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Stimulation Effects of Gamma Radiation on Growth and Yield of Two Tomato (*Lycopersicon esculentum*, Mill) Cultivars

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Abstract. Dry seeds of two tomato (*Lycopersicon esculentum*, Mill) cultivars, namely Roma VF and Pearson A-1 Improved, were exposed to gamma radiation from a cobalt - 60 source to study the stimulation effects of radiation on growth and yield. Six radiation doses were used as follow, 0 (Control), 500, 1000, 2000, 3000 and 4000 R. Sensitivity assessments were based on measurements of plant height, shoot fresh weight, leaf area, early yield, total yield and average fruit weight and number of fruit per plant. Different stimulating effects were observed in the studied characters due to the used doses of gamma radiation. These stimulating effects were more obvious when the dose 1000 R was used. Moreover, the two cultivars varied in their response to the different radiation doses, indicating the presence of interaction effects between radiation treatments and cultivars.

Introduction

Stimulation effects following low dose irradiation of seeds have been reported by many investigators since the turn of the century and has been reviewed by Sax [1]. The commonly reported expressions of these effects were more vigorous vegetative growth [2, 3, 4], earlier maturity [5, 6] and higher yield [7, 8, 9].

Irradiation of seeds before sowing has many advantages. Its chief merits are : 1) organization of irradiation treatment in specially equipped places with subsequent transportation of seeds, thus facilitating easy handling and store of the irradiated material, 2) irradiation of material in due time, and 3) complete absence of radioactivity both in the seed and in the harvested yield.

In 1970, the FAO / IAEA consultant Group [10] strongly recommended tomato as a test plant due to its economic importance and its adaptability to many climatic condition.

The experiments described herein were conducted to investigate the effects of low level of gamma radiation, from cobalt-60 source, on the growth and yield of two tomato cultivars.

Materials and Methods

This work was carried out during 1994 and 1995 growing seasons at the Agricultural Research and Experimental Station, College of Agriculture, King Saud University at Dierab, Riyadh, Saudi Arabia.

Dry seeds of two tomato cultivars, Rome VF and Pearson A-1 Improved, were used for this study and they were subjected to gamma radiation from a cobalt-60 source, installed at King Faisal Specialist Hospital, Riyadh, Saudi Arabia, on 10 Jan., 1994. The doses used were : 0 (Control), 500, 1000, 2000, 3000 and 4000 Roentgen (R) at a dose rate of 1562.5 R/min. Ten grams of seeds were used for each radiation treatment. Both treated and untreated seeds (control) were sown in the nursery on 15 Jan., 1994. Seedlings were transplanted on 20 Feb., 1994 in a greenhouse using a split-plot system in a randomized complete block design with four replications. Tomato cultivars were randomized in the main plots, whereas the radiation doses were allocated to the sub-plots. Each sub-plot consisted of two rows with 8 plants each, spaced at 50 cm. The general cultural practices such as irrigation, fertilization and pest control were carried out whenever it appeared necessary and as usually practiced in commercial tomato production. On 10 Jan., 1995, the experiment was repeated exactly the same way as that of previous season.

The following measurements were recorded on three plants in each experimental unit:

1) Main stem height at the beginning of blooming stage.
2) Shoot fresh weight at the beginning of the flowering stage.
3) Leaf area of fully grown leaves, detached from the above samples, using a leaf area meter (LI- Cor, model LI - 3000 A).

The following measurements were recorded on the remaining plants in each sub-plot:

1) Early yield was considered as weight of the fruits harvested in the first two picking.

2) Total yield was measured as the weight of all harvested fruits throughout the entire harvested season.
3) Fruit number per plant was recorded by dividing the total number of picked fruits by corresponding number of plants.
4) Fruit weight was determined by dividing total yield by total number of fruits harvested.

Data recorded were statistically analyzed as described by Steel and Torrie [11, p.633] and means were compared using the least significant difference (LSD) test at the 5% level.

Results

1. Vegetative characters:

a) Plant height

Results presented in Table 1 showed that cultivar Pearson A-1 Improved was significantly taller than Roma VF. The radiation treatments induced significant stimulation effects. The highest plant height mean was associated with dose 1000 R, followed by the dose 2000 R, but the difference between them was not significant in the first season. However, such a stimulating effect did not follow a regular trend, since the average plant height of the plants grown from the seeds that were irradiated with the dose 3000 R appeared to be approximately similar to that of 500 R treatment. Increasing the dose over 3000 R had an opposite effect. The average plant height of 4000 R was significantly lower than those in the other doses and the control in both seasons. The two cultivars responded differently to the various radiation doses and with significant interaction effects. In case of Roma VF, the highest radiation dose (4000 R) did not cause any reduction below the control, whereas, Pearson A-1 Improved responded to the 4000 R dose with significantly lower average plant height than in the control.

Table 1. Effect of different gamma radiation doses on plant height (m) of two tomato cultivars, at the beginning of blooming stage

Cultivar	Gamma ray dose (R)						
	0	500	1000	2000	3000	4000	Mean
			First season (1994)				
Roma VF	1.75 d	1.94 cd	2.48 a	2.26 b	2.04 c	1.78 d	2.04 B
Pearson A-1 Improved	2.29 b	2.47 b	2.73 a	2.79 a	2.35 b	1.65 c	2.36 A
Mean	2.02 C	2.21 B	2.61 A	2.53 A	2.19 B	1.72 D	
			Second Season (1995)				
Roma VF	1.65 d	1.98 c	2.70 a	2.52 b	2.02 c	1.69 d	2.09 B
Pearson A-1 Improved	2.24 c	2.44 b	2.77 a	2.72 a	2.30 c	1.78 d	2.37 A
Mean	1.94 D	2.21 C	2.73 A	2.62 B	2.16 C	1.73 E	

Means followed with the same letter within a comparable group of means do not significantly differ according to LSD test at 0.05 level.

b- Shoot fresh weight:

Data in Table 2 indicated that Roma VF cultivar produced a significantly higher shoot fresh weight than Pearson A-1 Improved. The radiation treatments showed stimulating effects on this character, since the mean values, with the exception of that of the highest dose (4000 R), were significantly higher than the control mean. Interactions were found among the doses and cultivars, i.e. the two cultivars did not follow the same trend. The effects of the interactions were found to resemble those noticed on plant height (Table 1).

Table 2. Effect of different gamma radiation doses on shoot fresh weight (Kg) of two tomato cultivars at the beginning of flowering stage

Cultivar	Gamma ray dose (R)						
	0	500	1000	2000	3000	4000	Mean
			First season (1994)				
Roma VF	0.865 c	0.924 c	1.314 a	1.261 a	1.064 b	0.871 c	1.049 A
Pearson A-1 Improved	0.666 d	0.692 d	1.144 a	1.083 b	0.753 c	0.423 e	0.793 B
Mean	0.765 E	0.808 D	1.229 A	1.172 B	0.908 C	0.647 F	
			Second season (1995)				
Roma VF	1.565 e	1.801 d	2.317 a	2.181 b	1.907 c	1.577 e	1.891 A
Pearson A-1 Improved	1.353 e	1.621 d	2.091 a	1.919 b	1.720 c	0.788 f	1.581 B
Mean	1.459 E	1.711 D	2.204 A	2.050 B	1.813 C	1.182 F	

Means followed with the same letter within a comparable group of means do not significantly differ according to LSD test at 0.05 level.

c) Leaf area

As shown in Table 3, Roma VF had a significant larger leaf area than Peason A-1 Improved. Also, the influence of the radiation treatments and the interaction on this character, seemed to follow the same above - mentioned trend noticed in case of plant height and shoot fresh weight.

Table 3. Effects of different gamma radiation doses on total leaf area (cm^2) per plant of two tomato cultivars, at the beginning of flowering stage.

Cultivar	Gamma ray dose (R)						
	0	500	1000	2000	3000	4000	Mean
			First season (1994)				
Roma VF	19845 e	21370 d	35038 a	30749 b	25904 c	19599 e	25418 A
Pearson A-1 Improved	14820 d	15985 cd	27700 a	25807 b	17335 c	7734 e	18230 B
Mean	17332 E	18677 D	31369 A	28278 B	21620 C	13667 F	
			Second Season (1995)				
Roma VF	25968 e	31669 d	51778 a	42937 b	36428 c	25492 e	35712 A
Pearson A-1 Improved	20134 d	27452 c	40625 a	35747 b	28973 c	8479 e	26902 B
Mean	23051 E	29561 D	46201 A	39342 B	32701 C	16986 F	

Means followed with the same letter within a comparable group of means do not significantly differ according to LSD test at 0.05 level.

2. Yield and yield components

a) Early and total yield

The results presented in Tables 4 and 5 showed that Roma VF produced significantly higher early and total yield than Pearson A-1 Improved. Radiation treatments induced stimulating effect, especially when the 1000 R dose was used. On the contrary, raising the radiation dose over 3000 R resulted in the least early and total yield. However, the two cultivars responded differently to the highest radiation dose (4000 R). The depressing effect of the highest dose was found significant, as compared to the control treatment, only in Pearson A-1 Improved.

Table 4. Effects of different gamma radiation doses on early yield (the 1st two pickings, Kg) per plant of two tomato cultivars

Cultivar	Gamma ray dose (R)						
	0	500	1000	2000	3000	4000	Mean
			First season (1994)				
Roma VF	0.209 e	0.262 d	0.313 a	0.293 b	0.275 c	0.211 e	0.260 A
Pearson A-1 Improved	0.154 e	0.202 d	0.271 a	0.251 b	0.223 c	0.131 f	0.205 B
Mean	0.181 E	0.232 D	0.292 A	0.272 B	0.249 C	0.171 F	
			Second Season (1995)				
Roma VF	0.244 e	0.291 d	0.446 a	0.414 b	0.384 c	0.247 e	0.337 A
Pearson A-1 Improved	0.206 e	0.226 d	0.297 a	0.259 b	0.237 c	0.155 f	0.230 B
Mean	0.225 E	0.258 D	0.371 A	0.336 B	0.311 C	0.201 F	

Means followed with the same letter within a comparable group of means do not significantly differ according to LSD test at 0.05 level

Table 5. Effects of different gamma radiation doses on total yield (Kg) per plant of two tomato cultivars

Cultivar	Gamma ray dose (R)						
	0	500	1000	2000	3000	4000	Mean
				First season (1994)			
Roma VF	1.261 e	1.571 d	1.884 a	1.762 b	1.652 c	1.272 e	1.567 A
Pearson A-1 Improved	0.925 e	1.215 d	1.627 a	1.509 b	1.342 c	0.788 f	1.234 B
Mean	1.093 E	1.393 D	1.755 A	1.635 B	1.497 C	1.030 F	
				Second Season (1995)			
Roma VF	1.467 e	1.755 d	2.679 a	2.489 b	2.310 c	1.484 e	2.031 A
Pearson A-1 Improved	1.240 e	1.359 d	1.783 a	1.542 b	1.426 c	0.933 f	1.380 B
Mean	1.353 E	1.557 D	2.231 A	2.015 B	1.868 C	1.208 F	

Means followed with the same letter within a comparable group of means do not significantly differ according to LSD test at 0.05 level.

b) Fruit weight

Results listed in Table 6 indicated that the average fruit weight of Pearson A-1 Improved was significantly heavier than that of Roma VF. Concerning the radiation treatments, none of the doses applied had any effect on fruit weight. Also , no interaction was found among the doses and cultivars.

Table 6. Effect of different gamma radiation doses on average fruit weight (gm) of two tomato cultivars

Cultivar	Gamma ray dose (R)						
	0	500	1000	2000	3000	4000	Mean
				First season (1994)			
Roma VF	50.5 a	50.6 a	50.6 a	50.2 a	50.5 a	50.8 a	50.5 B
Pearson A-1 Improved	90.2 a	90.1 a	90.2 a	90.0 a	90.0 a	89.9 a	90.1 A
Mean	70.3 A	70.3 A	70.2 A	70.1 A	70.2 A	70.3 A	
				Second Season (1995)			
Roma VF	50.4 a	50.7 a	50.6 a	50.7 a	50.9 a	50.7 a	50.7 B
Pearson A-1 Improved	90.7 a	90.8 a	90.8 a	90.6 a	90.7 a	90.6 a	90.7 A
Mean	70.5 A	70.7 A	70.7 A	70.6 a	70.8 A	70.6 A	

Means followed with the same letter within a comparable group of means do not significantly differ according to LSD test at 0.05 level.

c) Fruit number

Table 7 showed that Roma VF plants produced a significantly higher number of fruits per plant than those of Pearson A-1 Improved. The general effect of radiation doses and their interactions with cultivars on this character followed almost the same trend noticed in the case of both early and total yield.

Table 7. Effect of different gamma radiation doses on average fruit number per plant of two tomato cultivars

Cultivar	Gamma ray dose (R)						
	0	500	1000	2000	3000	4000	Mean
				First season (1994)			
Roma VF	24.9 e	30.9 d	37.2 a	35.1 b	32.6 c	25.0 e	30.9 A
Pearson A-1 Improved	10.2 e	13.5 d	18.0 a	16.7 b	14.8 c	8.7 f	13.6 B
Mean	17.5 E	22.2 D	27.6 A	25.9 B	23.7 C	16.8 E	
				Second season (1995)			
Roma VF	29.1 e	34.6 d	52.0 a	49.1 b	45.4 c	29.2 e	39.9 A
Pearson A-1 Improved	13.7 d	14.9 c	19.6 a	17.1 b	15.1 c	10.3 e	15.2 B
Mean	21.4 E	24.7 D	35.6 A	33.1 B	30.5 C	19.7 F	

Means followed with the same letter within a comparable group of means do not significantly differ according to LSD test at 0.05 level.

Discussion

From the results reported above, it is obvious that the vegetative growth of both cultivars was significantly stimulated by the radiation treatments (Tables 1, 2 and 3). The highest stimulation effect was noticed on the plants grown from seeds that were treated with 1000 R. Higher radiation dose resulted in a significantly reduced growth. These results concur the finding of several investigators, such as Badr *et al* [4], Benedek *et al* [2] and Sidrak and Suess [9], who reported stimulation effects from the low doses of gamma radiation on the vegetative growth of different tomato cultivars.

The two cultivars have shown different degree of sensitivity to the radiation treatments, as indicated by the different response to the higher radiation dose. The harmful effect of the 4000 R treatment was obvious in the case of Pearson A-1 Improved cultivar. Several investigations on the biological effects of ionizing radiation have shown varietal differences in radiosensitivity among the different species [4, 12, 13, 14]. These differences indicate that the genetic constitution of a given variety has an effect on its radiosensitivity, i.e. a genotype - dependent mechanism is involved in the damage or repair of radiation - induced damage within the organism.

The positive stimulation effects of the radiation treatments on the vegetative growth could be attributed to the increased rate of cell division and / or cell elongation. Holsten *et al* [15] concluded that there were precise means available for the assay of radiation effect on plant growth by both cell division and cell enlargement. Moreover, Mahna and Singh [16] stated that gamma radiation caused an increase in epidermal cell size in tomato leaves. Similar results were also reported by Al-Safadi and Simon [17] who found that cell size increased at all doses (0.5 - 4.0 K-rad) of gamma rays in carrot. This fast growth might be advantageous in arid regions where the growing season is short.

The results of early and total yield as well as fruit number (Tables 4, 5 and 7) clearly indicated that these characters were favorably stimulated by radiation treatments, specially in the case of 1000 R dose. Further increase in the radiation doses (over 3000 R) appeared to be undesirable. The favorable effect of these particular doses of radiation might be expected as an end result of the previously mentioned stimulating effects, that were reflected on the vegetative growth characters. The increased average leaf area per plant (Table 3) would be expected to enhance the rate and efficiency of photosynthesis, which leads to a marked rise in leaves dry matter content, and consequently, would be associated with improved productivity. Furthermore, possible changes have been suggested in nutritional and translocational patterns of plants grown from irradiated seeds, e.g., Skrybykina and Invanova [18] found that presowing seed irradiation of tomato with gamma rays, stabilized mineral metabolism in plants , resulting in a 27 - 40% increase in productivity, compared with the control.

The effect of the highest dose on the individual cultivars, in comparison with the control, was likewise found similar to those noticed for the vegetative characters. Favorable effects of radiation on tomato yield and its component were also reported by other investigators [4, 7, 8, 9, 19, 20]. Average fruit weight was not affected by the radiation treatments (Table 6). Differences were only observed between the two cultivars, suggesting that this character is more associated with the cultivar itself. Similar results were reported by Perez Thalovera and Moya [19].

In view of the above mentioned results, the use of radiation might be recommended as an easy tool for seed treatment to stimulate and increase the tomato productivity.

References

[1] Sax, K. "The Stimulation of Plant Growth by Ionizing Radiation". *Radiation Botany*, 3 (1963), 179 -186.

[2] Benedek, M., Pannonhalmi, K., Izsaki, Z., Jeszenak, G. and Matyus, M. "Investigation on Radioactive Stimulation in Tomatoes". *Agrartudomanyi Egyetem Godolla*, 43 (1973) , 21-48. In: *Hort. Abstr.*, 43, No. 246 (1973).

[3] Sulejmanova, I.G. "Changes in Growth and Productivity of Tomatoes from Seeds Receiving Gamma Irradiation". *Trudy Inst. Genet. Selek. Akad. Nauk Azer.*, 6 (1970), 204-209. In: *Hort. Abstr.*, 41 (1971).

[4] Badr, H. M., El-Shal, M.A. and Abdel-Kader, M.M. "Effect of Low Doses of Gamma Radiation on the Growth and Yield of Two Varieties of Tomato". *Alex. J. Agric. Res.*, 26 (1978), 715 -720.

[5] Alarkon, K., Bozova, L. and Stoeva, N. "Studies on the Index of Earliness in Tomato Plants from Seeds and Seedlings Irradiated with Low Doses of Gamma Rays". *Rasteniev dui Naulsi.*, 24 (1987), 40-42. In: *Hort. Abstr.* 57 (1987), No: 7819.

[6] Maltseva, S. "The Effcet of Sowing Date on the Manifestation of the Irridiation - Stimulating Effect In Tomatoes". *Radiobiologiya*, 19 (1980), 152 - 154.

[7] Voloozh, D. and Zham · Yansuren, D. " The Effect of Gamma Irradiation of Seed on the Yield of Outdoor Tomatoes in Mongolia". *Atom Energiya*, 41 (1976), 149 - 151, In: *Hort. Abstr.*, 47 (1977), No: 6616.

[8] Gertsukii, D. F., Mukhim, V.P. and Ter - Saakov, A. "The Effect of Gamma Irradiation of Seeds on the Growth, Development and Productivity of Greenhouse Tomato". *Izestiya Timiryazevskoi Selskokhozyaistvennoi Akademii.*, 4 (1977), 152-159. In: *Hort. Abstr.*, 48 (1978), No:533.

[9] Sidrak, G.H. and Suess, A. " Effect of Low Doses of Gamma Radiation on the Growth and Yield of Two Varieties of Tomato". *Radiation Botany*, 13 (1973), 309-314.

[10] FAO - IAEA Consultants, *Crop Meeting on the Effect of Low Doses of Radiation on Crop Plants*. Vienna, (1970).

[11] Steel, R.G. and Torrie, J.H. *Principles and Procedures of Statistics*. New York: McGraw - Hill Book Co., 1980.

[12] Monti, L.M. and Donini, B. " Response to Chronic Gamma Irradiation of Twenty - Four Pea Genotypes." *Radiation Botany*, 8 (1968), 473 - 487.

[13] Al-Rubeai, M.A.F. and Godward, M.B.E. "Genetic Control of Radiosensitivity in *Phaseolus Vulgaris*". *Environmental and Experimental Botany*, 21 (1981), 211-214.

[14] Abdel-Fattah, M.A. "Stimulation Effect of Gamma Radiation on Two Tomato Cultivars and Their First Generation Hybrid". *Ph.D. Thesis*, Alexandria Univiversity, Faculty of Agriculture, 1993.

[15] Holsten, R.D., Sugii, M. and Steward, F.C. "Direct and Indirect Effect of Radiation on Plant Cells: Their Relation to Growth and Growth Induction". *Nature*, 208 (1965), 850 - 865.

[16] Mahna, S.K. and Singh, D. " Influence of Mutagnic Factors on Epidermis of Tomatillo, Current Tomato and Tomato". *Biologia Plantarm.*, 18 (1976), 429 -435.

[17] Al-Safadi, B. and Simon, P.W. "The Effect of Gamma Radiation on the Growth and Cytology of Carrot Tissue Culture". *Environmental and Experimental Botany*, 30 (1990), 361-371.

[18] Skrybykina, M.I. and Ivanova, L.N. "Effect of Gamma Irradiation and Synthetic Growth Regulators on the Meneral Nutrition and Growth of Tomato Plants". *Fiziol. Osob. Sel'skokhozyaistvennykh. Kul'tur. V. Vostochnoi. Sibiri.*, 14 (1986), 102 - 105. In: *Hort. Abastr.*, 57 (1987), No: 9522.

[19] Perez Talavera, S. and Moya, C. " Performance of Some Yield Components as Indicators of Radiosensitivity in Tomato". *Fundamentales en Agricultura Tropical.*, 38 (1986), 8. In: *Plant Breed. Abstr.*, 58 (1988), No: 3577.

[20] Alarkon , K., Bozova, L. and Stova, N. "Studies on the Index of Earliness in Tomato Plants from Seeds and Seedlings Irridiated with Llow Doses of Gamma Rays". *Rasteniev dui Nauki*, 24 (1987), 40-42. In: *Hort. Abstr.*, 57 (1987), No:7819.

التأثير المنشط لأشعة جاما على نمو وإنتاجية صنفين من الطماطم

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(قدم للنشر فى ٢٨ / ١٤١٦/٧ هـ وقبل للنشر فى ١٠/ ٢ / ١٤١٧ هـ)

ملخص البحث: تم تعريض البذور الجافه لصنفي الطماطم Roma VF و Peason A-1 Improved لجرعات منخفضة من أشعة جاما و هي : صفر ، ٥٠٠ ، ١٠٠٠، ٢٠٠٠، ٣٠٠٠ و ٤٠٠٠ رونتجين من مصدر الكوبالت المشع. درس تأثير هذه المعاملات على بعض صفات النمو الخضري مثل طول النبات ووزن المجموع الخضرى و المساحة الورقية وكذلك على بعض صفات النمو الثمري مثل المحصول المبكر والمحصول الكلي ووزن الثمار وعدد الثمار. أوضحت نتائج الدراسة بصفة عامة أن جميع الصفات المقيسة في الصنفين المستخدمين قد ازدادت جوهريا و خاصة فى الجرعات المتوسطة وإن اختلفت استجابة مدى كل صنف عن الآخر. كما أوضحت نتائج الدراسة زيادة معنوية فى النمو الخضرى و الثمري عند معاملة البذور بـ ١٠٠٠ رونتجين مقارنة ببقية المعاملات. وقد أدت زيادة جرعات الأشعة عن هذا الحد الى تناقص معنوي في النمو والإنتاج. وقد أوضحت النتائج وجود تفاعل معنوي بين المعاملات بالأشعة والأصناف المستخدمة.