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Effect of wound healing period and temperature, irradiation and post-irradiation storage temperature on the rot incidence of potatoes, after infection with *Fusarium sulfurium*

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ABSTRACT

Effect of woundhealing period and temperature, irradiation dose and postirradiation storage temperature on the rot incidence of potatoes, after infection with Fusarium sulfurium.

Report 88.
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16 figures, 4 tables, 13 references.

Losses during storage in potatoes are mainly due to sprouting and rotting. It has indicated that irradiation by low dose (50 to 100 Gy) during the dormancy period is most effective for sprout inhibition. Some investigators, however, stated an increase of storage rot after an irradiation treatment. The effect of wound healing temperature and period, irradiation dose and post irradiation storage temperature are tested on potatoes infected with Fusarium sulfurium. A dose of 75 and 100 Gy reduces the loss of weight and gives a complete sprout inhibition to the end of the storage period. An irradiation treatment within 2 weeks after harvest gives the best results. The effect of wound healing temperature and period and irradiation dose on the rot incidence was not measurable because the percentage rot incidence was too low and spread too large for finding significant differences.

Key words: bulb products, irradiation, potatoes, sprout inhibition, wound healing, mould, Fusarium sulfurium

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SUMMARY

Potatoes are important, as a source of nutrition, all over the world. The losses in potato tubers during storage are mainly due to sprouting and rot. This is a common problem in most countries especially in the tropical countries.
Many investigators have confirmed the effectiveness of irradiation for the control of sprouting. A number of investigations, however, stated an increase of storage rot after an irradiation treatment probably caused by disturbance of the resistance against fungal attack of potatoes. These investigations did not include the effect of a wound healing period as well as lowering of the irradiation dose on the percentage of storage rot.
Therefore, the effect of irradiation doses, wound healing temperature, post-harvest irradiation time (= wound healing period) and storage temperature on a number of quality parameters such as loss of weight, sprout inhibition and rot incidence have been investigated. The potatoes were infected with Fusarium sulfurium, irradiated with a dose range of 50 to 100 Gy, after a wound healing period varying from 0 to 4 weeks at 15 or 20 ^{o}C. The product was stored at 10 and 20 ^{o}C and 90% relative humidity.
It appeared from the results that a dose of 75 and 100 Gy reduces the loss of weight and gives a complete sprout inhibition to the end of the storage period. A dose of 50 Gy was not effective to the end. A treatment within 2 weeks after harvest gives the best results. The effect of dose, wound healing period and temperature on the rot incidence was not measurable because the percentages infected potatoes were too low and the spread too large for finding significant differences.

1 INTRODUCTION

The losses in potato tubers during storage are mainly due to sprouting and rot. This is a common problem in most countries especially in the tropical countries. One of the most promissing applications to inhibit the sprouting and the extention of the storage life of potatoes is gamma irradiation. Also the mould attack, resulting in rot, can be reduced by irradiation (Levis & Mathur 1963; Nair et al. 1973). On the other hand other authors mentioned that an irradiation treatment induces some unfavorable side effects e.g. enhancement of storage rot and discolouration after boiling.

Rot incidence is associated with a decrease in the resistance of tubers to phytopathogenic micro-organisms, caused by an irradiation treatment (Burton & Hannan 1957; Langerak et al. 1986).

The delay of the appearance of rot in potatoes, however, depend not only on the irradiation dose but also on the wound healing period and temperature, post-harvest irradiation time and storage temperature (Langerak et al. 1986).

In more studies it has indicated that, during the dormancy period, an irradiation treatment with low doses (50 to 100 Gy) is most effective for sprout control. On the other hand the doses should not exceed 100 Gy to avoid unnecessary side effects of irradiation due to damage of the wound healing ability (Metlitsky et al. 1968). An irradiation dose over 150 Gy decreases the wound healing ability, increases the storage rot, spoilage and sweetening and decreases the vitamin C content (Brownell et al. 1957; Cloutier et al. 1959; Metlitsky et al. 1968). Also this dose could bring changes in chemical composition which did not disappear during subsequent storage (Metlitsky et al. 1968).

Sparenberg (1974) reported that irradiation of potatoes immediately after harvest strongly suppresed sprout formation. Irradiation gave less good results after 2 weeks. Langerak et al. (1986) also proved that an irradiation treatment within 2 weeks after harvest gives the best results concerning sprout inhibition and rot incidence. Roushdy et al. (1973) advised to irradiate as soon as possible after harvest and curing, preferable within 4 weeks.

It is known that wound healing before irradiation can reduce rotting during subsequent storage. Because the wound healing ability of potato tubers is reduced by irradiation (Brownell et al. 1957) the tubers should be kept first 2 weeks at ambient temperature to ensure the healing of tissue damage by harvesting and handling (Metlitsky et al. 1968).

The pre-irradiation temperature and relative humidity plays a very important role at the wound healing. To complete the wound healing process, curing at about 15 to 20 °C with high humidity (not less than 85 %) under good air condition for 1 to 2 weeks is necessary (Workman et al. 1950; Radatz 1967; Wigginton 1974). The formation of wound periderm is delayed not only at low temperature but also at high temperature (Wigginton 1974).
During the curing period the storage temperature must not be allowed to exceed 22 °C (Meijers 1981).
In relation to the above mentioned problem following research have been set up with the aim: Study the effect of wound healing period and temperature, irradiation dose and post-irradiation storage temperature on the keeping quality and particular on the rot incidence of potatoes.

2 MATERIALS AND METHODS

The experiment have been set op on the following conditions:

- Wound healing at 15 °C (ambient temperature) and 20 °C (tropical condition);
- Wound healing period:
  at 15 °C for 0, 2 and 4 weeks
  at 20 °C for 0, 1 and 2 weeks;
- Irradiation with a dose of 0, 50, 75 and 100 Gy (dose rate 108 $Gy.h^{-1}$);
- Post-irradiation storage at 10 °C (mild cooling) and 20 °C (tropical condition);

2.1 Sample material

The experiment was carried out with potatoes variety "Bintje". The sample material was purchased from "proefboerderij De Bouwing" located in Randwijk, the Netherlands.
All potatoes were damaged artificially by means of a stamp with three pins of 2 mm long and 3 mm diameter and with a distance of approximately 50 mm. After the damaging the potatoes were sprayed with a spore suspension of 10^4 $spores.ml^{-1}$ Fusarium sulfurium. For each treatment 125 potatoes, divided in 5 samples of 25 potatoes per box, were taken.

2.2 Loss of weight

The loss of weight in potato tubers was estimated by weighting the whole boxes of potatoes. The loss of weight was calculated according the following equation:

$$\frac{W_p - W_b}{W_i - W_b} \times 100\% = \text{loss of weight } [\%]$$

Where: W_p = present weight of the box including the potatoes
W_b = weight of the empty box
W_i = initial weight of the box including the potatoes

2.3 Sprouting

Potatoes with sprouts smaller than 5 mm were considered as not to be sprouted. The sprouting was estimated by counting all sprouted potatoes in each box.
The percentage of sprouted potatoes was calculated according to the following equation:

$$\frac{N_s}{25} \times 100\% = \text{sprouting } [\%]$$

Where: N_s = number of sprouted potatoes in the box
25 = total nuber of potatoes in the box

During the storage the length of sprouts was estimated by individualy all sprouts per potato. For the estimation of the sprout activity in a very early stage also the sprouts smaller than 5 mm were involved. The length of sprouts was registred using the following class distribution:

class 1 = < 0,5 cm
class 2 = 0,5 to 5,0 cm
class 3 = > 5,0 cm

2.4 Rot incidence

The rot incidence was estimated by individualy observing all potatoes. The rotten tubers were not removed in order to imitate the practice. The rot percentage was calculated according the following equation:

$$\frac{N_r}{25} \times 100\% = \text{rot incidence } [\%]$$

Where: N_r = number of rotten potatoes in the box
25 = total number of potatoes in the box

2.5 General appearance

The general appearance was estimated by observing the whole box using the following score grade:

5 = excelent
4 = good
3 = moderate (just marketable)
2 = poor (not acceptable)
1 = very poor

3 RESULTS AND DISCUSSION

To eliminate the large amount of data only the most representative figure are presented.

In this report all mentioned standard errors (SE) are expressed as standard error of the mean (standard deviation devide by square root of number of replicates).

3.1 Loss of weight

The average loss of weight of potatoes, irradiated and unirradiated are mentioned in figures 1 to 4.
The potatoes stored at 20 °C showed a significant higher loss of weight than the product stored at 10 °C. The effect of wound healing temperature on the loss of weight was negligible.
In the beginning of the storage period the difference in loss of weight between irradiated and unirradiated samples was small. On the end of the storage period, however, the loss of weight in the control samples and 50 Gy were significant higher than in the objects treated with higher doses, probably due to sprouting. This difference was in potatoes stored at 20 °C higher than at 10 °C. Also a postponed irradiation treatment enhanced these differences.
This is in agreement with previous studies of Langerak et al (1986).

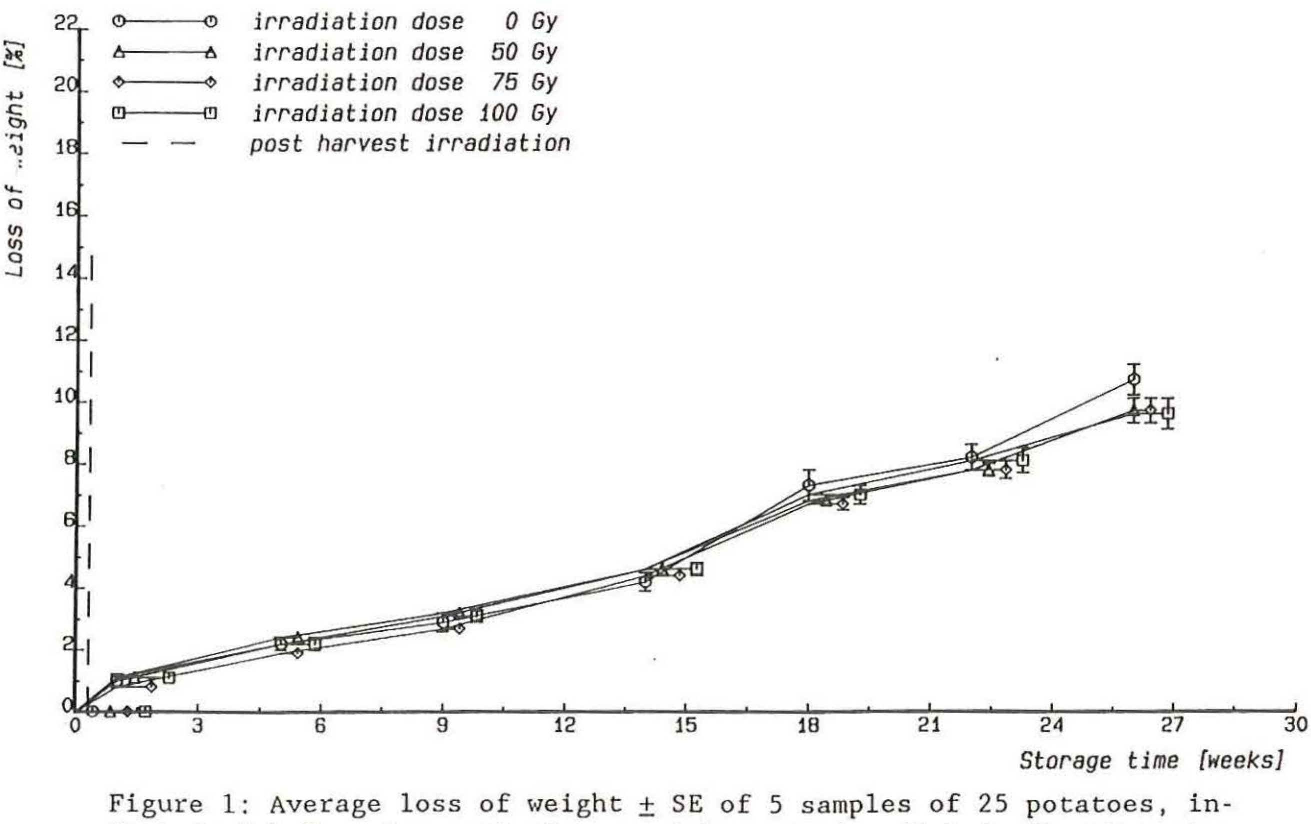

Figure 1: Average loss of weight ± SE of 5 samples of 25 potatoes, infected with <u>Fusarium sulfurium</u>, post-harvest irradiated after 0 weeks storage at 15 °C and subsequently stored at 10 °C.

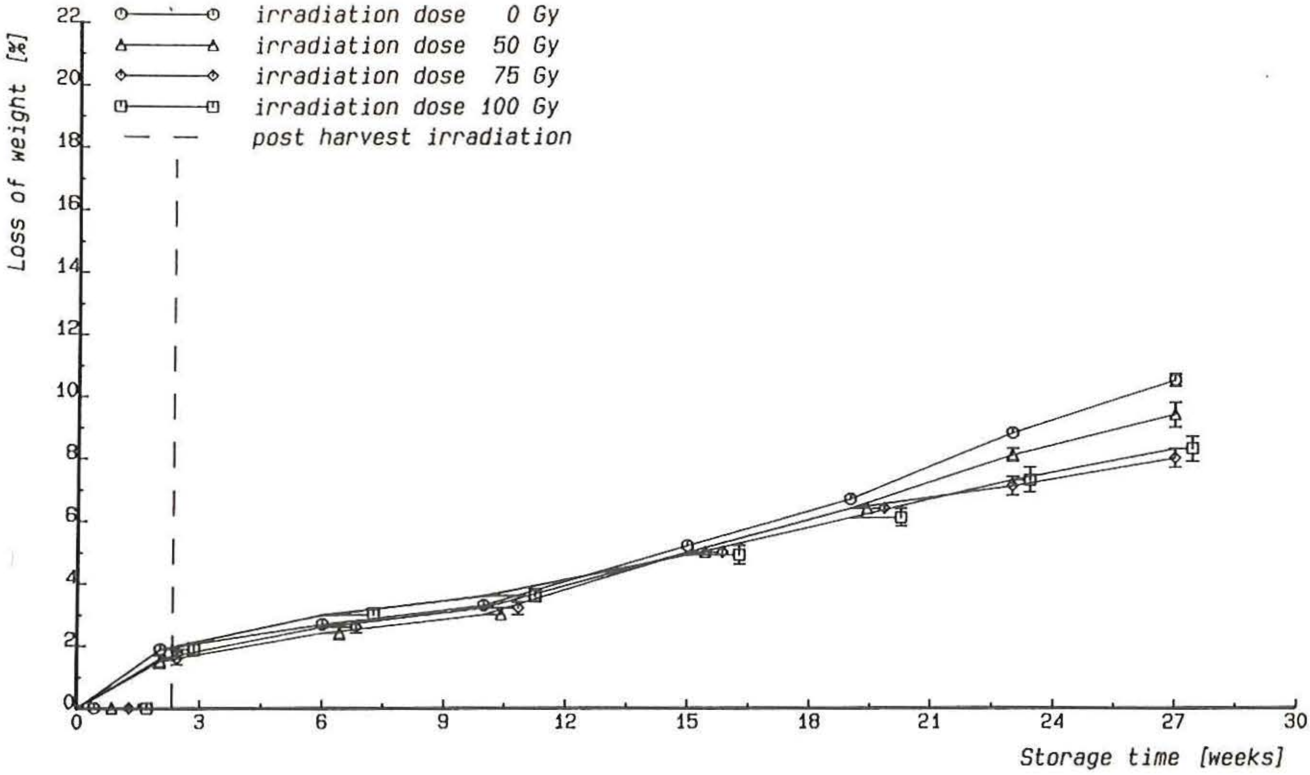

Figure 2: Average loss of weight ± SE of 5 samples of 25 potatoes, infected with Fusarium sulfurium, post-harvest irradiated after 2 weeks storage at 15 °C and subsequently stored at 10 °C.

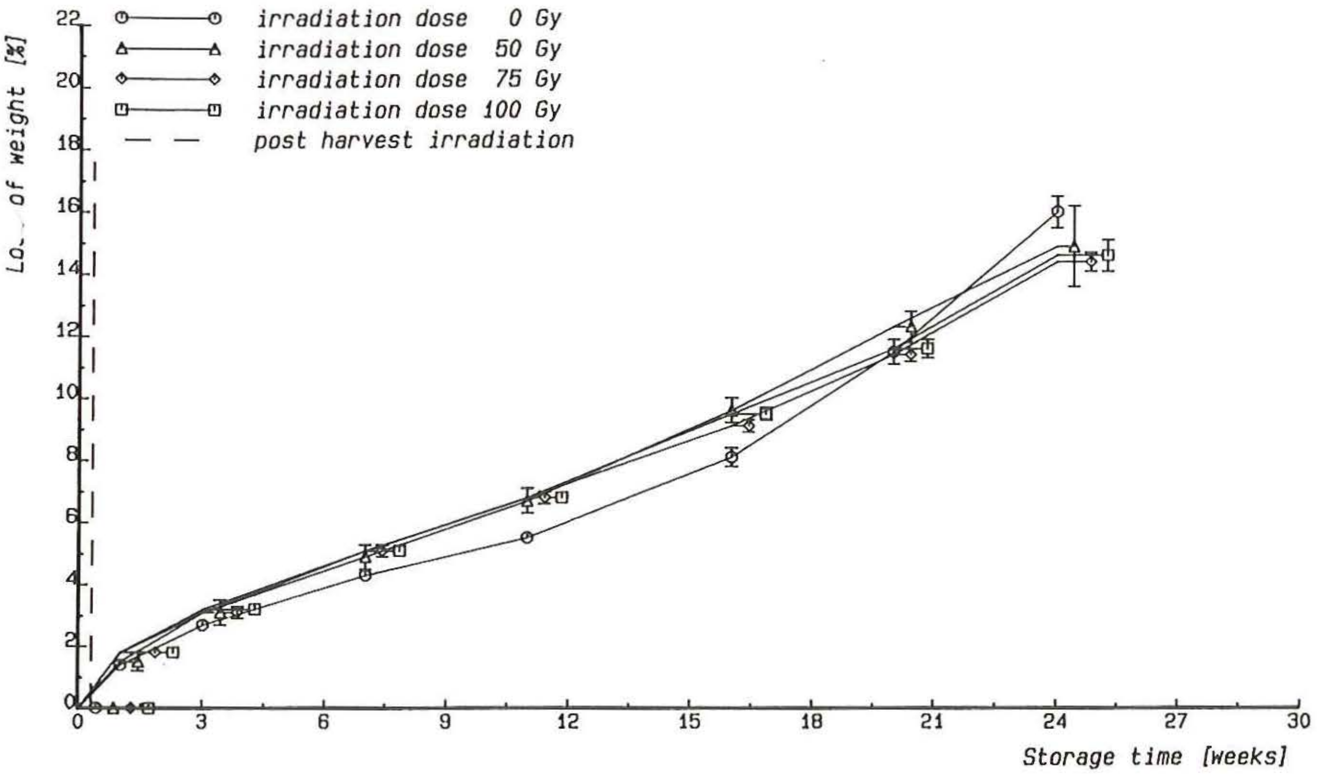

Figure 3: Average loss of weight ± SE of 5 samples of 25 potatoes, infected with Fusarium sulfurium, post-harvest irradiated after 0 weeks storage at 15 °C and subsequently stored at 20 °C.

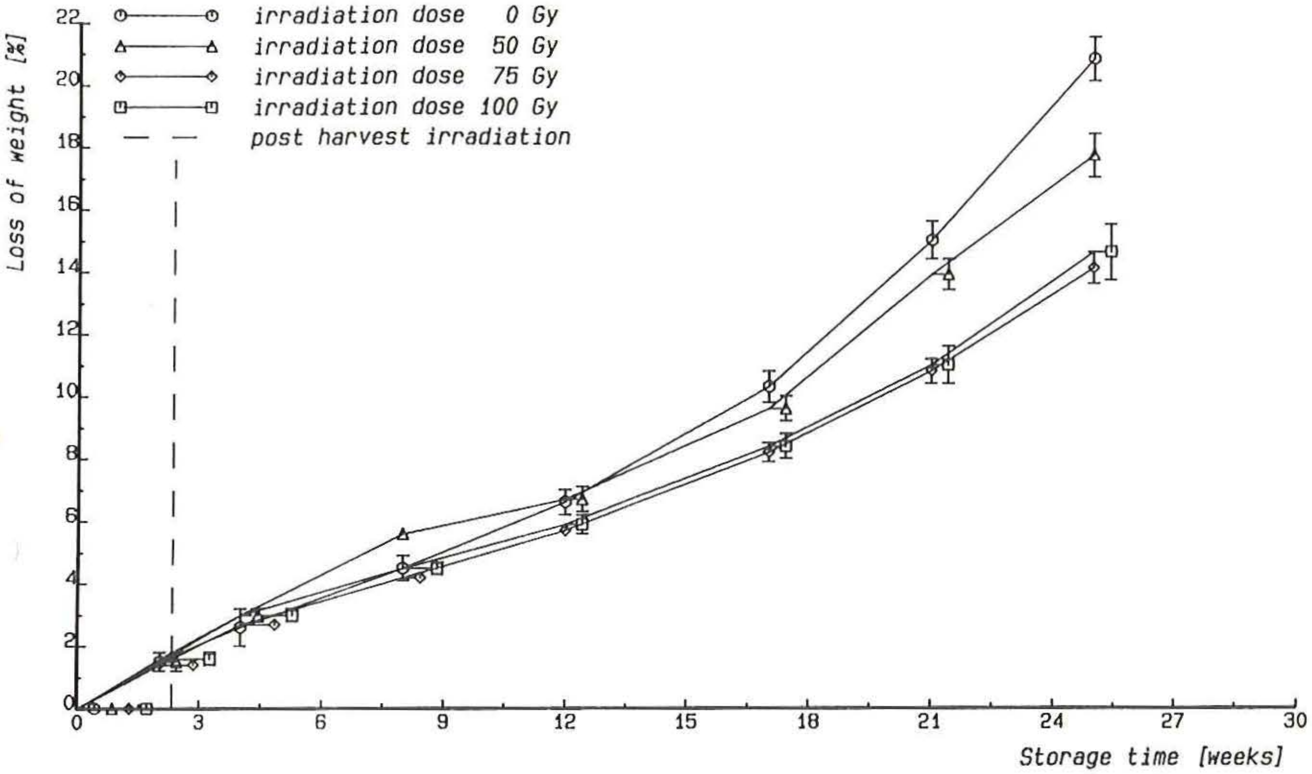

Figure 4: Average loss of weight ± SE of 5 samples of 25 potatoes, infected with Fusarium sulfurium, post-harvest irradiated after 2 weeks storage at 15 °C and subsequently stored at 20 °C.

3.2 Sprouting

3.2.1 Percentage of sprouted potatoes

The percentage of sprouted potatoes of irradiated and unirradiated samples are mentioned in figures 4 to 8.
The potatoes stored at 10 and 20 °C start to sprout after 5 and 2 weeks respectively, so this season the dormancy period was rather short, probably due to a dry period during growing. The dormancy period of potatoes stored at 10 °C was shortened by a post-harvest irradiation period (PHI) at 15 or 20 °C. At 20 °C, however, the dormancy period was lengthened by a PHI period at 15 °C.
The effect of an irradiation treatment on sprouting was estimated by the following factors:

- irradiation dose;
- storage temperature;
- postponed irradiation treatment (PHI).

At 10 °C an irradation dose of 50 Gy was almost sufficient for sprout inhibition, but for a storage period longer than 22 weeks a dose of 75 Gy was necessary. For potatoes stored at 20 °C a dose of 50 Gy was not effective; for a complete sprout inhibition till the end of the storage period a dose of 100 Gy has to be applied.
It proves from this experiment that a post-harvest irradiation period of 2 and 4 weeks at 15 or 20 °C for wound healing shortened the dormancy period and enhanced the percentage of sprouted potatoes. This is in agreement with previous studies from Sparenberg (1974), Roushdy et al. (1973) and Langerak et al. (1986).
An irradiation treatment immediately after harvest was the most effective concerning sprout inhibition.

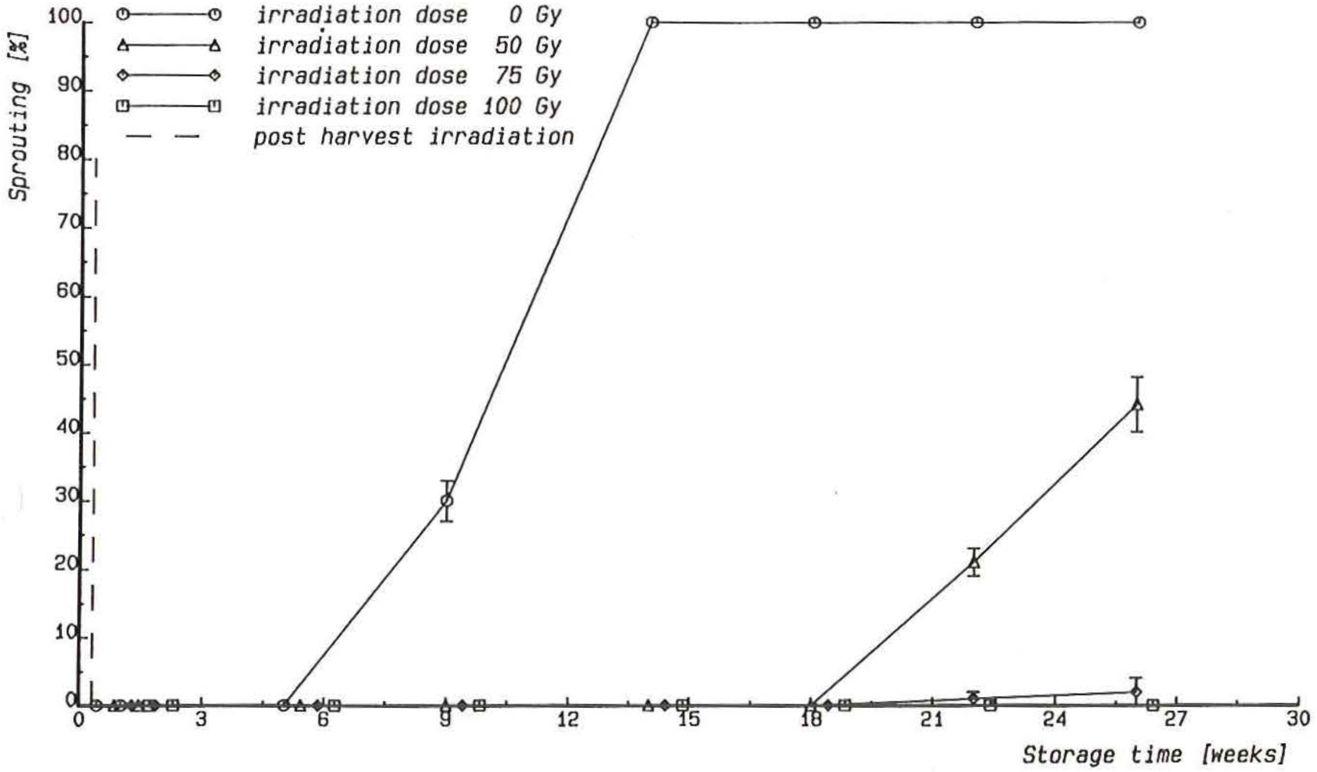

Figure 5: Average sprouting ± SE of 5 samples of 25 potatoes, infected with Fusarium sulfurium, post-harvest irradiated after 0 weeks at 15 °C and subsequently stored at 10 °C.

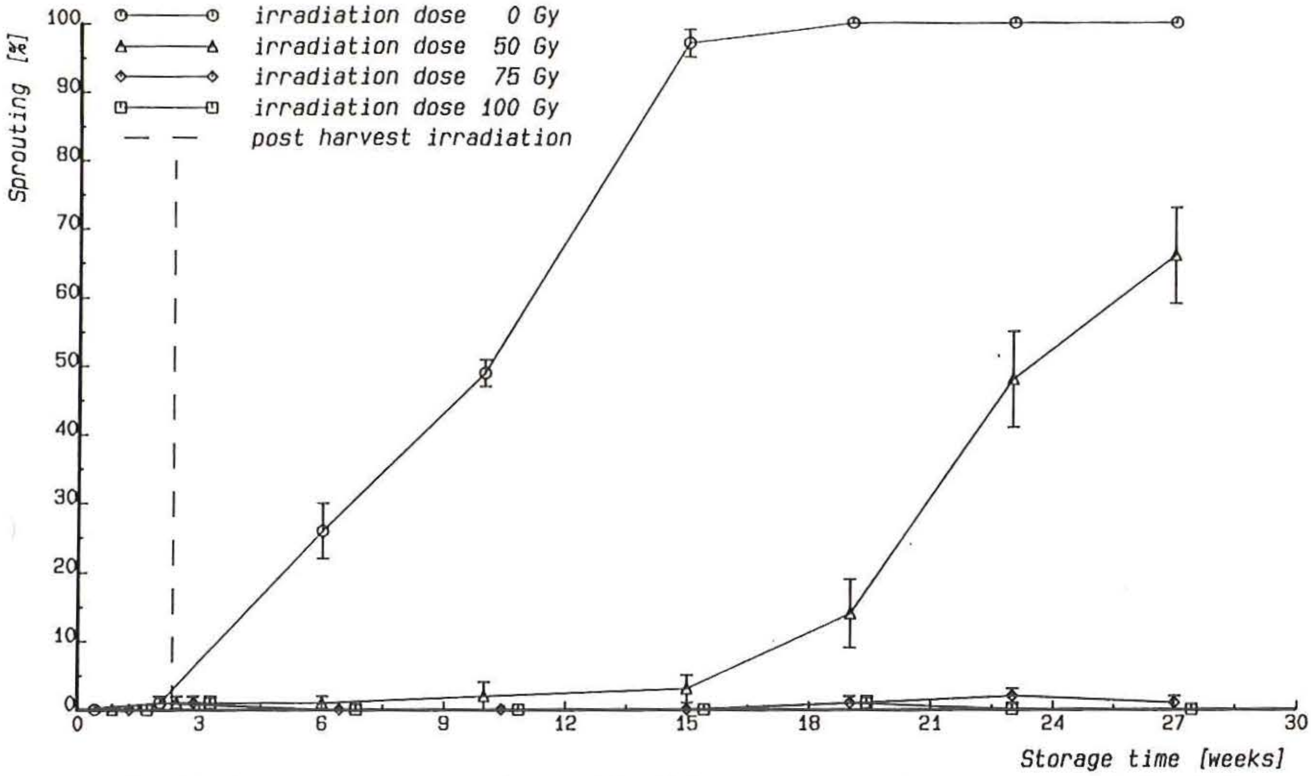

Figure 6: Average sprouting ± SE of 5 samples of 25 potatoes, infected with Fusarium sulfurium, post-harvest irradiated after 2 weeks at 15 °C and subsequently stored at 10 °C.

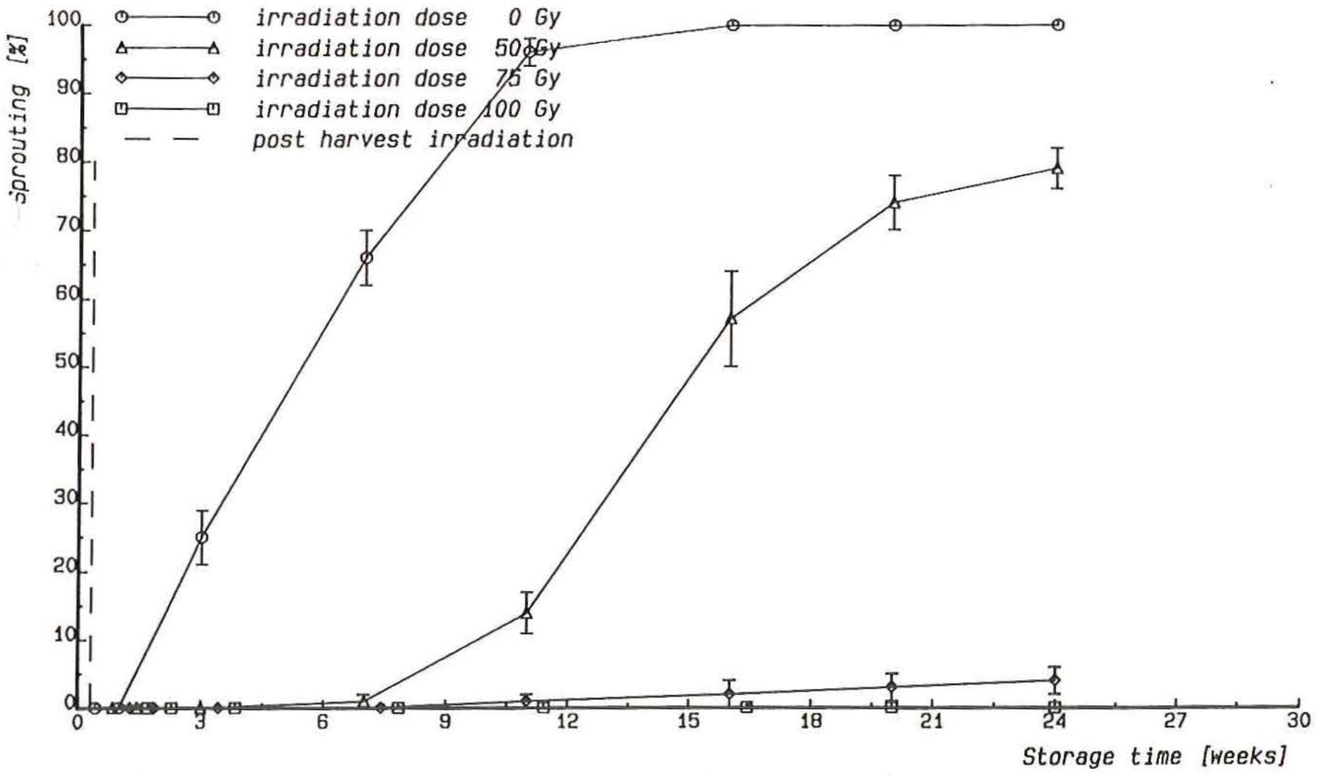

Figure 7: Average sprouting ± SE of 5 samples of 25 potatoes, infected with Fusarium sulfurium, post-harvest irradiated after 0 weeks at 15 °C and subsequently stored at 20 °C.

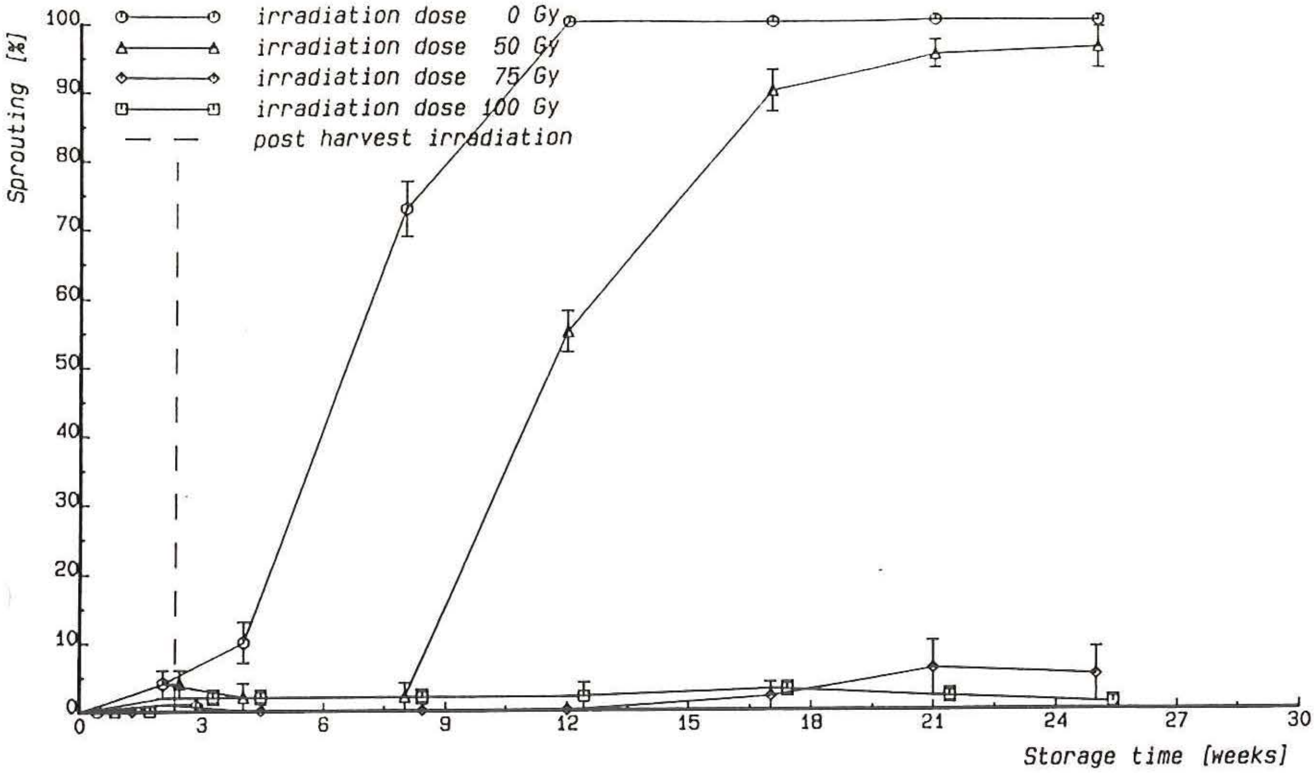

Figure 8: Average sprouting ± SE of 5 samples of 25 potatoes, infected with Fusarium sulfurium, post-harvest irradiated after 2 weeks at 15 °C and subsequently stored at 20 °C.

3.2.2 Length of sprouts

The average number of sprouts and frequency distribution of sprout-lenght of irradiated and unirradiated potatoes are mentioned in figures 9 to 12.

These results shown that in general an irradiation treatment effectively inhibits sprouting of potatoes, except a dose of 50 Gy. The potatoes irradiated with 50 Gy often showeda larger number of sprouts in class 1 (< 0,5 cm) than in the unirradiated samples, because the adventive eyes were activated, probably as a reaction to stress. During the storage the growth was delayed and only a part of the sprouts reached class 2 (0,5 cm to 5,0 cm) and seldom class 3 (> 5,0 cm). In comparison with the control the sprouts of the irradiated samples were thin and weak and broke of by touching.

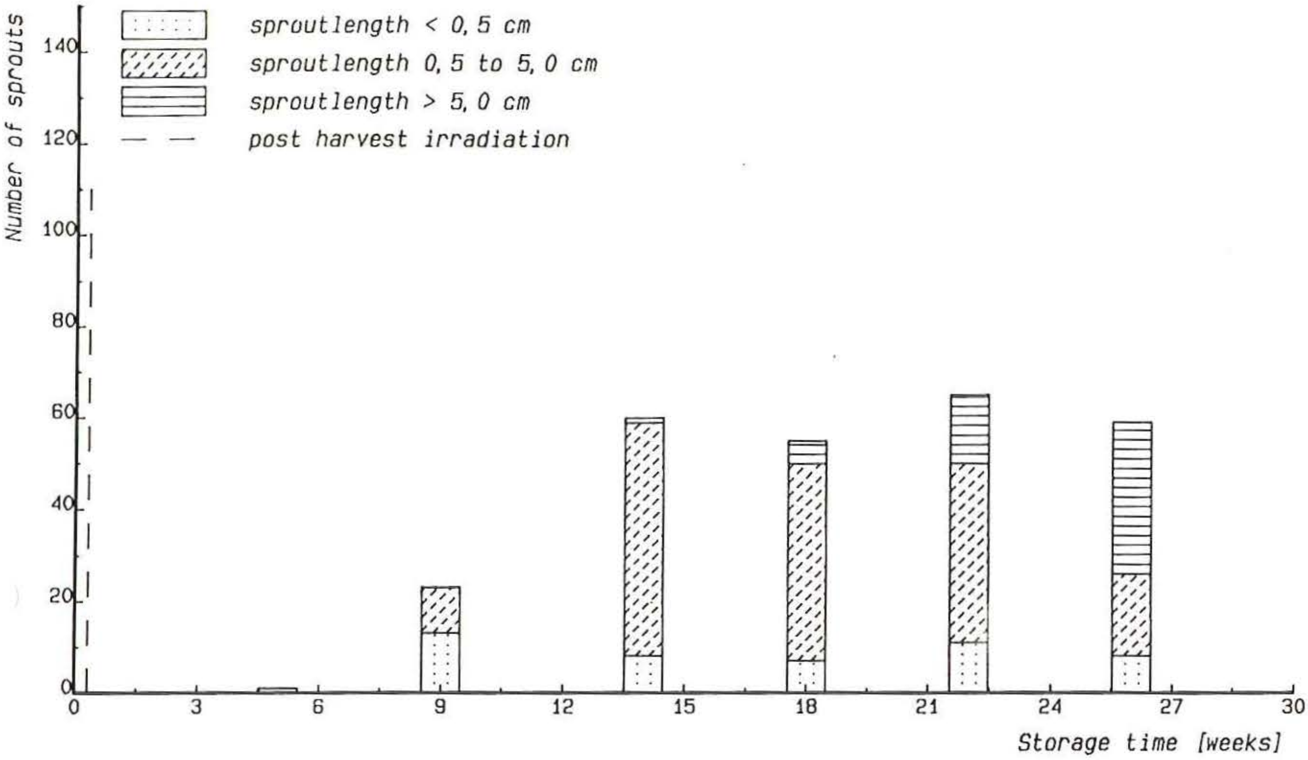

Figure 9: Average number of sprouts and frequency distribution of sprout length of 5 samples of 25 potatoes, infected with <u>Fusarium sulfurium</u>, post-harvest irradiated with 0 Gy after 0 weeks storage at 15 °C and subsequently stored at 10 °C.

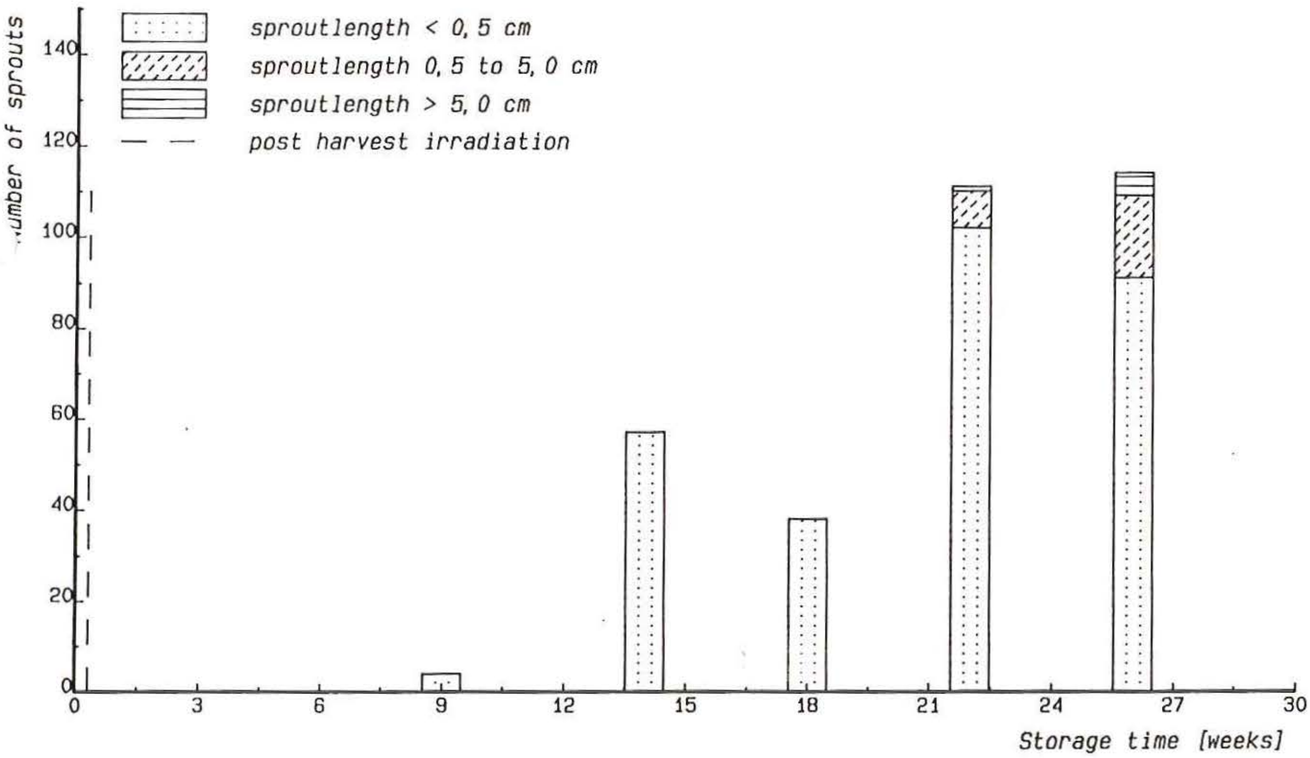

Figure 10: Average number of sprouts and frequency distribution of sprout length of 5 samples of 25 potatoes, infected with <u>Fusarium sulfurium</u>, post-harvest irradiated with 50 Gy after 0 weeks storage at 15 °C and subsequently stored at 10 °C.

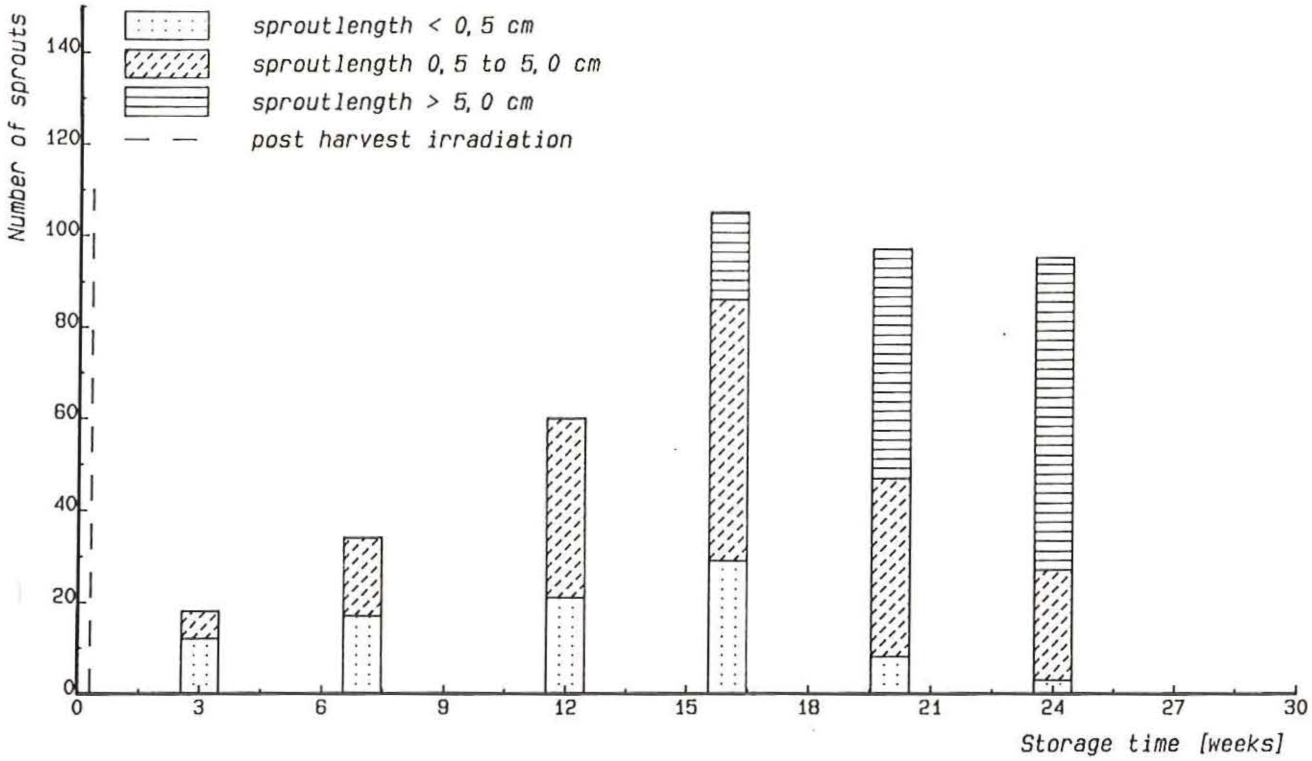

Figure 11: Average number of sprouts and frequency distribution of sprout length of 5 samples of 25 potatoes, infected with <u>Fusarium sulfurium</u>, post-harvest irradiated with 0 Gy after 0 weeks storage at 15 °C and subsequently stored at 20 °C.

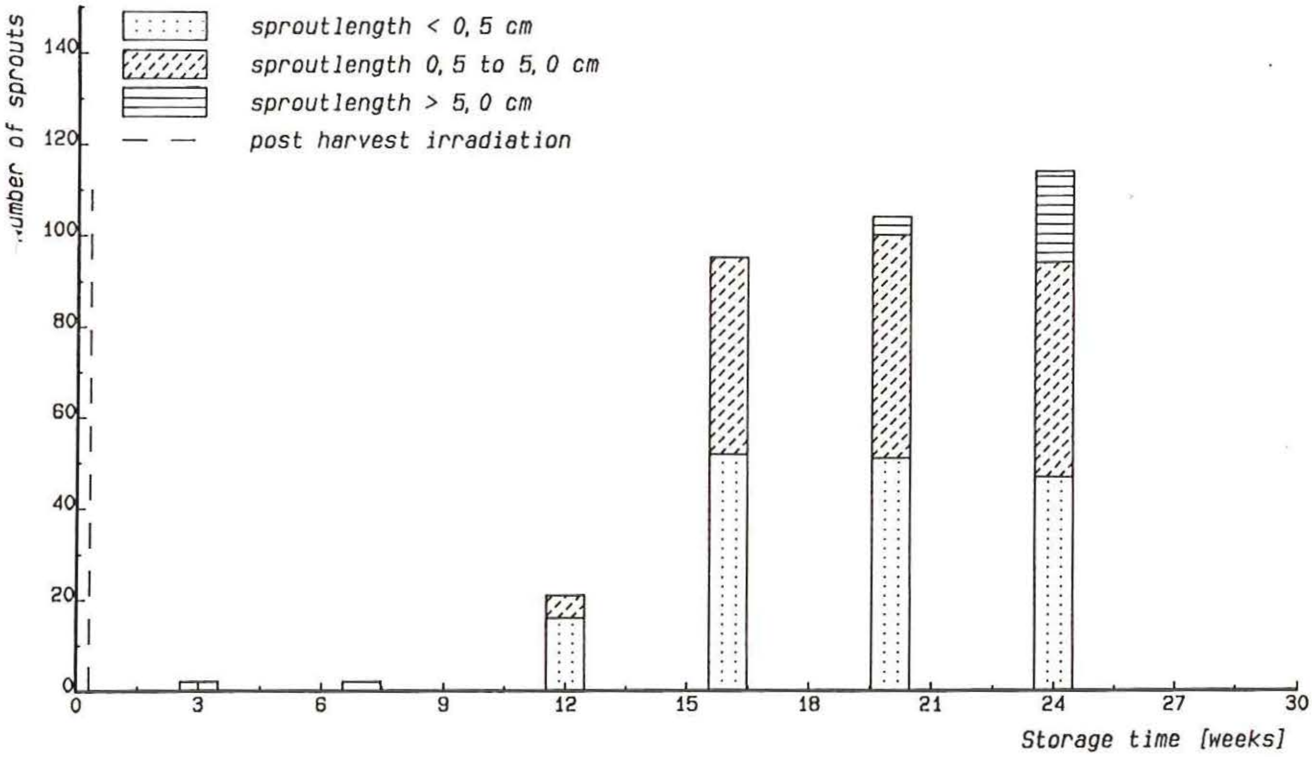

Figure 12: Average number of sprouts and frequency distribution of sprout length of 5 samples of 25 potatoes, infected with <u>Fusarium sulfurium</u>, post-harvest irradiated with 50 Gy after 0 weeks storage at 15 °C and subsequently stored at 20 °C.

3.3 Rot incidence

The results of the estimation of rot incidence are mentioned in tables 1 to 4.
These tables indicate that that during storage at 10 °C hardly any rot incidence was found in all infected samples. An irradiation treatment immediately applied after harvest, even with a dose of 100 Gy did not increase the percentage of rot, altough it proves from paralell experiment that a wound healing process needs at least 7 days before it has finished.
Because of the absence of rot it was not possible to study the effect of different wound healing temperatures on the development of rot. At 20 °C a small increase of rot incidence was noticed in the objects, irradiated with 50 and 100 Gy immediately after harvest.
After a wound healing period of 2 and 4 weeks at 15 °C the percentage of rot was negligible. However a very small amount of rot was found by a dose of 100 Gy applied after a wound healing period of 2 weeks at 20 °C.
The spread in the samples was too large for finding a significant difference between the different treatments. Optimum cultivation measures in the field were may be the important factors in relation to the high resistance of the product against fungi. These effects on the rot incidence were not involved in the study.

Table 1: Average rot incidence ± SE of 5 samples of 25 potatoes, infected with <u>Fusarium sulfurium</u>, post-harvest irradiated after different periods at 15 °C and subsequently stored at 10 °C.

WP [weeks]	ST [°C]	SP [weeks]	irradiation dose [Gy] 0	50	75	100
0	15	0	0.0	0.0	0.0	0.0
		***				
	10	1	0.0	0.0	0.0	0.0
		5	0.0	0.0	0.0	0.0
		9	0.0	0.0	0.0	0.0
		14	0.0	0.0	0.0	0.0
		18	0.0	0.0	0.0	0.0
		22	0.0	0.0	0.0	0.0
		26	0.0	0.0	0.0	0.0
2	15	0	0.0	0.0	0.0	0.0
		2	0.8 ± 0.8	0.0	0.0	0.0
		***				
	10	6	0.8 ± 0.8	0.0	0.0	0.0
		10	0.8 ± 0.8	0.0	0.0	0.0
		15	0.8 ± 0.8	0.0	0.0	0.0
		19	0.8 ± 0.8	0.0	0.0	0.0
		23	0.8 ± 0.8	0.0	0.0	0.0
		27	0.8 ± 0.8	0.0	0.0	0.0
4	15	0	0.0	0.0	0.0	0.0
		2	0.0	0.0	0.0	0.0
		***				
	10	6	0.0	0.0	0.0	0.0
		10	0.0	0.8 ± 0.8	0.0	0.0
		15	0.0	0.8 ± 0.8	0.0	0.0
		19	0.0	0.8 ± 0.8	0.0	0.0
		23	0.0	0.8 ± 0.8	0.0	0.0
		27	0.0	0.8 ± 0.8	0.0	0.0

WP = wound healing period (before irradiation)
ST = storage temperature (before and after irradiation)
SP = total storage period (before and after irradiation)
*** = time of irradiation

Table 2: Average rot incidence ± SE of 5 samples of 25 potatoes, infected with Fusarium sulfurium, post-harvest irradiated after different periods at 20 °C and subsequently stored at 10 °C.

WP [weeks]	ST [°C]	SP [weeks]	irradiation dose [Gy] 0	50	75	100
0	20	0	0.0	0.0	0.0	0.0
		***				
	10	1	0.0	0.0	0.0	0.0
		5	0.0	0.0	0.0	0.0
		9	0.0	0.0	0.0	0.0
		14	0.0	0.0	0.0	0.0
		18	0.0	0.0	0.0	0.0
		22	0.0	0.0	0.0	0.0
		26	0.0	0.0	0.0	0.0
1	20	0	0.0	0.0	0.0	0.0
		1	0.0	0.0	0.0	0.0
		***				
	10	5	0.0	0.0	0.0	0.0
		9	0.0	0.0	0.0	0.0
		14	0.0	0.0	0.0	0.0
		18	0.0	0.0	0.0	0.0
		22	0.0	0.0	0.0	0.0
		26	0.0	0.0	0.0	0.0
2	20	0	0.0	0.0	0.0	0.0
		1	0.0	0.0	0.0	0.0
		***				
	10	5	0.0	0.0	0.0	0.0
		9	0.0	0.0	0.0	0.0
		14	0.0	0.0	0.0	0.0
		18	0.0	0.0	0.0	0.0
		22	0.0	0.0	0.0	0.0
		26	0.0	0.0	0.0	0.0

WP = wound healing period (before irradiation)
ST = storage temperature (before and after irradiation)
SP = total storage period (before and after irradiation)
*** = time of irradiation

Table 3: Average rot incidence ± SE of 5 samples of 25 potatoes, infected with Fusarium sulfurium, post-harvest irradiated after different periods at 15 °C and subsequently stored at 20 °C.

WP [weeks]	ST [°C]	SP [weeks]	irradiation dose [Gy] 0	50	75	100
0	15	0	0.0	0.0	0.0	0.0
		***				
	20	1	0.0	0.0	0.0	0.0
		3	0.0	0.0	0.0	0.0
		7	0.0	0.0	0.0	0.0
		11	0.0	0.0	0.0	0.0
		16	0.0	0.8 ± 0.8	0.0	0.8 ± 0.8
		20	0.0	1.6 ± 1.0	0.0	1.6 ± 1.0
		24	0.0	1.6 ± 1.0	0.0	2.4 ± 1.6
2	15	0	0.0	0.0	0.0	0.0
		2	0.0	0.0	0.0	0.0
		***				
	20	4	0.0	0.0	0.0	0.0
		8	0.0	0.0	0.8 ± 0.8	0.0
		12	0.0	0.0	0.8 ± 0.8	0.8 ± 0.8
		17	0.0	0.0	0.8 ± 0.8	0.8 ± 0.8
		21	0.0	0.0	0.8 ± 0.8	0.8 ± 0.8
		25	0.0	0.0	0.8 ± 0.8	0.8 ± 0.8
4	15	0	0.0	0.0	0.0	0.0
		2	0.0	0.0	0.0	0.0
		4	0.0	0.0	0.0	0.0
		***				
	20	8	0.0	0.0	0.0	0.0
		12	0.0	0.8 ± 0.8	0.0	0.8 ± 0.0
		17	0.0	0.8 ± 0.8	0.0	0.8 ± 0.8
		21	0.0	0.8 ± 0.8	0.0	0.8 ± 0.8
		25	0.0	0.8 ± 0.8	0.0	0.8 ± 0.8

WP = wound healing period (before irradiation)
ST = storage temperature (before and after irradiation)
SP = total storage period (before and after irradiation)
*** = time of irradiation

Table 4: Average rot incidence ± SE of 5 samples of 25 potatoes, infected with <u>Fusarium sulfurium</u>, post-harvest irradiated after different periods at 20 °C and subsequently stored at 20 °C.

WP [weeks]	ST [°C]	SP [weeks]	irradiation dose [Gy] 0	50	75	100
0	20	1	0.0	0.0	0.0	0.0
		***				
	20	3	0.0	0.0	0.0	0.0
		7	0.0	0.0	0.0	0.0
		11	0.0	0.0	0.0	0.0
		16	0.0	0.8 ± 0.8	0.0	0.8 ± 0.8
		20	0.0	1.6 ± 1.0	0.0	1.6 ± 1.0
		24	0.0	1.6 ± 1.0	0.0	2.4 ± 1.6
1	20	0	0.0	0.0	0.0	0.0
		1	0.0	0.0	0.0	0.0
		***				
	20	3	0.0	0.0	0.0	0.0
		7	0.0	0.0	0.0	0.8 ± 0.8
		11	0.0	0.0	0.0	0.8 ± 0.8
		16	0.0	0.8 ± 0.8	0.0	0.8 ± 0.8
		20	0.0	0.8 ± 0.8	0.0	0.8 ± 0.8
		24	0.0	2.4 ± 0.8	0.0	1.6 ± 1.0
2	20	0	0.0	0.0	0.0	0.0
		1	0.0	0.0	0.0	0.0
		***				
	20	3	0.0	0.0	0.0	0.0
		7	0.0	0.8 ± 0.8	0.0	0.0
		11	0.0	0.8 ± 0.8	0.0	0.0
		16	0.0	0.8 ± 0.8	0.0	0.0
		20	0.0	0.8 ± 0.8	0.0	1.6 ± 1.0
		24	0.0	1.6 ± 1.6	0.0	3.2 ± 2.0

WP = wound healing period (before irradiation)
ST = storage temperature (before and after irradiation)
SP = total storage period (before and after irradiation)
*** = time of irradiation

3.4 General appearance

The results of general appearance estimation are presented in figures 13 to 16.

In general an irradiation treatment immediately applied after harvest with doses over 50 Gy gave the highest quality scores. A postponed irradiation treatment after harvest lowered the quality score for all objects. The unirradiated samples stored at 10 and 20 °C were just marketable (score 3) after 18 and 16 weeks respectively.

A dose of 50 gave an extension of 4 weeks, while potatoes irradiated with doses of 75 and 100 Gy were qualified in general as good (score 4) till the end of the storage period (27 weeks).

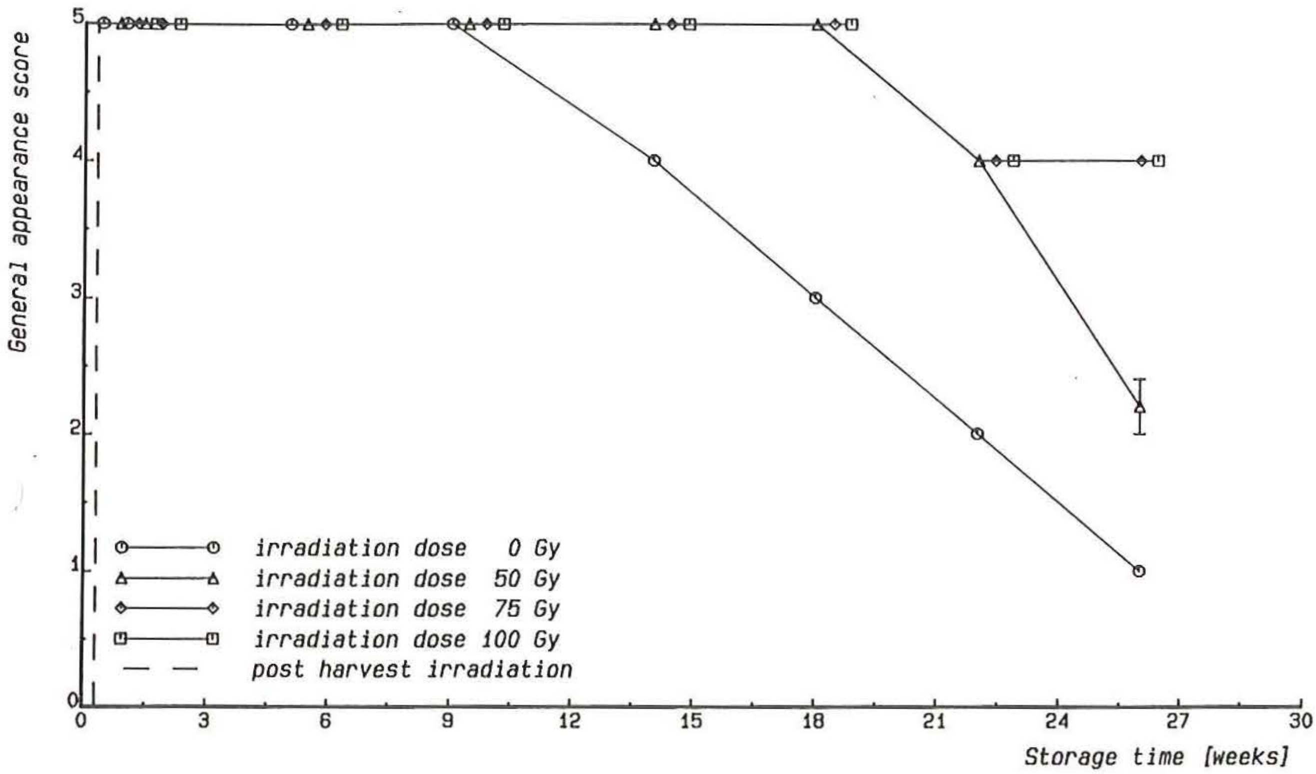

Figure 13: Average general appearance ± SE of 5 samples of 25 potatoes, infected with <u>Fusarium sulfurium</u>, post-harvest irradiated after 0 weeks storage at 15 °C and subsequently stored at 10 °C.

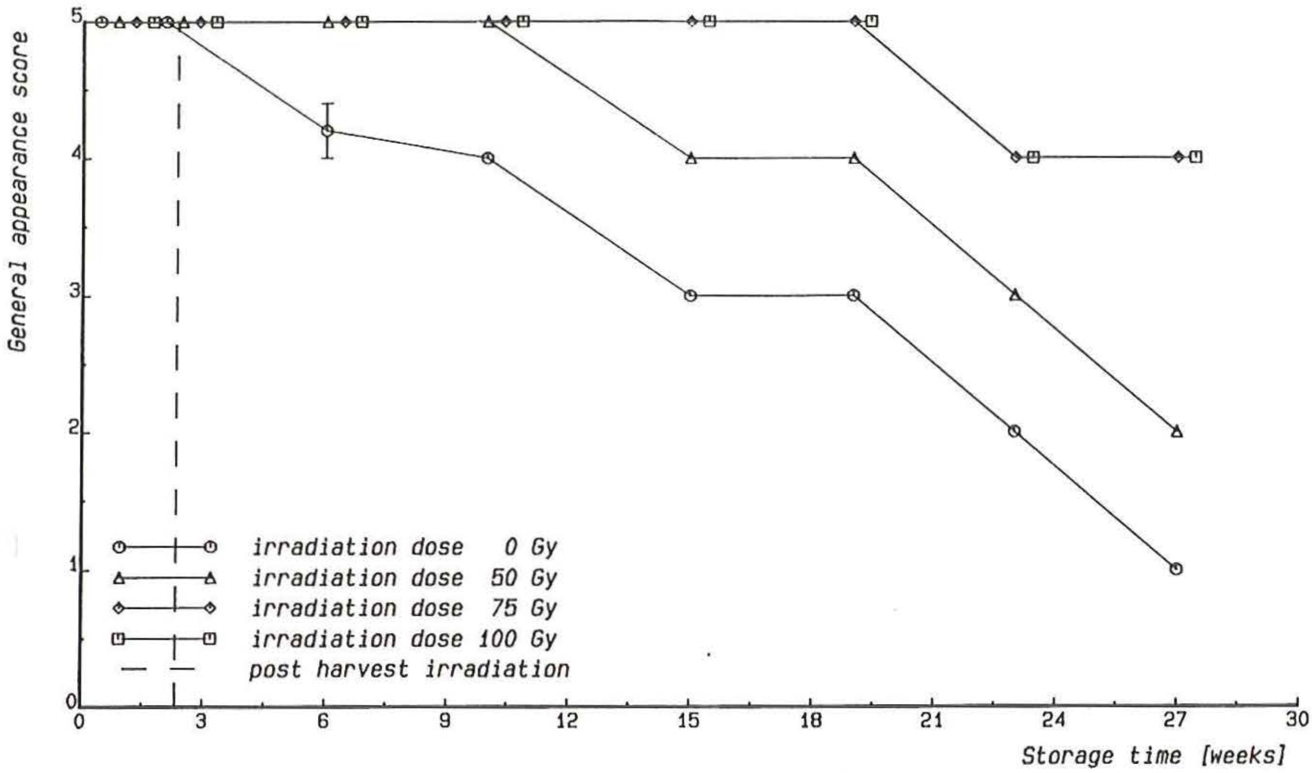

Figure 14: Average general appearance ± SE of 5 samples of 25 potatoes, infected with Fusarium sulfurium, post-harvest irradiated after 2 weeks storage at 15 °C and subsequently stored at 10 °C.

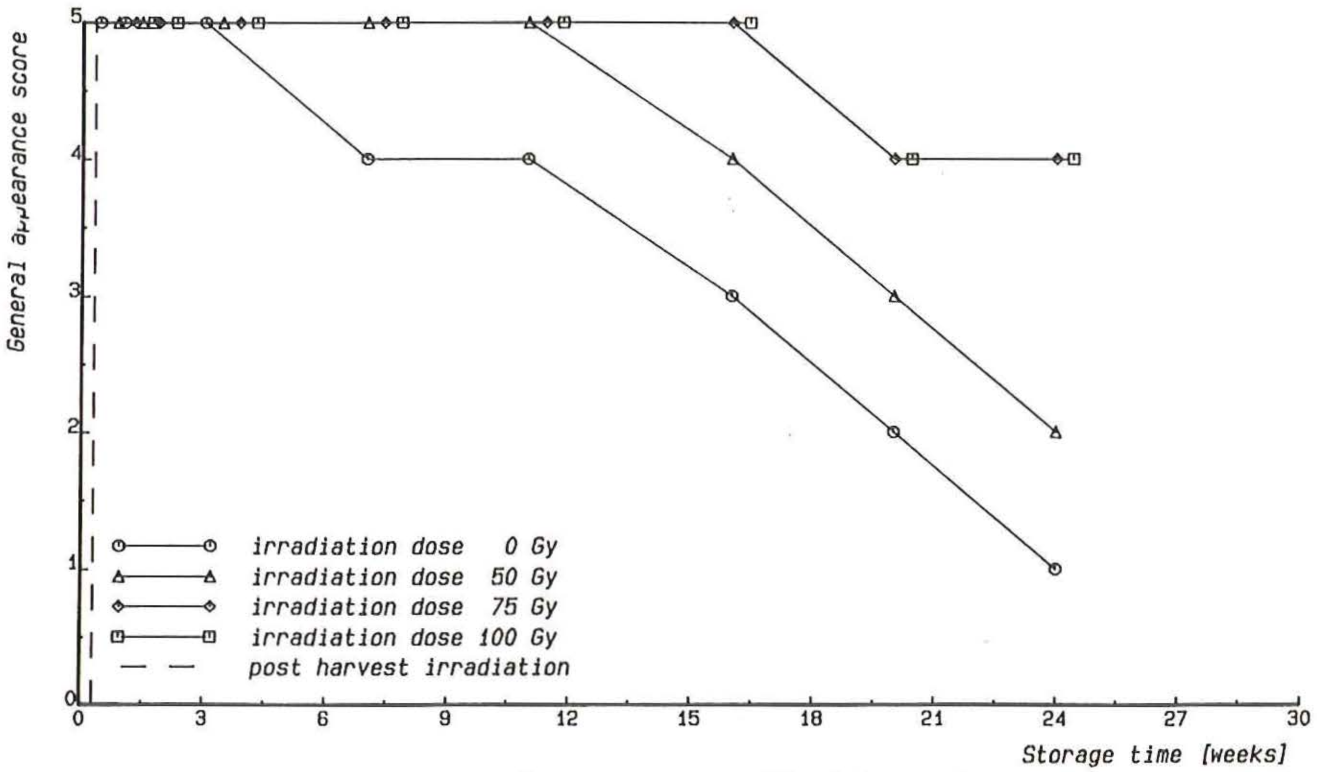

Figure 15: Average general appearance ± SE of 5 samples of 25 potatoes, infected with Fusarium sulfurium, post-harvest irradiated after 0 weeks storage at 15 °C and subsequently stored at 20 °C.

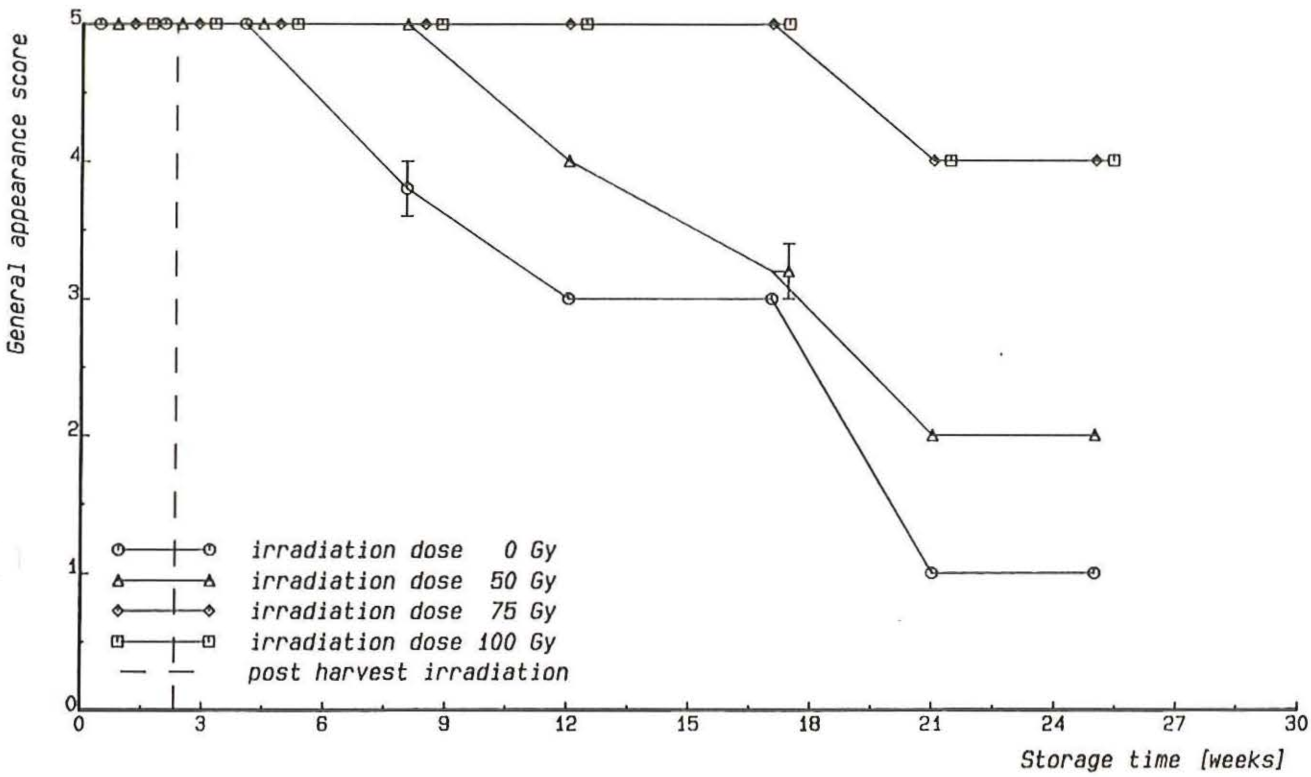

Figure 16: Average general appearance ± SE of 5 samples of 25 potatoes, infected with Fusarium sulfurium, post-harvest irradiated after 2 weeks storage at 15 °C and subsequently stored at 20 °C.

4 CONCLUSIONS

From the experiment the following conclusions can be drawn:

- During storage at 10 and 20 °C the dormancy period was 5 and 2 weeks respectively;
- A dose of 75 and 100 Gy reduced the loss of weight and gave a complete sprout inhibition to the end of the storage period;
- A dose of 50 Gy stimulated sprouting (enhanced the number of sprouts) but delayed the growth (limited sprout length);
- An irradiation treatment within 2 weeks after harvest gave the best results concerning sprout inhibition; a longer post-harvest irradiation period at higher temperatures gave a higher percentage of sprouted potatoes;
- An irradiation treatment immediately applied after harvest or a high dose did not significantly increase the percentage of rot;
- Optimum cultivation measures in the field probably played an important role in relation to the resistance of the product against fungi.

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