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# BETA RADIATION EFFECTS ON THE GROWTH PARAMETERS OF *PHASEOLUS VULGARIS* L.

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**Abstract:** This investigation is carried out to determine the effect of low dose beta rays on the growth parameters of *Phaseolus vulgaris.* The seeds of four different varieties of *Phaseolus vulgaris* were treated with beta rays from Sr-90 source emitting beta rays at the rate of 7.4835 mrad/hr. The local variety 3 is predicted to be more radiostimulative and local variety 2 more radiosensitive. In general lower doses stimulated the growth by significantly affecting the growth parameters whereas the higher ones caused radiation injury.
**Keywords:** Beta radiation, *Phaseolus vulgaris*, Growth parameters.

## Introduction

The ionizing radiation exposure causes several effects on plants, based on their accumulation and localization. DNA is usually believed to be the primary site of radiation stress, radionuclide enters into the cellular compartments and sometimes binds with the DNA and influences its synthesis, effects amino acids and disturbs various metabolic processes such as respiration, photosynthesis, growth, enzyme synthesis and hormonal activities (Rabie *et.al.*, 1996). The type of irradiation (acute or chronic), dose rate, dose type and the physiological parameters of the species exposed along with the developmental stage at the time of irradiation are important to conquer radiation stress. Low and moderate stress is overcome by the adaptive response of the plants which are sometimes manifested as the stimulatory response seen in plants, while the higher radiation stress damages the plant. Ionizing radiation stimulation causes some morphogenetic changes in plants during early developmental stages (Mericle and Mericle, 1967). Many studies has shown that low doses of ionizing radiation can stimulate plant growth during initial growth phases (Sparrow, 1966; Taylor, 1968; Mujeeb, 1974, Mathew and Gaur, 1975; Croute *et.al.*, 1982; Raghava & Raghava, 1989, Thapa, 1999, Grover and Khan, 2014), whereas the higher doses were reported to be inhibitory and lethal for plant growth and metabolism (Kumari and Singh, 1996; Radhadevi and Nayer, 1996; Marcu *et.al.,* 2013).

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Since now a very few works has been conducted on the beta radiation effects on plants. This study is dedicated to the study of the influence of low dose beta radiation on the *Phaseolus vulgaris* seeds and its effects on the early ontogenic stages of plant germination as obtained from the pre sowing irradiation of seeds.

**Materials and Methods**

Seed Samples and Irradiation

The seeds of four varieties including three local ones Local Variety1 (LV1), Local Variety 2 (LV2), Local Variety 3 (LV-3) and one Hybrid variety (HV) of *Phaseolus vulgaris* were taken for the study. The seeds were first surface sterilized with 0.1% mercuric chloride and then washed successively with distilled water. The surface sterilized seeds were soaked in distilled water overnight and then subjected to radiation with different beta ray doses with a Sr-90 source emitting beta ray at the rate of 7.4835 mrad/hr.

**Experimental design**

The seeds were germinated in petri dishes with moistened filter paper. A completely randomized design (CRD) with replication was planned for the experiment. The emergence of radicle is taken as an indicator of germination. The germinating seeds were scored daily and the germinating speed (S) and germination percentage is calculated according to the following formula (Chiapusio *et.al.*, 1997):

$$S\ (\text{seedday}^{-1}) = (N_1 \times 1) + (N_2 - N_1) \times ½ + \ldots\ldots\ldots\ldots\ldots\ldots (N_n - N_{n-1}) \times 1/n \qquad \ldots(1)$$

Where $N_1$, $N_2$,……., $N_{n-1}$, $N_n$ = Proportions of germinated seeds observed at 1, 2,……..n-1 and n days.

The germination percentage is measured on 4th day using the formula:

$$\text{Germination Percentage} = \frac{\text{Total number of germinated seeds}}{\text{Total number of seeds}} \times 100 \qquad \ldots(2)$$

In parallel to this study another experiment is conducted consisting of growing irradiated seeds in plastic pots of size (22 × 20 × 15) cm. The pots were maintained in field in a complete randomized design with replications. Homogeneous garden soil is used without any fertilizer. The pots were maintained at field weighing and measuring at daily basis. Water is applied manually to maintain soil moisture at field capacity as well as weed was controlled regularly. Growth parameters such as shoot length, root length, survival percentage, number of branches, number of leaves, moisture content were recorded at regular periods. The plants were then removed from pots and their roots washed. Dry weight is measured after complete drying of plants.

**Data Analysis**

Analysis of variance is used to evaluate the effect of radiation dose. Means were compared by using Fishers Least Significance Difference (LSD) test at 5% probability using statistical program SPSS.

**Results and Discussions**

Germination Speed and Germination Percentage

The germination speed and germination percentage are significantly delayed by higher doses of beta irradiation. A slight increase in germination speed and percentage is reported at lower doses, compared to the non-irradiated ones (Fig. 1). Higher doses delay the germination parameters.

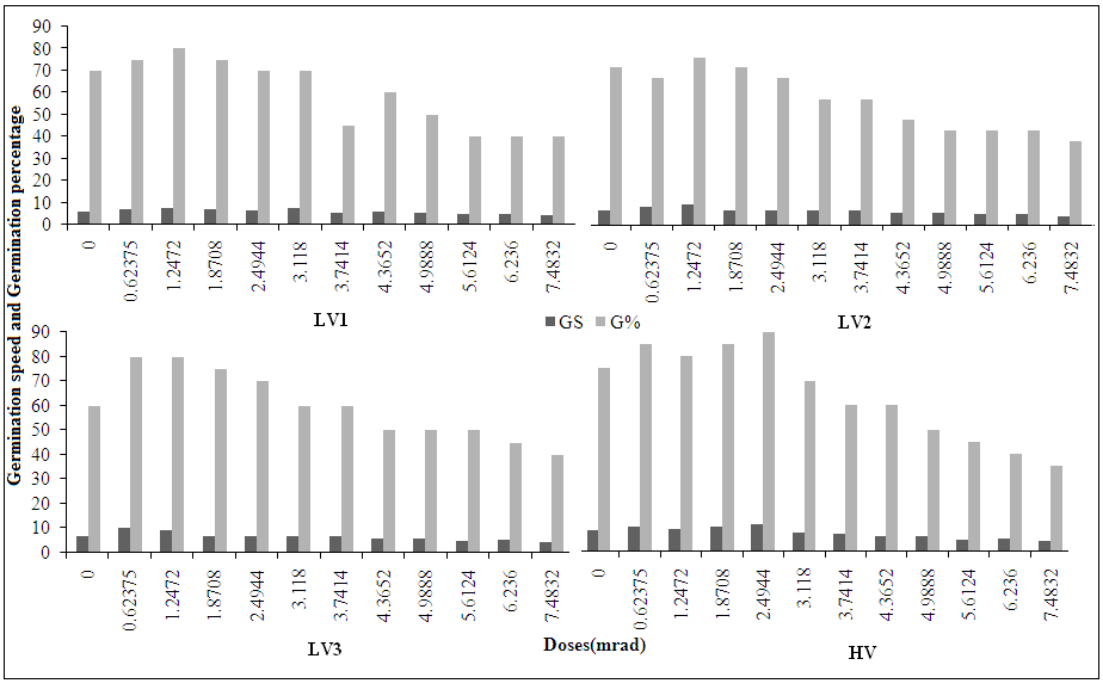


**Fig 1.** Effect of beta radiation on the germination speed (GS) and germination percentage (G%) of different varieties of *Phaseolus vulgaris*.

**Beta radiation exposure effect on radicle growth**

The data presented in Table 1 shows that the irradiation doses have a significant effect on the radicle lengths. In all the varieties a stimulatory growth has been reported at lower doses. The radicle lengths were found to show increase in length compared to control in LV1 upto the dose of 6.236 mrad exposure. The largest radicle length is seen in the LV2, predicting it as a fastest growing variety. However the higher doses (1.8708 mrad) decreases the radicle length growth. In LV3 and HV beta radiation exposure is seemed to stimulate the growth in all

doses when compared to control. The maximum growth is seen at lower doses which decrease with increase in dose. However in general all the varieties has shown a little stimulatory effects at lower doses while delayed effects are reported at higher ones.

**Table1**. The effect of beta radiation on the radicle length (cm) on different varieties of *Phaseolus vulgaris*

| Dose (mrad) | LV1 | SD | LV2 | SD | LV3 | SD | HV | SD |
|---|---|---|---|---|---|---|---|---|
| 0 | $2.875^{F}$ | 0.1552 | $5.735^{C}$ | 0.1309 | $1.820^{K}$ | 0.0834 | $2.320^{H}$ | 0.1240 |
| 0.62375 | $3.855^{B}$ | 0.3441 | $6.700^{A}$ | 0.1522 | $5.975^{A}$ | 0.2173 | $3.260^{E}$ | 0.1314 |
| 1.2472 | $4.630^{A}$ | 0.3757 | $6.370^{B}$ | 0.1720 | $5.555^{B}$ | 0.1146 | $3.850^{C}$ | 0.1504 |
| 1.8708 | $3.855^{B}$ | 0.2064 | $4.970^{DE}$ | 0.1922 | $5.015^{D}$ | 0.1040 | $4.665^{B}$ | 0.1040 |
| 2.4944 | $3.445^{C}$ | 0.1791 | $4.890^{E}$ | 0.1294 | $5.125^{C}$ | 0.1070 | $4.875^{A}$ | 0.1585 |
| 3.118 | $3.455^{C}$ | 0.1356 | $5.040^{D}$ | 0.1392 | $4.470^{F}$ | 0.1418 | $3.695^{D}$ | 0.0999 |
| 3.7414 | $2.980^{EF}$ | 0.1963 | $4.011^{G}$ | 0.1268 | $4.540^{F}$ | 0.1095 | $3.130^{F}$ | 0.1218 |
| 4.3652 | $3.215^{D}$ | 0.1843 | $5.030^{D}$ | 0.1261 | $4.710^{E}$ | 0.1553 | $3.035^{G}$ | 0.1309 |
| 4.9888 | $3.015^{E}$ | 0.1348 | $4.655^{F}$ | 0.1191 | $3.660^{H}$ | 0.1142 | $3.030^{G}$ | 0.1455 |
| 5.6124 | $3.400^{C}$ | 0.1257 | $3.690^{H}$ | 0.1619 | $3.750^{G}$ | 0.1051 | $3.120^{FG}$ | 0.2331 |
| 6.236 | $2.950^{EF}$ | 0.1878 | $4.000^{G}$ | 0.2248 | $3.340^{I}$ | 0.1142 | $2.370^{H}$ | 0.1342 |
| 7.4832 | $2.445^{G}$ | 0.1191 | $3.735^{H}$ | 0.1268 | $3.030^{J}$ | 0.1081 | $2.345^{H}$ | 0.2114 |

Mean values in vertical columns followed by different letters are significantly different at 5% level of significance using Fishers test.

LV1= Local Variety 1, LV2= Local Variety-2, LV3= Local Variety 3, HV= Hybrid Variety, SD= Standard Deviation

**Beta radiation exposure effects on plant growth**

Effect of beta rays on basic growth parameters on different varieties of *Phaseolus vulgaris* are depicted in Table 2-5.

**Table 2.** The effect of beta radiation on growth parameters of *Phaseolus vulgaris* (LV1)

| Dose (mrad) | RL(cm) | SL(cm) | NoB/Plant | NoL/Plant | SW(gm) | SDW(gm) | RW(gm) | RDW(gm) |
|---|---|---|---|---|---|---|---|---|
| 0 | $7.00^{J}$ | $15.00^{I}$ | $4.80^{D}$ | $9.00^{D}$ | $1.74^{H}$ | $0.32^{G}$ | $0.25^{F}$ | $0.03^{G}$ |
| 0.62375 | $10.88^{BC}$ | $20.46^{C}$ | $6.80^{B}$ | $12.40^{B}$ | $3.80^{C}$ | $0.64^{B}$ | $0.58^{C}$ | $0.07^{C}$ |
| 1.2472 | $13.48^{A}$ | $23.00^{A}$ | $7.80^{A}$ | $14.80^{A}$ | $4.64^{A}$ | $0.78^{A}$ | $0.76^{A}$ | $0.09^{A}$ |
| 1.8708 | $11.12^{B}$ | $22.00^{B}$ | $7.00^{B}$ | $12.60^{B}$ | $4.24^{B}$ | $0.72^{A}$ | $0.64^{B}$ | $0.08^{B}$ |
| 2.4944 | $10.78^{C}$ | $19.00^{D}$ | $6.00^{C}$ | $12.00^{B}$ | $3.48^{D}$ | $0.55^{CD}$ | $0.58^{C}$ | $0.07^{C}$ |
| 3.118 | $10.40^{D}$ | $18.00^{E}$ | $6.00^{C}$ | $10.80^{C}$ | $3.12^{E}$ | $0.54^{C\ DE}$ | $0.57^{C}$ | $0.07^{C}$ |
| 3.7414 | $7.46^{I}$ | $16.00^{H}$ | $5.60^{C}$ | $9.40^{D}$ | $2.86^{FG}$ | $0.50^{DEF}$ | $0.25^{F}$ | $0.05^{F}$ |
| 4.3652 | $10.00^{E}$ | $17.96^{E}$ | $5.80^{C}$ | $10.60^{C}$ | $3.48^{D}$ | $0.52^{D\ E}$ | $0.54^{C}$ | $0.07^{D}$ |
| 4.9888 | $9.00^{G}$ | $17.14^{G}$ | $6.00^{C}$ | $9.60^{D}$ | $3.00^{E\ F}$ | $0.47^{E\ F}$ | $0.37^{E}$ | $0.06^{E}$ |
| 5.6124 | $9.68^{F}$ | $17.62^{F}$ | $5.80^{C}$ | $9.60^{D}$ | $3.10^{E}$ | $0.60^{BC}$ | $0.47^{D}$ | $0.06^{E}$ |
| 6.236 | $8.00^{H}$ | $15.10^{I}$ | $5.60^{C}$ | $9.60^{D}$ | $2.80^{G}$ | $0.44^{F}$ | $0.27^{F}$ | $0.03^{G}$ |
| 7.4832 | $6.98^{J}$ | $14.00^{J}$ | $4.00^{E}$ | $5.60^{E}$ | $0.50^{I}$ | $0.08^{H}$ | $0.24^{F}$ | $0.03^{G}$ |

Mean values in vertical columns followed by different letters are significantly different at 5% level of significance using Fishers test

RL= Root Length, SL= Shoot Length, NoB= No. of Branches, NoL=No. of Leaves, SW= Shoot Weight, SDW= Shoot Dry weight, RW= Root Weight, RDW= Root Dry Weight

**Table 3.** The effect of beta radiation on growth parameters of *Phaseolus vulgaris* (LV2)

| Dose (mrad) | RL(cm) | SL(cm) | NoB/Plant | NoL/Plant | SW(gm) | SDW(gm) | RW(gm) | RDW(gm) |
|---|---|---|---|---|---|---|---|---|
| 0 | $14.50^{C}$ | $16.98^{C}$ | $5.00^{A}$ | $8.00^{B}$ | $2.50^{B}$ | $0.43^{A}$ | $0.50^{B}$ | $0.059^{D}$ |
| 0.62375 | $14.94^{B}$ | $17.20^{B}$ | $5.00^{A}$ | $9.80^{A}$ | $2.64^{A\ B}$ | $0.45^{A}$ | $0.51^{B}$ | $0.064^{C}$ |
| 1.2472 | $16.00^{A}$ | $17.94^{A}$ | $5.20^{A}$ | $10.00^{A}$ | $2.70^{A}$ | $0.45^{A}$ | $0.54^{A}$ | $0.068^{B}$ |
| 1.8708 | $12.52^{F}$ | $15.00^{E}$ | $4.00^{B\ C}$ | $8.00^{B}$ | $2.00^{\ DE}$ | $0.35^{CD}$ | $0.38^{G}$ | $0.046^{H}$ |
| 2.4944 | $14.04^{D}$ | $16.96^{C}$ | $4.80^{A\ B}$ | $8.26^{B}$ | $2.32^{C}$ | $0.39^{B}$ | $0.48^{C}$ | $0.057^{E}$ |
| 3.118 | $13.12^{E}$ | $16.26^{D}$ | $4.80^{A\ B}$ | $7.80^{B}$ | $2.32^{C}$ | $0.39^{B}$ | $0.43^{E}$ | $0.053^{G}$ |
| 3.7414 | $10.68^{G}$ | $13.50^{G}$ | $3.40^{C\ D}$ | $7.00^{C}$ | $1.92^{E}$ | $0.33^{D}$ | $0.31^{H}$ | $0.034^{I}$ |
| 4.3652 | $12.98^{E}$ | $15.00^{E}$ | $4.00^{B\ C}$ | $8.40^{B}$ | $2.20^{C}$ | $0.38^{B}$ | $0.42^{F}$ | $0.055^{F}$ |
| 4.9888 | $10.86^{G}$ | $14.46^{F}$ | $3.80^{C}$ | $7.00^{C}$ | $2.16^{CD}$ | $0.36^{BC}$ | $0.45^{D}$ | $0.034^{I}$ |
| 5.6124 | $9.40^{H}$ | $12.00^{I}$ | $2.80^{D}$ | $6.60^{C}$ | $1.26^{G}$ | $0.27^{E}$ | $0.27^{I}$ | $0.024^{K}$ |
| 6.236 | $9.50^{H}$ | $12.70^{H}$ | $3.60^{C\ D}$ | $7.00^{C}$ | $1.50^{F}$ | $0.28^{E}$ | $0.31^{H}$ | $0.031^{J}$ |
| 7.4832 | $5.46^{I}$ | $7.50^{J}$ | $1.60^{E}$ | $3.80^{D}$ | $1.20^{G}$ | $0.22^{F}$ | $0.23^{J}$ | $0.092^{A}$ |

Mean values in vertical columns followed by different letters are significantly different at 5% level of significance using Fishers test

RL= Root Length, SL= Shoot Length, NoB= No. of Branches, NoL=No. of Leaves, SW= Shoot Weight, SDW= Shoot Dry weight, RW= Root Weight, RDW= Root Dry Weight

**Table 4.** The effect of beta radiation on growth parameters of *Phaseolus vulgaris* (LV3)

| Dose (mrad) | RL(cm) | SL(cm) | NoB/Plant | NoL/Plant | SW(gm) | SDW(gm) | RW(gm) | RDW(gm) |
|---|---|---|---|---|---|---|---|---|
| 0 | $4.14^{J}$ | $7.46^{I}$ | $2.40^{C}$ | $4.20^{H}$ | $1.77^{FG}$ | $0.27^{G}$ | $0.51^{K}$ | $0.07^{H}$ |
| 0.62375 | $13.14^{B}$ | $17.16^{B}$ | $4.40^{AB}$ | $8.60^{B}$ | $2.56^{B}$ | $0.43^{B}$ | $1.34^{A}$ | $0.68^{A}$ |
| 1.2472 | $14.08^{A}$ | $18.00^{A}$ | $5.20^{A}$ | $9.80^{A}$ | $2.78^{A}$ | $0.60^{A}$ | $1.29^{B}$ | $0.16^{B}$ |
| 1.8708 | $12.14^{C}$ | $17.04^{B}$ | $4.00^{B}$ | $8.20^{B\ C}$ | $2.56^{B}$ | $0.43^{B}$ | $1.25^{C}$ | $0.16^{B}$ |
| 2.4944 | $11.52^{D}$ | $17.02^{B}$ | $4.00^{B}$ | $8.00^{B\ C}$ | $2.46^{BC}$ | $0.42^{B}$ | $1.20^{D}$ | $0.16^{B}$ |
| 3.118 | $11.14^{E}$ | $16.28^{C}$ | $3.80^{B}$ | $7.60^{C\ D}$ | $2.54^{B}$ | $0.39^{C}$ | $1.02^{E}$ | $0.15^{C}$ |
| 3.7414 | $10.03^{G}$ | $13.54^{F}$ | $2.40^{C}$ | $5.20^{FG}$ | $1.73^{G}$ | $0.30^{F}$ | $0.67^{I}$ | $0.06^{H}$ |
| 4.3652 | $10.84^{F}$ | $14.98^{D}$ | $2.80^{C}$ | $6.80^{D\ E}$ | $2.36^{C\ D}$ | $0.37^{D}$ | $0.91^{F}$ | $0.14^{D}$ |
| 4.9888 | $10.74^{F}$ | $15.04^{D}$ | $2.60^{C}$ | $6.20^{E}$ | $2.30^{D}$ | $0.37^{D}$ | $0.87^{G}$ | $0.12^{E}$ |
| 5.6124 | $9.96^{G}$ | $14.46^{E}$ | $2.60^{C}$ | $6.00^{EF}$ | $1.98^{E}$ | $0.33^{E}$ | $0.77^{H}$ | $0.11^{E}$ |
| 6.236 | $9.46^{H}$ | $12.68^{G}$ | $2.40^{C}$ | $4.80^{G\ H}$ | $1.86^{EF}$ | $0.29^{F}$ | $0.55^{J}$ | $0.09^{F}$ |
| 7.4832 | $7.18^{I}$ | $11.98^{H}$ | $2.40^{C}$ | $4.40^{G\ H}$ | $1.80^{F\ G}$ | $0.29^{F}$ | $0.52^{K}$ | $0.08^{G}$ |

Mean values in vertical columns followed by different letters are significantly different at 5% level of significance using Fishers test

RL= Root Length, SL= Shoot Length, NoB= No. of Branches, NoL=No. of Leaves, SW= Shoot Weight, SDW= Shoot Dry weight, RW= Root Weight, RDW= Root Dry Weight

The result shows the increasing radiation doses has adverse and inhibitory effects on the plant growth. The seeds exposed to higher doses reported reduced root and shoot growth. In addition the number of leaves and branches were also found to decrease in higher doses. So was the fresh and dry weight of the plants. In LV1, significant increase in all the growth parameters were found upto the dose of 6.236 mrad, compared to control. The highest growth

reported in 1.2472 mrad. The growth rate first increased with dose and then successively decreases with higher treatments. The dose of 7.4832 mrad is found to show negative effects on growth parameters. In LV2 all the higher doses is found to produce draft plants with reduced roots. The growth rate decreases with 1.8708 mrad exposure.

**Table 5.** The effect of beta radiation on growth parameters of *Phaseolus vulgaris* (HV)

| Dose (mrad) | RL(cm) | SL(cm) | NoB/Plant | NoL/Plant | SW(gm) | SDW(gm) | RW(gm) | RDW(gm) |
|---|---|---|---|---|---|---|---|---|
| 0 | $7.04^{J}$ | $12.16^{J}$ | $4.10^{J}$ | $3.60^{H}$ | $1.61^{I}$ | $0.27^{G}$ | $0.47^{G}$ | $0.06^{H}$ |
| 0.62375 | $11.92^{E}$ | $16.44^{E}$ | $10.30^{E}$ | $9.60^{C}$ | $2.32^{E}$ | $0.39^{D}$ | $1.12^{B}$ | $0.13^{D}$ |
| 1.2472 | $12.46^{D}$ | $17.14^{D}$ | $10.96^{D}$ | $11.40^{B}$ | $2.35^{DE}$ | $0.40^{CD}$ | $1.12^{B}$ | $0.14^{C}$ |
| 1.8708 | $13.00^{C}$ | $19.04^{B}$ | $15.00^{B}$ | $11.60^{B}$ | $3.36^{B}$ | $0.56^{B}$ | $1.15^{AB}$ | $0.15^{B}$ |
| 2.4944 | $18.04^{A}$ | $21.48^{A}$ | $18.00^{A}$ | $16.00^{A}$ | $3.78^{A}$ | $0.65^{A}$ | $1.16^{A}$ | $0.20^{A}$ |
| 3.118 | $15.00^{B}$ | $18.06^{C}$ | $11.40^{C}$ | $11.60^{B}$ | $2.36^{D}$ | $0.42^{C}$ | $1.02^{C}$ | $0.15^{B}$ |
| 3.7414 | $11.04^{G}$ | $14.04^{F}$ | $9.10^{F}$ | $8.80^{D}$ | $2.34^{DE}$ | $0.40^{CD}$ | $0.81^{D}$ | $0.12^{E}$ |
| 4.3652 | $11.20^{F}$ | $14.14^{F}$ | $7.12^{G}$ | $7.60^{E}$ | $2.23^{F}$ | $0.39^{D}$ | $0.71^{E}$ | $0.09^{F}$ |
| 4.9888 | $9.96^{H}$ | $13.10^{H}$ | $5.06^{I}$ | $7.00^{F}$ | $2.46^{C}$ | $0.36^{E}$ | $0.62^{F}$ | $0.08^{G}$ |
| 5.6124 | $10.08^{H}$ | $13.34^{G}$ | $6.60^{H}$ | $7.00^{F}$ | $2.16^{G}$ | $0.36^{E}$ | $0.71^{E}$ | $0.09^{F}$ |
| 6.236 | $7.98^{I}$ | $12.88^{I}$ | $5.14^{I}$ | $4.80^{G}$ | $1.83^{H}$ | $0.30^{F}$ | $0.58^{F}$ | $0.07^{G}$ |
| 7.4832 | $6.98^{J}$ | $11.92^{K}$ | $4.02^{J}$ | $3.60^{H}$ | $1.46^{J}$ | $0.25^{H}$ | $0.30^{H}$ | $0.04^{I}$ |

Mean values in vertical columns followed by different letters are significantly different at 5% level of significance using Fishers test

RL= Root Length, SL= Shoot Length, NoB= No. of Branches, NoL=No. of Leaves, SW= Shoot Weight, SDW= Shoot Dry weight, RW= Root Weight, RDW= Root Dry Weight

Stimulatory response is seen in lower doses (1.2472 mrad), which reports higher growth compared to control. Irradiation in LV3 is found to stimulate the growth parameters, compared to control. All the doses are reported to increase the root and shoot length of plants and hence the other associated growth parameters. The result obtained from hybrid varieties also shows similar characteristics. The dose of 7.4832 mrad exposure is found to produce reduced root-shoot length in LV1 and HV. The stimulation and root shoot elongation at lower doses is successively reflected by the increase in dry and fresh weight. The stimulation at lower doses is also reported by many workers at different plant species (Charbaji and Nabulsi, 1999; Thapa, 2004; Klarizze, 2005; Chicea and Racuciu, 2007, 2008). This stimulation may be due to the accelerated cell division or due to the activation of certain growth regulators (Zaka, 2004).

The reduction in plant height by higher doses is consistent with the findings of several workers (Kharkwal, 2000). The retarding effect of higher doses may be due to the injury caused in seeds by higher irradiation effects (Akhaury and Singh, 1993; Mehetre *et.al.*, 1994; Thapa, 1999).

## Conclusions

The result of this research shows stimulatory effects of beta radiation at lower doses and inhibitory effect at higher doses. The maximum stimulation is seen in 1.2472 mrad exposure for local varieties and 2.4944 mrad exposure for the hybrid variety. All the growth parameters are found to be affected slightly by lower doses. Delayed and decreasing trends are however reported with increase in dose. The local variety 3 is reported to be more radiostimulative, than the other three varieties, showing maximum growth, after radiation exposure. Local variety 2 is found to be more radiosensitive compared to others. Overall it can be concluded higher radiation causes lethal effect on seed germination and plant growth. However more research is needed to investigate the stimulatory effects of beta radiation on plant growth.

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