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THE EFFECT OF VARIOUS γ-RAY DOSES ON THE DEVELOPMENT DYNAMICS OF BEAN (*PHASEOLUS)* PLANTS GROWN FROM SEEDS EXPOSED TO PRE-SOWING IRRADIATION

N.R. Guliyeva

Institute of Radiation Problems of ANAS
naraguliyeva01@gmail.com

Abstract: The seeds of the common bean plant (Phaseolus vulgaris), which is one of the most important vegetables in terms of nutrients and extent of usage, were irradiated with different doses of γ-rays generated by the radioisotope Co-60 and the effects of ionizing radiation on the plant growth and development have been studied. Relatively low (1-50 Gy) and high doses (100-300 Gy) of radiation were found to have stimulating and inhibiting effects, respectively, on plant growth as well as development.

Keywords: bean (Phaseolus vulgaris), γ-irradiation, biometric indices

1. Introductıon

It is known that despite the complete cessation of biological processes in the seeds of higher plants during the dormancy, their genetic development program, which carries heredity, is protected from the effects of environmental factors, regardless of the stage of plant ontogenesis and species affiliation. It has been established that although treatment of seeds with γ-rays before sowing in a certain dose range (called the stimulating dose range) does not change the genetic development program, the energy of this radiation in small doses is sufficient to affect regulatory systems. This can lead to the realization of the development program and the rapid passage of the initial phases of ontogenesis. As a result, plant growth and development are accelerated, the ripening period is shortened, productivity under favorable conditions increases, and in some cases, even their quality indices can improve [1, 3].

According to the previous reports, pre-sowing irradiation of seeds in stimulating doses increased the productivity of the potato, cucumber, pea and tomato by 10-40%, and the maize, wheat, bean, sunflower, rice, sugar beet, barley, cabbage and carrot by 30%, 9-11%, 10%, 10-20%, 10-12%, 15-20%, 7-15%, 13-20%, 25-35%, respectively [2].

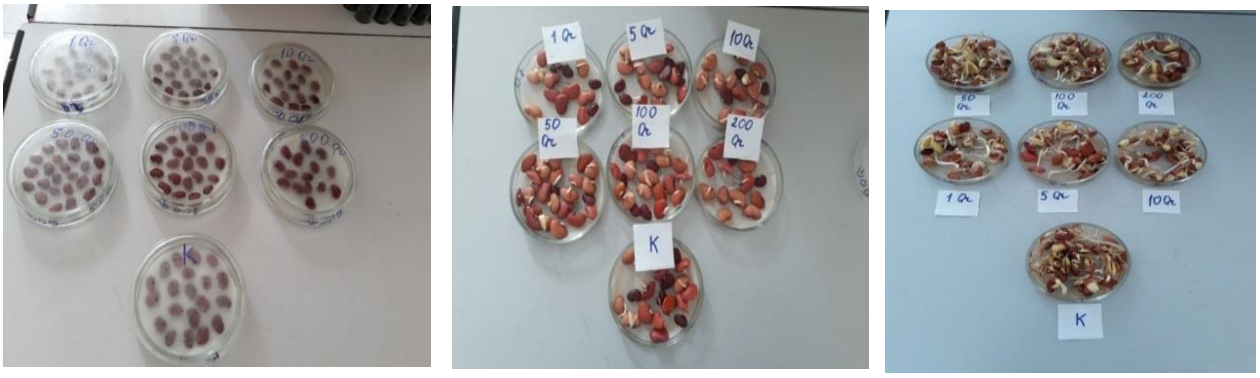
The presented research aimed at the establishment of physiological and biochemical bases of the regulation mechanisms against changes in biochemical indices that occurred in tissues and cells of bean plants exposed to pre-sowing γ-irradiation.

2. Materıals and methods

The “Sevinj” variety of common bean (*Phaseolus vulgaris*) was chosen as the study object (Figure 1). Bean is an important vegetable due to nutrient content as well as the extent of usage. Ripe bean pods contain 14.0% dry matter, including 6% proteins, 4% nitrogenous substances, 4-6% carbohydrates, 2.9% sugar, 1% cellulose, 0.7% minerals, and dry seeds contain about 30% proteins. The amount of protein in 3 kg of beans is equal to the amount of protein in 1 kg of meat [4].

Fig. 1. The appearance of bean seeds

Calculation of germination percentage of irradiated seeds. Using the "RUXUND 20000" device, seeds were irradiated with γ-rays of 1, 5, 10, 50, 100, 200, and 300 Gy doses, produced by the Co-60 isotope. Both irradiated and control seeds were sterilized in 3% hydrogen peroxide solution for 15 min before sowing and germinated in a dark environment on wet filter paper, in Petri dishes under sterile conditions. Seed germination percentage was determined for 1-, 3- and, 5-day-old seedlings and calculated by the formula: $\boldsymbol{a = \frac{n}{m}\ 100\%}$. Where "a" is the germination percentage, "n" and "m" are the number of germinated and total seeds, respectively. 100 is the percentage conversion coefficient. The time-dependent dynamics of seed germination in control and experimental variants are shown in Figure 2.



A B C

Fig. 2. Time-dependent dynamics of been seed germination. A: 1-day-old, B: 3-day-old, C: 5-day-old seedlings.

Selection of plant growing conditions. After the formation of 10-12 mm long roots, the seedlings were placed in vegetation pots and their development continued in a hydroponic system, under artificial climate conditions. The photoperiod in the artificial climate chamber was 12 hours, the temperature was maintained at 23/15 ± 1°C (day/night) by incandescent lamps (220 V, 150 W), the light intensity was maintained at 37.6 W/m^2 using fluorescent lamps, and the relative humidity during the day was 55% and 70% at night. Ordinary tap water was used as a planting substrate.

Determination of biological indices of bean seedlings. Biometric indices of bean seedlings were studied during the first 15 days of their development. These indices include area, weight, width, length, the thickness of the leaf. To measure the area of the leaf (As), it is ironed, then its projection is obtained by spreading it on the millimeter paper on the table. The area of the leaf is then calculated using this projection. The area was determined on millimeter paper, biometric measurements related to mass and weight (weight of leaf, root, plant as a whole) were taken using ordinary scales, and length measurements with an ordinary ruler.

To determine the dry weight (M_d) of the leaf, the leaves of the seedlings were separated from the stem, washed with distilled water, and dried with filter paper. They were kept in a thermostat at 70°C for 48 hours until the stable dry weight was obtained. In the end, the weight of the dried leaves was determined with an analytical balance.

3. Results and dıscussıon

Phenological observations were performed on seedlings, then dynamics of biometric indices (weight, length, area, etc. of plant, leaf, root) of 5, 10, and 15-day-old seedlings, grown from seeds exposed to pre-sowing irradiation, was determined to depend on development stages of the plant. The results obtained are shown in Figure 3.

As seen in Figure 3A, any doses of γ-rays inhibited the growth and development of the 5-day-old seedlings. Differences in biometric indices of plants exposed to pre-sowing irradiation by 5Gy dose can already be observed. Exposure of seeds to a dose of 100 Gy significantly slows down the growth of the plant, at a dose of 200 Gy delay increased, and at a dose of 300 Gy, the seed germination rarely occurred.

For the 10-day-old seedlings, we see a different picture (Figure 3B). In this case, the growth and development of the plant were accelerated by any radiation dose, except 200, 300 Gy, but at 1 Gy and 5 Gy (especially at 5 Gy), the differences in biometric indices of the plant are almost indistinguishable.

Acceleration of plant growth and development at a radiation dose of 5 Gy was more characteristic of the15-day-old seedlings (Figure 3C). Thus, at this irradiation dose, the biometric indices of the plant were significantly higher compared with the control.

A

B

C

Fig. 3. (A) 5-day-old, (B) 10-day-old, and (C) 15-day-old seedlings grown under hydroponic conditions from bean seeds exposed to pre-sowing irradiation.

Our results unequivocally suggest that a radiation dose of 5 Gy stimulates the growth and development of the bean plant, which has several genetic, physiological, and biochemical bases.

The table shows the germination percentage of the 1-, 3- and 5-day-old seedlings.

Table. Time-dependent changes in germination percentage of bean seeds exposed to pre-sowing irradiation under hydroponic conditions

Irradiation doses	Germination, (%)	Irradiation doses	Germination, (%)	Irradiation doses	Germination, (%)
1 day		3 days		5 days	
1 Gy	60	1 Gy	75	1 Gy	90
5 Gy	40	5 Gy	85	5 Gy	95
10 Gy	60	10 Gy	60	10 Gy	80
50 Gy	40	50 Gy	80	50 Gy	90
100 Gy	55	100 Gy	75	100 Gy	85
200 Gy	50	200 Gy	85	200 Gy	90
Control	33	Control	69	Control	90

Based on the results, the germination percentage of the 1- and 3-day-old seedlings depends significantly on the radiation dose. Thus, the germination percentage at any radiation dose is significantly (~ 1.6 times) higher than that of the control. Interestingly, the germination percentage in the 5-day-old seedlings almost does not depend on the radiation dose. In this case, the germination percentage is approximately the same in control and irradiated seeds.

The results obtained on the biometric characteristics of bean seedlings, grown under hydroponic conditions from seeds exposed to pre-sowing irradiation, are given below in the form of diagrams (Figure 4-6).

The total length of the seedlings, grown from seeds exposed to pre-sowing irradiation, varies depending on the radiation dose and the development period of the plant (Figure 4). As seen in the table, the 1 Gy dose of radiation slightly slowed the growth of the plant during the 5 days of development, but in the 10-day-old seedlings, on the contrary, this irradiation dose stimulated and accelerated the growth of the plant. As seen in Table 4, growth and development took place in all variants during the first 10 days, and the seedlings were longest at a dose of 50 Gy. During the next 5 days, only seedlings are grown from seeds irradiated with 1Gy, and 5Gy doses continued to grow. In the remaining variants, growth was maintained almost at the level of the 10-day-old seedlings. Plant growth and development parameters were found to be highest at the radiation doses of 1-50 Gy with little differences at each stage of development. At a dose of 200 Gy, the mentioned values were weakened, and at a dose of 300 Gy, no positive results were obtained.

In the control variants, the height of the seedlings varied similarly and always lagged slightly behind the seedlings grown from the irradiated seeds, depending on the radiation doses. The question may arise: How to explain the regulatory effect of low and medium radiation doses on the growth and development of plants during periods of active growth? Extensive physiological and biochemical research is needed to answer this question. The results obtained in this area suggest that these radiation doses primarily affect the genetic apparatus and activate the genes that responsible for the growth and development of the plant. These genes activate biochemical processes occurring at various levels of the energy exchange leading to improved growth and development, including biological productivity (data not shown).

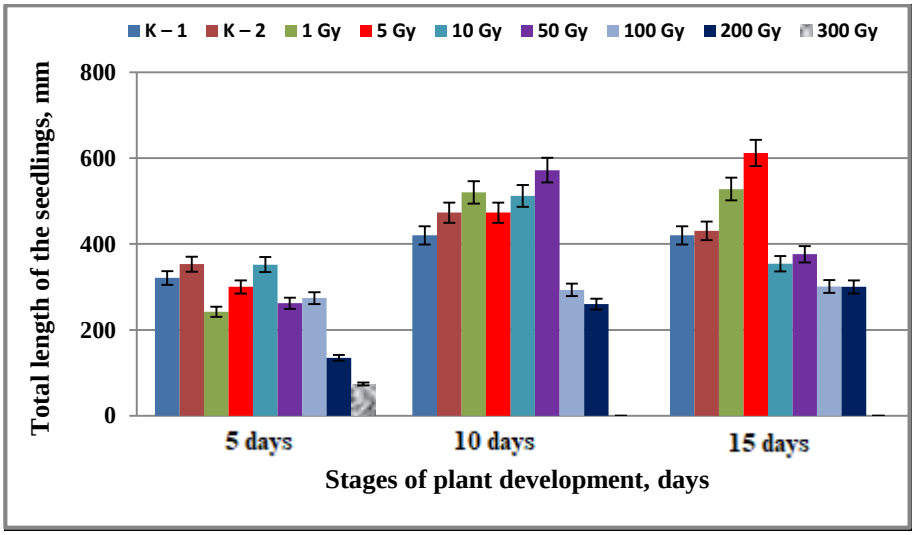


Fig. 4. The total length of the seedlings, grown under hydroponic conditions from seeds exposed to pre-sowing irradiation

Pre-sowing treatment of seeds with γ-rays also had a significant effect on root length (Figure 5). As seen in the figure, the length of the roots similar to the total length of the plant depends on both the radiation dose and the growth period of the plant. Based on the results of the study, the dependence of the root length of the seedlings grown from irradiated seeds on time and radiation dose was more pronounced compared with the dependence of the root length of the control samples on the development dynamics. The growth rate of the plant root length was similar during the first 5 days of the development of plants exposed to pre-sowing irradiation with any doses except 100Gy. The growth rate intensified on the 10th day of the development and the 15th day, in plants exposed to pre-sowing irradiation with doses of 1-50 Gy and 1-100 Gy, respectively. The highest growth rate of the root was observed on the 15th day of the development. At the 5 Gy radiation dose, the difference in growth was approximately 20% higher than on the 10th day.

At the dose of 100 Gy, no change was observed in the length of the roots depending on the rate of plant development, and at the dose of 200 Gy, although the length of the roots did not change in the initial development phase, it significantly decreased in the subsequent phases. In the case of 300 Gy dose of radiation, the length of the roots in the 5-day-old seedlings did not differ from that of the control plant, and in the 10- and 15-day-old seedlings, the roots were destroyed.

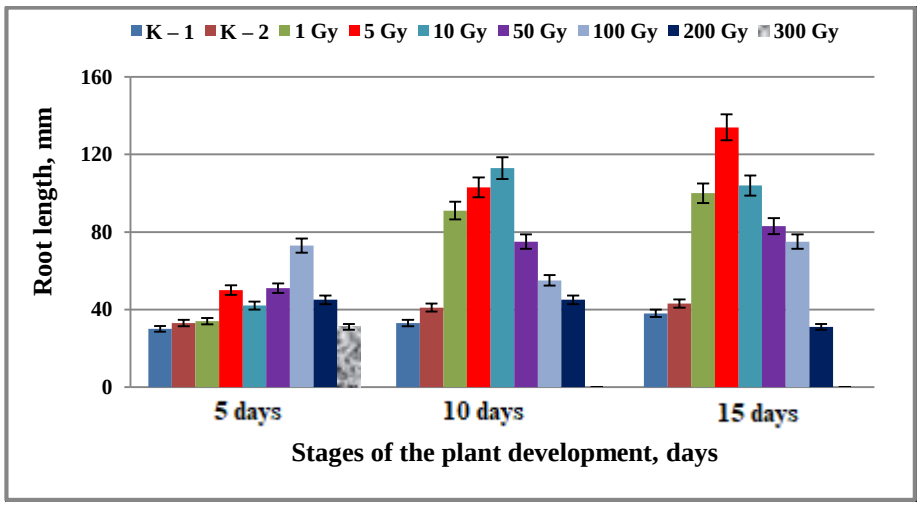


Fig. 5. Root length of the seedlings grown under hydroponic conditions from seeds exposed to pre-sowing irradiation

The results on the leaf length are presented in Figure 6. Depending on plant development dynamics and irradiation doses, a slight tendency to increase was observed in the plant leaf length of both variants, control, and grown from seeds exposed to pre-sowing irradiation (1, 5, 10, and 50 Gy). At 100 Gy, and 200 Gy doses, although no changes depending on plant development dynamics occurred, the dependence between the leaf length and irradiation doses was observed. Thus, at 100 Gy and 200 Gy irradiation, the leaf length was shorter by ~30 %, and ~70 %, respectively.

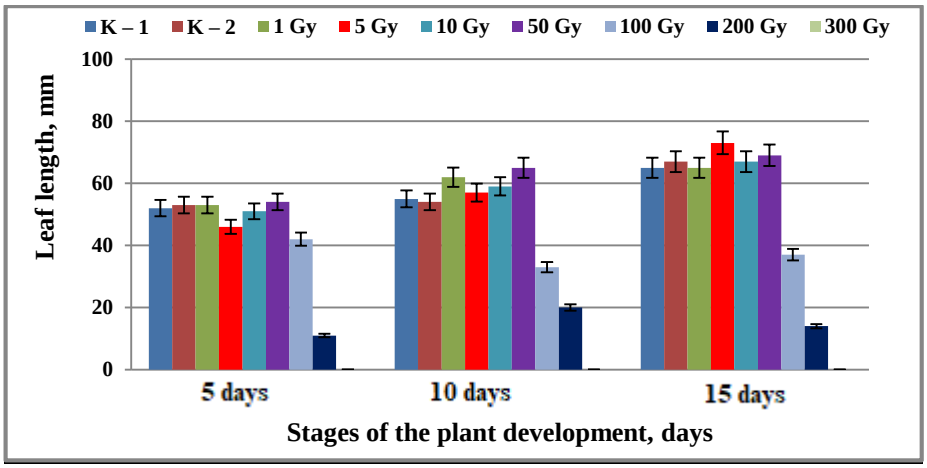


Fig. 6. Leaf length of the seedlings grown under hydroponic conditions from seeds exposed to pre-sowing irradiation

The data on the total mass of seedlings and mass of roots and leaves are presented in Figures 7,8 and 9.

The total mass of the control plant did not change markedly depending on the development stages (Figure 7). Whereas, in plants grown from seeds exposed to pre-sowing irradiation, a significant increase in plant total mass was observed during initial (when 10-day-old seedlings were compared with 5-day-old ones) as well as subsequent (when 15-day-old seedlings were compared with 10-day-old ones) development stages.

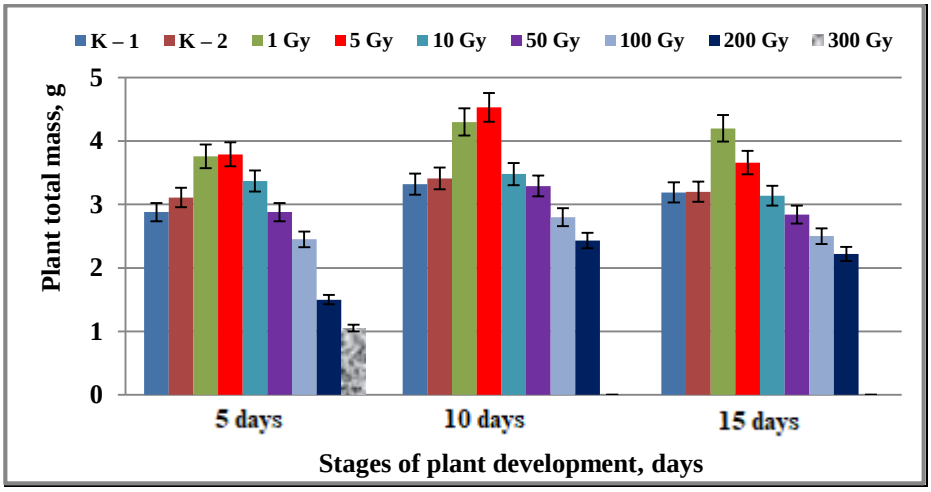


Fig. 7. The total mass of the seedlings grown under hydroponic conditions from seeds exposed to pre-sowing irradiation

Based on the results, the dynamics of the mass of seedlings depends on both the radiation dose and the development period of the plant. While small radiation doses, except small deviations, have a stimulating effect on seedling development, large radiation doses, on the contrary, have an inhibitory effect.

According to the results (Figure 8) on the root mass of plant seedlings, unlike the total mass of plant seedlings, the root mass of control samples increased during initial development and then sharply decreased. To be more precise, the root mass of the 10-day-old seedlings increased by ~17% compared to the 5-day-old seedlings of control samples, while that of the 15-day-old seedlings decreased by ~40%.

Similar results were obtained with the seedlings grown from seeds exposed to pre-sowing irradiation. Thus, at any radiation dose, there is a tendency to increase the mass of roots for the 10-day-old seedlings, and decrease for the 15-day-old seedlings.

As seen in Figure 9, the leaf mass of the control plants gradually increases according to the growth dynamics of the plants, and this increase is about ~20% (for 10-day-old seedlings) and ~30% (for 15-day-old seedlings) compared to the control.

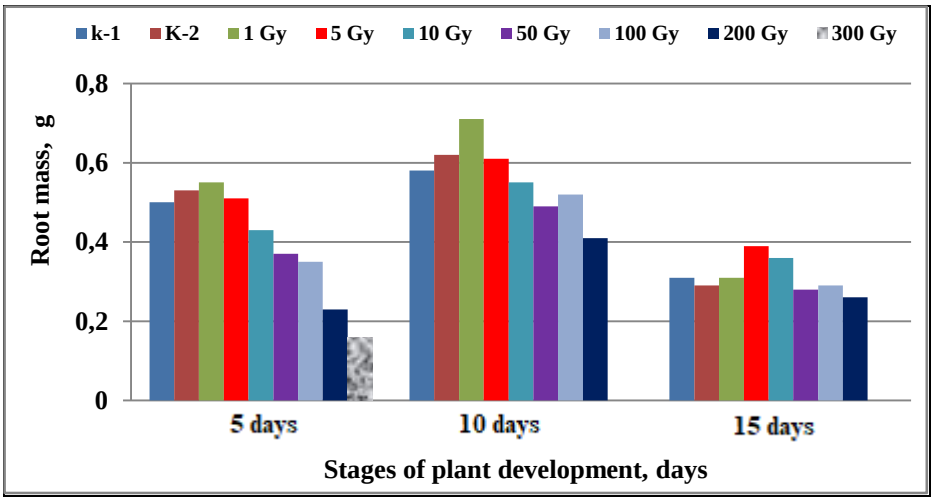


Fig. 8. The root mass of the seedlings grown under hydroponic conditions from seeds exposed to pre-sowing irradiation

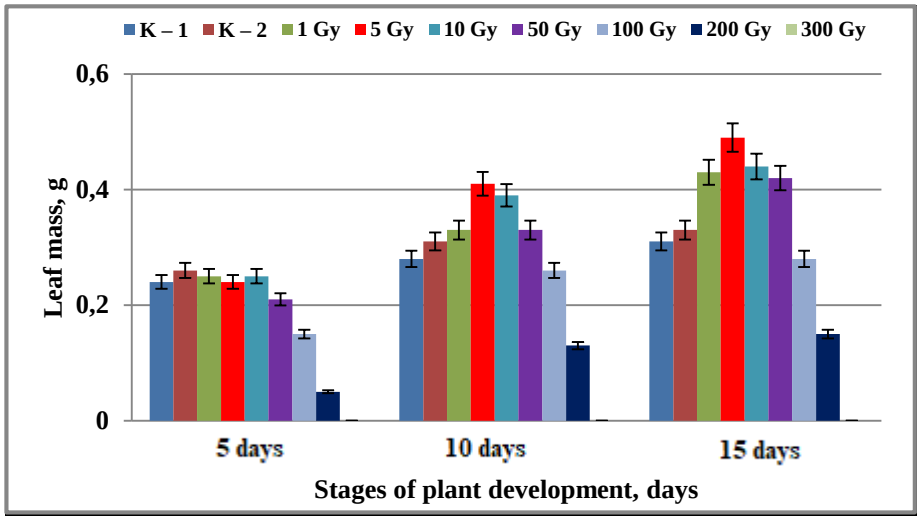


Fig. 9. Leaf mass indices of the seedlings grown under hydroponic conditions from seeds exposed to pre-sowing irradiation

Thus, a different picture was observed for seedlings whose seeds had been exposed to pre-sowing irradiation. Thus, for the 5-day-old seedlings, there is no significant difference in leaf mass in the range of 1-50 Gy radiation dose compared to the control, and an increase in radiation dose in the range of 100-200 Gy leads to a large-scale decrease in leaf mass. In contrast, in the 10- and 15-day-old seedlings, an increase in the radiation dose is accompanied by an increase in leaf mass at doses of 1 and 5 Gy, and a decrease at doses above 50 Gy.

Summarizing the results on the total mass, leaf, and root mass of seedlings, as well as their size, it can be concluded that pre-sowing irradiation of seeds in small doses can affect the accumulation of biomass during the development process, and this process depends also on the plant development period.

Finally, we can conclude that in agriculture today, exposure of plants to small doses of ionizing radiation or pre-sowing irradiation of seeds can stimulate their growth and development, shorten the growing season, increase productivity and improve product quality.

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ВЛИЯНИЕ ОБРАБОТКИ СЕМЯН ГАММА ЛУЧАМИ В РАЗНЫХ ДОЗАХ НА ДИНАМИКУ РАЗВИТИЯ ФАСОЛИ (*PHASEOLUS VULGARIS*).

Н.Р. Гулиева

Резюме: В представленной работе с использованием семена, обработанные перед посевом γ-лучами Co – 60 при разных дозах, было исследовано влияние ионизирующего излучения на рост и развития фасоли (*Phaseolus vulgaris*). Как известно, фасоль занимает важное место среди овощных культур как по питательному составу, так и по масштабу применения.

Показано, что если радиоактивное излучение в зависимости от фазы развития в области дозы облучения от 1 до 50 Гр проявляет стимулирующий эффект, то в области доз от 100 до 300 Гр имеет место ингибирование роста и развития этого растения.

***Ключевые слова*:** фасоль (Phaseolus vulgaris), γ-облучение, биометрические показатели

TOXUMLARIN MÜXTƏLİF DOZALARDA γ-ŞÜALARLA İŞLƏNMƏSİNİN LOBYA (*PHASEOLUS)* BİTKİSİNİN İNKİŞAF DİNAMİKASINA TƏSİRİ

N.R. Guliyeva

Xülasə: Təqdim olunan işdə qida tərkibinə və istifadə miqyasına görə tərəvəz bitkiləri arasında mühüm yer tutan adi lobya (Phaseolus vulgaris) bitkisinin toxumları Co-60 radioizotopunun yaratdığı γ–şüalarla

müxtəlif dozalarda şüalandırılmış və ionlaşdırıcı şüalanmanın onun böyümə və inkişafına təsiri öyrənilmişdir. Müəyyən olunmuşdur ki, bitkinin inkişaf mərhələlərindən asılı olaraq radioaktiv şüalanma nisbətən kiçik - 1-50 Qr dozalarda bitkinin böyümə və inkişafına stimullaşdırıcı, yuxarı - 100-300 Qr dozalarda isə, əksinə, onun böyümə və inkişafına inhibirləşdirici təsir göstərir

Açar sözlər: lobya (Phaseolus vulgaris), γ-radiasiya, biometrik göstəricilər.