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ASSESSMENT OF GAMMA IRRADIATION TREATMENTS FOR MANAGING *Sitophilus oryzae* (L.) IN PADDY SEEDS INTENDED FOR EXPORT

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ABSTRACT

The present study evaluated the effectiveness of gamma irradiation (50-400 Gy) for the management of *Sitophilus oryzae* in stored paddy and its impact on seed quality during three months of storage. Gamma irradiation significantly reduced adult emergence, seed damage, and weight loss, with complete suppression achieved at doses of 150 Gy and above. However, increasing irradiation dose caused a gradual decline in germination percentage and seedling vigour, while seed moisture content remained largely unaffected. Among the treatments, 150 Gy was identified as the optimum dose, providing complete insect control while maintaining acceptable seed quality. The results indicate that gamma irradiation is an effective, residue-free, and environmentally friendly alternative to chemical fumigants for the safe storage of paddy.

***Keywords* :** Gamma irradiation, *Sitophilus oryzae*, paddy, phytosanitary treatment, seed quality.

Introduction

Rice weevil, *Sitophilus oryzae* (L.), is one of the most destructive pests of stored cereals, causing significant quantitative and qualitative losses during storage. Infestation reduces grain quality and nutritional value, contaminates produce with insect fragments and excreta, and promotes fungal growth, thereby reducing its marketability and export value (Chang *et al*., 2017). Since paddy is one of India's major food and export commodities, protecting stored grains from insect damage is essential to minimize post-harvest losses and ensure food security.

The management of stored-grain pests has traditionally depended on chemical fumigants such as methyl bromide and phosphine. However, methyl bromide has been phased out due to its ozone-depleting properties (WMO, 1995), while the continuous use of phosphine has led to the development of resistant insect populations along with concerns regarding worker safety and environmental contamination (Acuna *et al*., 1997; Follett *et al*., 2013). These limitations have created the need for safer and environmentally sustainable alternatives for stored-grain protection.

Gamma irradiation has emerged as an effective, residue-free phytosanitary treatment for the management of stored-product insects. The International Standards for Phytosanitary Measures recommend irradiation doses ranging from 50 to 400 Gy for effective insect control. Gamma irradiation effectively suppresses *S. oryzae* while preserving the physicochemical quality of stored grains, making it a promising alternative to conventional fumigation.

Despite its effectiveness, higher doses of gamma irradiation may adversely affect seed germination, seedling vigour, root and shoot growth, and other physiological characteristics (Marcu *et al*., 2013). Therefore, determining an optimum irradiation dose is essential to achieve effective control of *S. oryzae* without compromising seed quality and viability. The present study was undertaken to evaluate the efficacy of different doses of gamma irradiation against *S.*

oryzae in stored paddy and to identify a suitable dose for effective pest management while maintaining seed quality. The main objective of this research is to study the different parameters mainly adult emergence, seed damage, weight loss, germination percentage, seedling vigour index and moisture content of the paddy seeds exposed to different dosages of gamma irradiation for up to 3 months of storage.

Materials and Methods

The study was conducted during 2025-2026 at Professor Jayashankar Telangana Agricultural University (PJTAU), Rajendranagar, Hyderabad, Telangana, India. Gamma irradiation treatments were carried out at the MFPI Quality Control Laboratory, Rajendranagar, Hyderabad.

Insect culture

A laboratory culture of *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) was maintained on paddy seeds (cv. RNR 15048) in plastic containers containing 1 kg of disinfected seed (13% moisture content). One hundred adults were introduced into each container and maintained at 28 ± 5°C and 75 ± 5% relative humidity. Male and female weevils were identified based on rostrum morphology as described by Azis and Kasim (2021). Fig 1

Gamma irradiation treatment

Disinfested paddy seeds (cv. RNR 15048) were artificially infested with five pairs of adult weevils in 500 g seed lots. After an oviposition period of 8 days, adults were removed and the infested seeds were incubated for 45 days. The samples were then exposed to gamma irradiation using a Cobalt-60 Gamma Chamber 5000 (Fig 2) at different dosages as mentioned in Table 1.

Fig. 1: Maintenance of *Sitophilus oryzae* culture in paddy

Fig. 2: Cobalt-60 Gamma Chamber 5000 for gamma irradiation treatment

Table 1 : Details of treatments imposed to study the effect of gamma irradiation rice weevils.

S. No	Treatment number	Dosages of gamma irradiation	Number of replications
1	T_1	50Gy	3
2	T_2	100Gy	3
3	T_3	150Gy	3
4	T_4	200Gy	3
5	T_5	250Gy	3
6	T_6	300Gy	3
7	T_7	350Gy	3
8	T_8	400Gy	3
9	T_9	Untreated control	3

Observations

All treatments were evaluated monthly for three months by recording adult emergence, seed damage (%), weight loss (%), germination (%), seedling vigour index, and seed moisture content. Seed damage was determined from a random sample of 100 seeds. Weight loss was calculated using the count and weight method of Harris and Lindblad (1978). Germination was assessed by the paper towel method following ISTA (1999), and seedling vigour index was calculated according to Baki and Anderson (1973) by multiplying germination percentage with mean seedling length. Seed moisture content was determined using hot air oven method.

Results

Adult emergence

The data present in Table 2 and chart 1 shows that the effect of gamma irradiation significantly reduced adult emergence of *Sitophilus oryzae* during storage ($P < 0.001$). Adult emergence increased gradually with storage period in lower irradiation doses and untreated control. The untreated control recorded the highest emergence with 7.46, 10.33 and 14.00 adults at one, two and three months after storage (MAS), respectively, with a mean of 10.60 adults. Irradiation doses of 50 and 100 Gy showed partial suppression, recording mean adult emergence of 9.44 and 7.45 adults, respectively. However, complete inhibition of adult emergence (0.00 adults) was observed at irradiation doses ≥150 Gy throughout the storage period. These results indicate that higher irradiation doses effectively prevented insect development and progeny production.

Seed damage

The data present in Table 2 shows that the gamma irradiation reduced seed damage caused by *Sitophilus oryzae* during storage. Seed damage increased progressively from one to three MAS in untreated control and lower irradiation doses due to continued pest activity. The highest damage was recorded in untreated control (30.33, 35.33 and 45.33% at one, two and three MAS, respectively) with a mean of 37.00%. Irradiation treatments of 50 and 100 Gy reduced seed damage, recording mean values of 17.55 and 11.78%, respectively, but provided incomplete protection. Complete prevention of seed damage (0.00%) was observed at and above 150 Gy across all storage periods, indicating effective suppression of feeding damage and infestation. The comparison of healthy paddy seeds with seed damaged by *Sitophilus oryzae* is give below

Weight loss

The data present in Table 3 shows that gamma irradiation exhibited a marked influence on the reduction of weight loss caused by *Sitophilus oryzae* during storage. The extent of weight loss increased with prolonged storage duration in untreated seeds and at lower irradiation doses, reflecting continued insect feeding and progressive deterioration of stored paddy. The untreated control recorded the maximum weight loss of 3.79, 4.42 and 5.67% at one, two and three MAS, respectively, with an overall mean of 4.63%. Application of 50 and 100 Gy irradiation resulted in reduced weight loss, with mean values of 2.20 and 1.47%, respectively, though complete protection was not achieved. In comparison, irradiation doses of 150 Gy and above completely prevented weight loss (0.00%) throughout the storage period, demonstrating effective suppression of insect feeding and associated grain losses.

Germination percentage

The data present in Table 3 shows that the Ggamma irradiation significantly affected germination of paddy seeds during storage, with a gradual decline observed with increasing irradiation dose and storage duration. The highest germination was recorded in 50 Gy treatment (90.00, 87.00 and 84.00% at one, two and three MAS, respectively) with a mean of 87.00%, followed by untreated control (86.00, 83.00 and 80.00%) with a mean of 83.00% and 100 Gy (80.00% mean). Higher doses showed a dose-dependent reduction in germination, with mean values of 76.11, 73.00, 69.00, 68.66, 69.00 and 65.00% at 150, 200, 250, 300, 350 and 400 Gy, respectively. The lowest germination was recorded at 400 Gy, declining from 68.00% at one MAS to 62.00% at three MAS, indicating radiation-induced effects on seed viability. Overall germination decreased from 77.33% at one MAS to 74.56% at two MAS and 71.70% at three MAS due to storage deterioration. Lower doses, particularly 50 Gy, maintained higher seed viability and remained above the certification standard, whereas higher doses (≥200 Gy) adversely affected germination.

Seedling vigour index

The data present in Table 4 that gamma irradiation significantly affected the seedling vigour index of paddy during storage, with a gradual reduction observed with increasing irradiation dose and storage period. The highest vigour index was recorded at 50 Gy (3227.00, 2983.00 and 2610.00 at one, two and three MAS, respectively) with a mean of 2940.00, followed by 100 Gy with a mean of 2776.00. Higher doses resulted in reduced vigour, with mean values of 2592.00, 2357.00, 1917.00, 1467.00, 1050.00 and 667.00 at 150, 200, 250, 300, 350 and 400 Gy, respectively. The lowest vigour index was observed at 400 Gy, declining from 950.00 at one MAS to 350.00 at three MAS. The untreated control recorded a mean vigour index of 2493.33, while lower doses (50–100 Gy) maintained better seedling performance. Overall mean vigour decreased from 2360.00 at one MAS to 2071.00 at two MAS and 1655.00 at three MAS, indicating storage-related deterioration.

Moisture content

The data present in Table 4 gamma irradiation had a minimal influence on the moisture content of paddy seeds during storage. A slight increase in moisture content was observed with advancement of storage period, which may be associated with ambient storage conditions, while higher irradiation doses resulted in a marginal reduction in moisture levels. The untreated control recorded the highest moisture content (11.42, 11.78 and 12.18% at one, two and three MAS, respectively) with a mean of 11.78%. The 50 and 100 Gy treatments recorded mean moisture contents of 11.69 and 11.59%, respectively, whereas the highest dose of 400 Gy recorded the lowest mean value of 10.79%. However, the variation among treatments was narrow, indicating that gamma irradiation caused only slight changes in seed moisture content. All treatments were maintained moisture levels within the prescribed seed storage limit (13%) up to three months of storage. Thus, gamma irradiation can be used for pest management without adversely affecting the moisture stability of stored paddy seeds.

Table 2: Mean adult emergence of *Sitophilus oryzae* and seed damage percentage done in paddy seeds exposed to gamma irradiation for up to 3 months of storage

Gamma irradiation dosages	Adult emergence (500 grams of seed)				Seed damage (%)			
	1 MAS	2 MAS	3 MAS	Mean	1 MAS	2 MAS	3 MAS	Mean
50 Gy	7.33 (15.71)	9.00 (17.46)	12.00 (20.27)	9.44 (17.81)	10.33 (18.75)	17.00 (24.35)	25.33 (30.22)	17.55 (24.44)
100 Gy	5.67 (13.77)	7.00 (15.34)	9.67 (18.11)	7.45 (15.74)	6.67 (14.96)	10.33 (18.75)	18.33 (25.35)	11.78 (19.69)
150 Gy	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
200 Gy	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
250 Gy	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
300 Gy	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
350 Gy	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
400 Gy	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Untreated control	7.46 (16.07)	10.33 (18.75)	14.00 (21.97)	10.60 (18.93)	30.33 (33.42)	35.33 (36.47)	45.33 (42.32)	37.00 (37.40)
Mean	2.27 (5.06)	2.93 (5.73)	3.96 (6.71)		5.26 (7.12)	6.96 (8.71)	9.89 (18.33)	
	SE(m) ±		**CD**		**SE(m) ±**		**CD**	
Concentrations (F1)	0.01		0.03		0.081		0.246	
Months after storage (F2)	0.01		0.02		0.094		0.271	
Interaction (F1*F2)	0.02		0.06		0.141		0.816	
CV (%)	1.11				3.91			

Table 3: Mean weight loss caused by *Sitophilus oryzae* and mean germination percentage of paddy seeds exposed to gamma irradiation for up to 3 months of storage

Gamma irradiation dosages	Weight loss (%)				Germination (%)			
	1 MAS	2 MAS	3 MAS	Mean	1 MAS	2 MAS	3 MAS	Mean
50 Gy	1.29 (6.53)	2.13 (8.39)	3.17 (10.26)	2.20 (8.39)	90.00 (71.57)	87.00 (68.87)	84.00 (66.42)	87.00 (68.87)
100 Gy	0.84 (5.25)	1.29 (6.53)	2.29 (8.71)	1.47 (6.83)	83.00 (65.65)	80.00 (63.43)	77.00 (61.34)	80.00 (63.43)
150 Gy	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	80.00 (58.05)	77.00 (61.34)	71.33 (57.63)	76.11 (60.74)
200 Gy	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	76.00 (60.67)	73.00 (58.69)	70.00 (56.79)	73.00 (58.69)
250 Gy	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	72.00 (58.05)	69.00 (56.17)	66.00 (54.33)	69.00 (56.17)
300 Gy	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	71.00 (57.42)	69.00 (56.17)	66.00 (54.33)	68.66 (55.96)
350 Gy	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	70.00 (56.79)	68.00 (55.55)	69.00 (56.17)	69.00 (56.17)
400 Gy	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	68.00 (55.55)	65.00 (53.73)	62.00 (51.94)	65.00 (53.73)
Untreated control	3.79 (11.23)	4.42 (12.14)	5.67 (13.78)	4.63 (12.38)	86.00 (86.00)	83.00 (65.65)	80.00 (63.43)	83.00 (65.65)
Mean	0.66 (2.56)	0.87 (3.01)	1.24 (3.64)		77.33 (63.31)	74.56 (59.96)	71.70 (58.04)	
	SE(m) ±		CD		SE(m) ±		CD	
Concentrations (F1)	0.048		0.135		0.089		0.253	
Months after storage (F2)	0.028		0.078		0.051		0.146	
Interaction (F1*F2)	0.083		0.235		0.154		N/S	
CV (%)	3.81							

Table 4: Mean seedling vigour index and moisture content of paddy seeds exposed to gamma irradiation for up to 3 months of storage

Gamma irradiation dosages	Seedling vigour index				Moisture content			
	1 MAS	2 MAS	3 MAS	Mean	1 MAS	2 MAS	3 MAS	Mean
50 Gy	3227.00	2983.00	2610.00	2940.00	11.32 (19.66)	11.68 (19.98)	12.08 (20.34)	11.69 (19.99)
100 Gy	3080.00	2823.00	2423.00	2776.00	11.22 (19.57)	11.58 (19.89)	11.98 (20.25)	11.59 (19.90)
150 Gy	2927.00	2650.00	2200.00	2592.00	11.12 (19.48)	11.48 (19.81)	11.88 (20.16)	11.45 (19.82)
200 Gy	2710.00	2410.00	1950.00	2357.00	11.02 (19.39)	11.38 (19.72)	11.78 (20.07)	11.32 (19.73)
250 Gy	2300.00	1950.00	1500.00	1917.00	10.88 (19.26)	11.23 (19.58)	11.63 (19.94)	11.25 (19.59)
300 Gy	1850.00	1500.00	1050.00	1467.00	10.72 (19.11)	11.08 (19.44)	11.48 (19.81)	11.09 (19.45)
350 Gy	1400.00	1100.00	650.00	1050.00	10.58 (18.98)	10.93 (19.31)	11.33 (19.67)	10.95 (19.32)
400 Gy	950.00	700.00	350.00	667.00	10.42 (18.83)	10.78 (19.17)	11.18 (19.53)	10.79 (19.18)
Untreated control	2800.00	2520.00	2160.00	2493.00	11.42 (19.75)	11.78 (20.07)	12.18 (20.43)	11.78 (20.08)
Mean	2360.00	2071.00	1655.00		10.97 (19.34)	11.32 (19.66)	11.72 (20.02)	
	SE(m) ±		CD		SE(m) ±		CD	
Concentrations (F1)	14.948		42.501		0.01		0.029	
Months after storage (F2)	8.631		24.538		0.006		0.017	
Interaction (F1*F2)	73.614		73.614		0.017		N/S	
CV (%)	2.21				2.16			

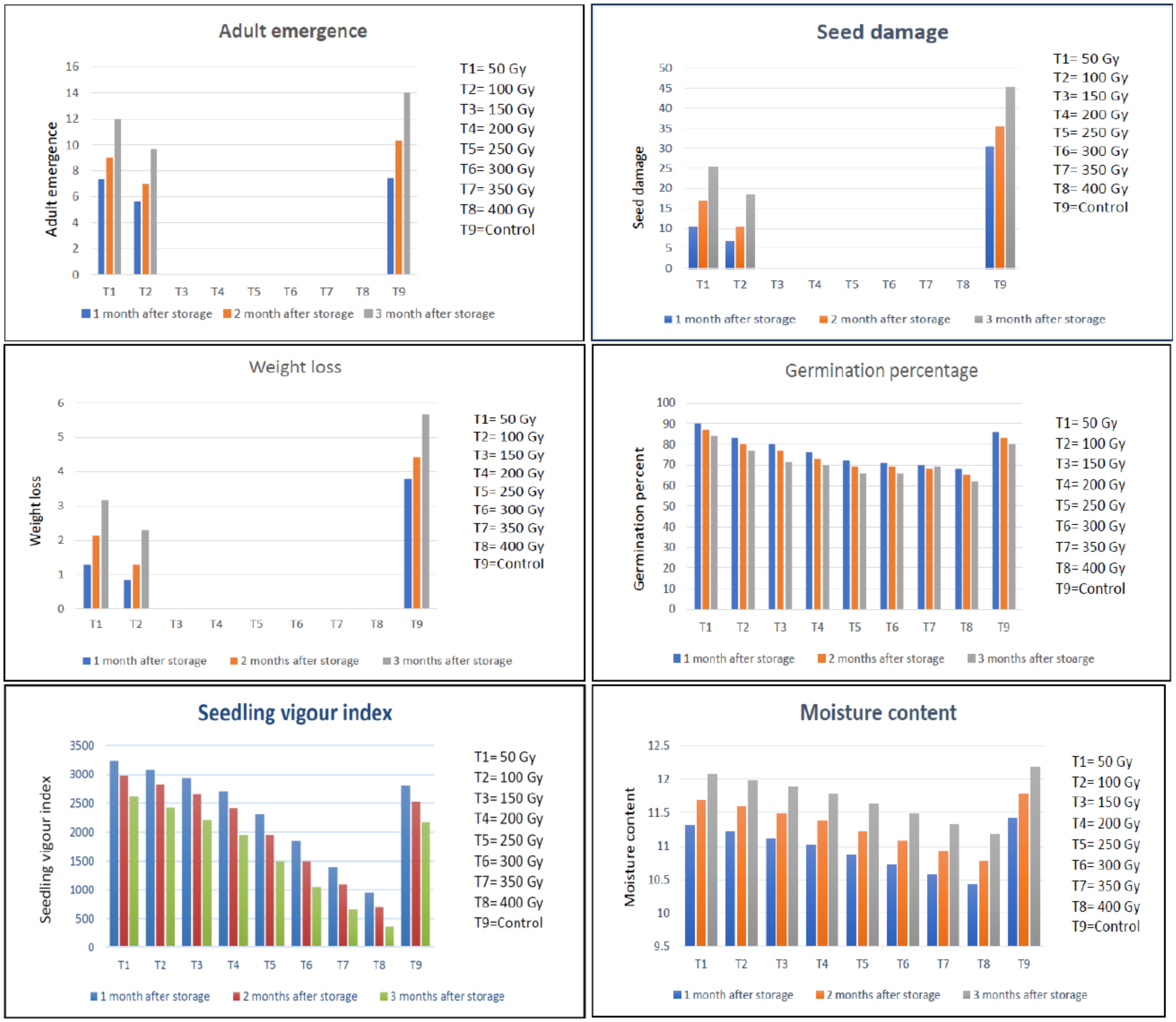

Fig. 4: Graphical representation (charts) of 6 parameters of paddy seeds exposed to gamma irradiation for up to 3 months of storage

Fig. 4 illustrate the effect of gamma irradiation on the storage performance of paddy seeds over a period of three months. The charts present the mean adult emergence of *Sitophilus oryzae*, mean seed damage and mean weight loss caused by *S. oryzae*, along with the mean germination percentage, mean seedling vigour index and mean moisture content of irradiated paddy seeds during storage. Together, these parameters demonstrate the influence of different gamma irradiation doses on insect infestation, seed quality and storage characteristics throughout the storage period.

Discussion

Gamma irradiation effectively reduced adult emergence, seed damage, and grain weight loss in a dose-dependent manner by disrupting insect development, reproduction, and feeding activity, thereby providing effective protection against *Sitophilus oryzae* during storage. Similar responses have been reported in stored-product insects, where increasing irradiation doses progressively suppressed insect survival and grain deterioration (Farghaly *et al*., 2014; Srimartpirom *et al*., 2018; Araujo *et al*., 2022). However, the beneficial effects of higher irradiation doses were accompanied by a gradual decline in germination percentage and seedling vigour, which may be attributed to radiation-induced physiological and cellular damage affecting seed viability and early growth, as also observed by Maity *et al*. (2009), Marcu *et al.* (2013) and Amirikhah *et al.* (2021). In contrast, seed moisture content remained largely unaffected, indicating that phytosanitary irradiation primarily targets insect pests without significantly altering the physical characteristics of the grain, consistent with previous reports (Bao *et al*., 2006). Overall, the results suggest that gamma irradiation is an effective and environmentally friendly alternative for stored-grain protection, provided that an optimum dose is selected to achieve efficient insect control while preserving seed quality.

Conclusion

Gamma irradiation proved to be an effective and environmentally friendly technique for protecting stored paddy against *Sitophilus oryzae*. Irradiation doses of 150 Gy and above completely inhibited adult emergence, preventing seed damage and weight loss during storage. However, increasing irradiation dose adversely affected germination and seedling vigour, whereas seed moisture content remained largely unchanged and within acceptable storage limits. Overall, 150 Gy was identified as the optimum dose, providing complete insect control while maintaining acceptable seed quality, making gamma irradiation a promising alternative to chemical fumigants for the safe storage of paddy.

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