GRI                        |           | 30.8a  | 38.3b | 29.0a | 26.4a | 29.2a |
| Okra                       | FGP (%)   | 90a    | 100a  | 94a   | 90a   | 95a   |
| MGT (days)                 |           | 3.57a  | 3.56a | 3.37a | 3.61a | 3.69a |
| GI                         |           | 42.7a  | 53.0b | 52.0b,c| 50.1c | 48.0d |
| GRI                        |           | 25.7a  | 34.3b | 28.7a | 25.5a | 26.6a |

Note: Values in the same row not sharing the same subscript are significantly different at p < 0.05

3.2. Seedling length
Analysis of variance showed differences in seedling length among radiation doses (table 2). The result showed a seedling length of cucumber at 50 Gy on the fourth day was highest at 3.3 cm. On the tenth day, there is no statistical difference of seedling length among groups except for dose at 200 Gy. Seedling length of okra was highest on the fifth day at doses of 50, 100, 150 and 200 Gy.

Table 2. Effects of gamma radiation doses on seedling length of cucumber and okra.

| Time (days) | Cucumber | Dose (Gy) | 0      | 50    | 100   | 150   | 200   |
|-------------|----------|-----------|--------|-------|-------|-------|-------|
|             | 4        | 2.8a      | 3.3b   | 2.8a  | 2.4a  | 2.5a  |
|             | 5        | 7.7a      | 8.8b   | 6.7a  | 6.7a  | 6.9a  |
|             | 6        | 11.1a,b   | 11.9a  | 10.0b,c| 10.9a,b,c| 9.5c  |
|             | 7        | 12.3a,b   | 12.7a  | 11.3a,b,| 11.8a,b,c| 10.6c |
|             | 8        | 12.9a     | 13.1a  | 12.0a,b| 12.2a,b| 11.2b |
|             | 9        | 13.2a     | 13.4a  | 12.3a,b| 12.5a,b| 11.4b |
|             | 10       | 13.4a     | 13.7a  | 12.8a,b| 12.7a,b| 11.8b |
| Okra        |          |           |        |       |       |       |       |
|             | 4        | 1.7a      | 1.9a   | 1.5a  | 1.8a  | 1.5a  |
|             | 5        | 2.2a      | 3.3b   | 3.3b  | 3.2b  | 3.1b  |
|             | 6        | 4.4a      | 4.2a   | 5.1a  | 4.8a  | 4.7a  |
|             | 7        | 4.4a      | 4.2a   | 5.1a  | 4.8a  | 4.7a  |
|             | 8        | 6.4a      | 6.1a   | 7.0a  | 6.9a  | 7.1a  |
|             | 9        | 7.9a      | 7.5a   | 8.3a  | 8.1a  | 8.6a  |
|             | 10       | 9.5a      | 9.0a   | 9.7a  | 9.7a  | 9.9a  |

Note: Values in the same row not sharing the same subscript are significantly different at p < 0.05
3.3. Fresh and dry weight
The fresh and dry weight of cucumber and okra were shown in figure 2. The result showed a decreasing of the fresh weight of cucumber when radiation dose was increased. Okra’s fresh weight was increasing when the radiation dose was increased.

4. Conclusion
When the living organism is exposed by ionizing radiations, there are many effects caused by the radiations ranging from low to high dose. For high dose, the killing effect is dominant which is suitable for sterilization. For medium dose, there are the optimized doses for mutation and mutation breeding. Low doses for stimulating and enhance germination and growth. Previous studies reported some evidence that the low dose affected various types of plants.

The enhancement effects of gamma radiation on germination may be attributed to Ribonucleic acid (RNA) or protein synthesis activation, which occurs during the early stage of germination (Abdel-Hady et al)[13]. Fan et al. found that free radicals generated due to gamma irradiation can act as stress signals and trigger stress responses in plants, resulting in an increased polyphenolic acid synthesis which has notable antioxidative properties [14]. Sjodin indicated that low doses of gamma radiation may increase the enzymatic activation and awakening of the young embryo, which results in stimulating the rate of cell division and enhances not only the germination process but also vegetative growth [15].

This study shows the low dose effects on enhancing the germination rate. Cucumber’s MGT, GI and GRI and seedling length on the fourth day are the most responsive to low dose radiation at 50 Gy. While okra’s GI, GRI and seedling length on the fifth day are the most responsive to low dose radiation at 50 Gy. These show that the low dose of gamma at 50 Gy affect the germination rate, corresponding to the previous study on tomato, sunflower and lettuce seeds [7–9]. These can conclude that the low dose gamma radiation can enhance germination rate and seedling growth of cucumber and okra seed during the early stage of germination.

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