



Studies of Gamma Irradiation on Performance of Turf Grass Species

Shrejal Tiwari¹, Anuj Kumar¹, R.K. Sharma², Roshan Gallani³, G.P.S. Rathore⁴, Praddyum¹

10.18805/ag.D-6259

ABSTRACT

Background: This experiment was conducted to study the effect of gamma irradiation on the quantitative traits of various turf grass species in the Malwa region. Turf grass, which is a primarily appreciated for its aesthetic and green cover, is important in industrial and rural areas to mitigate heat and drought stress with speeding development. However, the limited genetic variation in existing turfgrass varieties poses a challenge to breeding efforts aimed at improving stress tolerance and mutation is widely used for creating genetic variability in other crops to develop the varieties superior to parents and suitable for different climatic conditions. Therefore, this study aims to investigate the mutagenic effects of gamma irradiation on selected lawn grass species and optimizing the best suitable dose for Turf grass improvement.

Methods: The experiment was conducted in Mandsaur (Madhya Pradesh), India to explore possibility of gamma irradiation's impact on various characters of turf grass species. This experiment was conducted in randomized block design (RBD) with three replications. During the experiment, four different warm season grasses species were used, specifically *Cynodon dactylon* cv Burgasto, *Zoysia materella*, *Dactyloctenium aegyptium* and *Nassella tenuissima*, underwent treatment with different doses of gamma irradiation viz. 30 Gy, 60 Gy, 90 Gy and 120 Gray (Gy). To compare the effects, an untreated control treatment was also included in the study. Both quantitative as well as qualitative parameters were assessed.

Result: The results revealed that reduced growth with higher gamma irradiation doses. Furthermore, indicated that irradiated sprigs displayed denser shoots, finer growth, shorter internodes, leaves and enhanced colour retention even in winters. Notably, 60 Gy and 90 Gy induced the highest number of mutants (seven in total). Thus, the study suggests that gamma irradiation at doses of 30 Gy to below 100 Gy can effectively induce genetic variation in grass species.

Key words: Gamma irradiation, Genetic variation, Grass spp., Lawn, Mutation, Sprigs, Turf.

INTRODUCTION

'Lawn' is an area of land covered with grasses or other durable plant covers and maintained up to 5-6 cm for aesthetic and recreational purposes. Turf grass provides at least three major benefits to human activities, functional, recreational and ornamental (Sithin, 2021; Tiwari, 2024). Lawns offer several functional benefits, including effective control of soil erosion and dust/ sand dunes stabilization (Chou *et al.*, 2024 and Hussain and Hoque, 2022). The dense plant canopy of well-maintained turf grass species helps trap rain water, airborne particulate matter and gaseous pollutants, while also promoting groundwater recharge (Wadekar *et al.*, 2018). Lawns also play a key role in reducing urban heat, minimizing noise, glare and visual pollution (Braun *et al.*, 2024). In addition to their functional benefits, lawns provide recreational advantages by offering an excellent surface for outdoor sports and reducing injuries through cushioning. Aesthetically, lawns enhance the overall beauty of landscapes, leading to improve mental health and human productivity (Mathew *et al.*, 2021). Furthermore, the presence of a well-maintained lawn has a positive impact on house value, A beautifully landscaped front yard with lush lawns can instantly capture the attention of visitors and potential buyers, creating a strong first impression that enhances the overall curb appeal and perceived value of the property.

¹Department of Floriculture and Landscaping, KNK College of Horticulture, Mandsaur-458 895, Madhya Pradesh, India.

²Department of Vegetable Science, KNK College of Horticulture, Mandsaur-458 895, Madhya Pradesh, India.

³Department of Soil Science and Agri, Chemistry, KNK College of Horticulture, Mandsaur-458 895, Madhya Pradesh, India.

⁴Department of Statistics, KNK., College of Horticulture, Mandsaur-458 895, Madhya Pradesh, India.

Corresponding Author: Shrejal Tiwari, Department of Floriculture and Landscaping, KNK., College of Horticulture, Mandsaur-458 895, Madhya Pradesh, India.

Email: shrejaltiwari@gmail.com

How to cite this article: Tiwari, S., Kumar, A., Sharma, R.K., Gallani, R., Rathore, G.P.S. and Praddyum. (2025). Studies of Gamma Irradiation on Performance of Turf Grass Species. Agricultural Science Digest. 1-9. doi: 10.18805/ag.D-6259.

Submitted: 06-12-2024 **Accepted:** 30-05-2025 **Online:** 27-06-2025

The turf grass industry has emerged as a pivotal aspect of sports fields, exhibiting significant importance across various games and sports such as cricket, hockey, football and golf. The utilization of turf grass in these areas necessitates specific attributes, notably including a vibrant and lush green hue, exceptional tolerance to wear and tear and a low mowing tolerance. This is particularly crucial in

golf greens, where the grass is meticulously mowed to a height of less than 0.3 cm or 3 mm. With the rapid pace of urbanization, lawns are becoming an integral feature of urban and suburban environments, appearing in residential and corporate yards, public and industrial parks and playgrounds (Ignatieva *et al.*, 2020). Given the current urban expansion trends, Alig *et al.*, (2004) projected a 79% increase in lawn coverage across the United States by 2030. Furthermore, as many emerging economies in Asia and Africa increasingly embrace Western cultural influences, urban and suburban lawns are expected to expand significantly in these regions as well (Cilliers *et al.*, 2013 and Yang *et al.*, 2019).

For long term success of turf grass the proper selection should be done based on climatic requirement, cultural operation used and its purpose. However, not all turf grass can be grown in all regions and to develop turf grass for region requires its improvement (Mohd *et al.*, 2016). Turf breeding aims to develop and improve grass varieties specifically for use in sports fields, golf courses and other areas where a durable, attractive and high-performance turf is required. Turf grass improvement and breeding heavily rely on genetic variation to introduce and refine desirable traits. However, a significant challenge arises when it comes to warm season grasses, as the desired genetic variation is often lacking. This limitation can hinder efforts to develop improved turf grass varieties with enhanced characteristics.

Mutation breeding has been used to improve turf grasses, by inducing genetic mutations that result in desirable variation (Kunreddy *et al.*, 2025; Galatali *et al.*, 2023; Singh *et al.*, 2013 and Busey, 1980) These variations can then be selected and bred for desirable traits, such as increased stress tolerance for biotic and abiotic conditions associated with climate change and urbanization, better color and improved density. Henceforth, mutation breeding continues to be an effective tool in the development of new and improved turf grass varieties, that are easy to manage and durable.

MATERIALS AND METHODS

The experiment was performed to expose sprigs of four different grass species in (Fig 1) were exposed to various range of doses from 0, 30, 60, 90 and 120 Gray. Healthy sprigs were collected from department of floriculture and landscape architecture at college of horticulture, Mandsaur (MP). The sprigs were packed in the plastic bags and irradiated with different doses at Gamma chamber of IARI, Delhi. The control sprigs which were not irradiated but kept in sealed bags and spray with water to maintain moisture. The sprigs were planted in plastic bags with mixture of sand, soil and vermicompost with 30 sprigs per bags. The experiment was conducted in factorial RBD with 3 replications. For cultural operations, the irrigation was applied as per requirement, while hand weeding was done to suppress weeds from the Turf grass species.

Observations on various growth parameters: Survival percentage was observed at 6 weeks after plantation (WAP), leaf length (cm), leaf width (mm), stolon internodal length (cm), internodal diameter (mm) and leaf chlorophyll content (SPAD value) were recorded at an interval of 6, 12, 18, 24 weeks after planting, respectively. Whereas, parameters like leaf blade length (cm), leaf blade width (mm) and number of stolons were perceived at 12, 18, 20 WAP and canopy height was measured at 20 WAP.

The data were analyzed using statistical analysis by Panse and Sukhatme, 1967. With the help of 'F' variance ratio test the significance and non-significant effect of the different treatments was tested. The significant difference between treatment means was tested using critical difference (CD) at 5% level of significance.

RESULTS AND DISCUSSION

Survival percentage

Maximum survival percentage at 6 weeks after plantation (70.05%) was recorded with control viz 00 Gy which was followed by 30 Gy. Whereas, minimum survival percentage



Fig 1: The four spp. That were used in experiment: Bermuda grass var Bargusto. Manilla grass. Crowfoot grass. Mexican grass.

(9.86%) was recorded under 120 Gy treatment. The comparison among the responses of different species and their combine effect irrespective of gamma irradiation was found to be non-significant. Among species, maximum survival of 37.99% was noted in Bermuda grass (*Cyanodon dactylon*) whereas, 32.40% was the minimum survival in Crowfoot grass as presented in (Fig 2). Higher doses of γ -ray radiation had a notable impact on reducing survival rates in Bermuda grass (Mutlu *et al.*, 2015). And with higher dose decreased survival was recorded by (Mohd *et al.*, 2016).

Leave length

Significant effects were observed among species and gamma irradiation. Maximum length of leaves (cm) for 6,12,18, 20 WAP was observed with 30 Gy which was followed by 00 Gy. While minimum leaf length of was

reported in 120 Gy. However, interaction of gamma irradiation does not make the notable effect on the grasses treated expect 18 WAP, which shows that the experiment manipulated leaf lengths, with Mexican grass exhibiting elongation at 30 Gy and Bermuda grass showing the shortest at 120 Gy presented in (Fig 3).

Leave width

The findings indicate that control treatment showed the widest leaves which 30 Gy and 120 Gy displaying the narrowest leaves at 6,12,18,20 WAP followed. Leaf width varied non-significantly between 6 and 12 WAP, but was significant at 12 and 18 WAP with maximum leaf width of crowfoot grass without gamma treatment and minimum width with Bermuda grass at 120 Gy as mentioned in (Table 1).

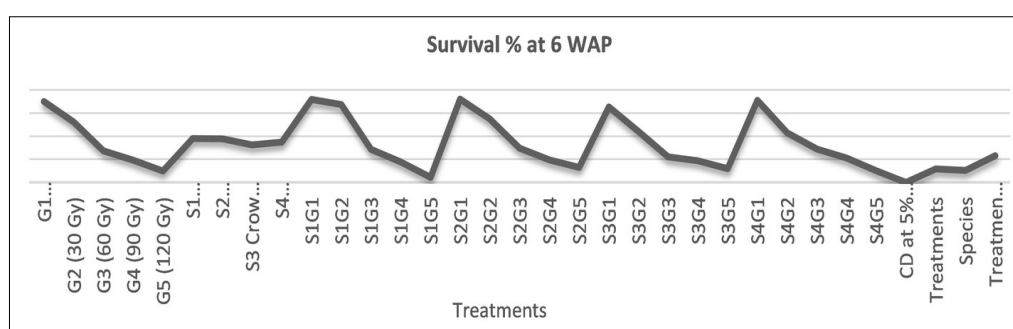


Fig 2: Survival percentage of Bermuda grass var Bargusto, Manilla grass, crowfoot grass, Mexican grass at 6 weeks after plantation.

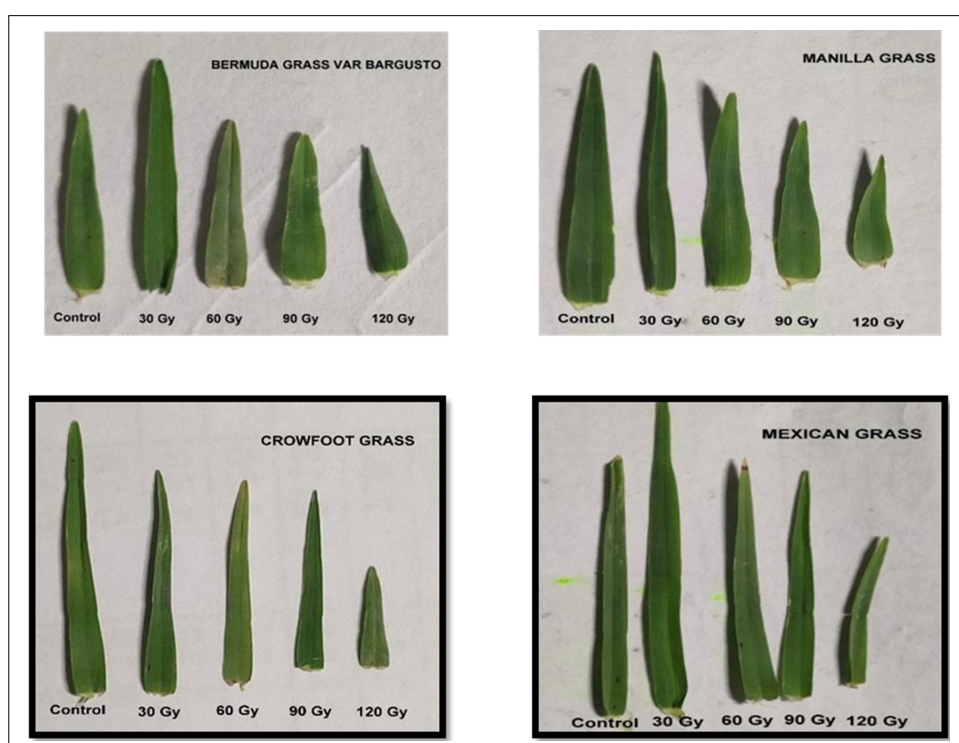


Fig 3: Effect of gamma irradiation on leaf length and width of Bermuda grass var Bargusto, Manilla grass, Crowfoot grass, Mexican grass.

Table 1: Effect of gamma irradiation on survival percentage, leaf length (cm), leaf width (mm) and stolon internodal length (cm) at 6, 12, 18 and 20 weeks after planting (WAP).

Treatment	Leaf length				Leaf width				Stolon internode length				Internodal diameter			
	6	12	18	20	6	12	18	20	6	12	18	20	6	12	18	20
Gamma irradiation																
G ₁ (Control)	1.51	1.76	1.71	1.73	2.01	2.10	2.16	2.29	3.61	3.63	3.68	3.68	0.62	0.74	0.88	1.03
G ₂ (30 Gy)	1.65	1.77	1.80	1.83	1.86	1.95	2.10	2.22	2.87	2.96	3.10	3.12	0.56	0.72	0.78	0.84
G ₃ (60 Gy)	1.44	1.61	1.66	1.70	1.78	1.90	2.02	2.17	2.37	2.96	2.93	3.04	0.44	0.61	0.76	0.80
G ₄ (90 Gy)	1.22	1.34	1.43	1.48	1.59	1.81	1.94	2.08	1.79	2.46	2.64	2.79	0.35	0.54	0.70	0.76
G ₅ (120 Gy)	0.66	0.88	1.09	1.17	0.73	1.30	1.32	1.41	1.27	1.85	2.01	2.18	0.27	0.35	0.54	0.54
Species																
S ₁ Bermuda grass var Bargusto	1.15	1.22	1.29	1.33	1.40	1.68	1.81	1.95	1.66	1.98	2.10	2.12	0.35	0.48	0.59	0.66
S ₂ Manilla grass	1.05	1.22	1.33	1.35	1.31	1.46	1.63	1.75	1.80	1.90	2.08	2.16	0.46	0.59	0.76	0.91
S ₃ Crowfoot grass	1.38	1.66	1.88	1.84	1.84	2.10	2.18	2.28	3.15	3.84	3.98	4.23	0.52	0.68	0.81	0.83
S ₄ Mexican grass	1.59	1.69	1.74	1.82	1.83	2.02	2.01	2.17	3.07	3.37	3.31	3.35	0.46	0.61	0.76	0.78
Interaction																
S ₁ G ₁	1.19	1.29	1.32	1.34	1.95	2.05	2.09	2.32	2.42	2.43	2.46	2.46	0.50	0.65	0.70	0.79
S ₁ G ₂	1.43	1.49	1.51	1.62	1.72	1.91	2.07	2.19	2.38	2.40	2.41	2.43	0.49	0.61	0.68	0.76
S ₁ G ₃	1.39	1.39	1.41	1.42	1.52	1.88	2.02	2.18	1.32	2.15	2.28	2.29	0.29	0.48	0.65	0.71
S ₁ G ₄	1.35	1.38	1.39	1.41	1.41	1.99	1.99	2.11	1.24	1.93	2.23	2.25	0.26	0.43	0.57	0.68
S ₁ G ₅	0.39	0.55	0.82	0.83	0.36	0.56	0.85	0.91	0.94	0.96	1.12	1.13	0.21	0.23	0.33	0.34
S ₂ G ₁	1.33	1.42	1.59	1.60	1.75	1.82	1.92	2.07	2.69	2.69	2.73	2.74	0.75	0.79	1.13	1.59
S ₂ G ₂	1.50	1.66	1.67	1.67	1.68	1.79	1.88	1.97	2.20	2.33	2.34	2.34	0.58	0.76	0.82	0.91
S ₂ G ₃	0.98	1.39	1.39	1.42	1.58	1.69	1.76	1.90	1.72	1.86	2.25	2.26	0.42	0.56	0.77	0.86
S ₂ G ₄	0.89	1.04	1.17	1.21	1.16	1.40	1.69	1.82	1.42	1.61	1.91	2.20	0.27	0.52	0.71	0.84
S ₂ G ₅	0.55	0.56	0.81	0.84	0.37	0.57	0.86	0.95	0.95	0.98	1.15	1.22	0.24	0.32	0.34	0.35
S ₃ G ₁	1.54	1.83	1.85	1.85	2.42	2.44	2.51	2.51	5.76	5.78	5.78	5.78	0.65	0.77	0.89	0.91
S ₃ G ₂	1.68	1.84	1.86	1.89	2.18	2.18	2.34	2.48	3.55	3.66	3.99	4.03	0.61	0.75	0.82	0.87
S ₃ G ₃	1.55	1.72	1.85	1.88	2.15	2.16	2.27	2.39	3.08	3.57	3.62	3.95	0.56	0.72	0.82	0.83
S ₃ G ₄	1.32	1.59	1.78	1.86	1.97	2.03	2.11	2.27	2.28	3.50	3.57	3.84	0.40	0.71	0.74	0.77
S ₃ G ₅	0.80	1.28	1.55	1.70	0.45	1.66	1.68	1.74	1.06	2.66	2.95	3.52	0.37	0.42	0.73	0.74
S ₄ G ₁	1.95	2.01	2.06	2.12	1.91	2.07	2.13	2.25	3.54	3.62	3.73	3.74	0.56	0.75	0.78	0.81
S ₄ G ₂	1.97	2.07	2.13	2.14	1.85	1.91	2.03	2.23	3.43	3.60	3.62	3.65	0.55	0.73	0.77	0.79
S ₄ G ₃	1.84	1.92	1.95	2.00	1.83	1.87	2.01	2.20	3.34	3.42	3.54	3.63	0.47	0.66	0.76	0.78
S ₄ G ₄	1.30	1.32	1.37	1.43	1.79	1.85	1.95	2.13	2.20	2.80	2.87	2.86	0.43	0.47	0.75	0.75
S ₄ G ₅	1.08	1.10	1.18	1.31	1.74	1.81	1.88	2.00	2.10	2.77	2.80	2.84	0.26	0.41	0.73	0.74
CD (P=0.05)																
Gamma Irradiation	0.40	0.33	0.16	0.21	0.35	0.42	0.28	0.10	0.79	1.01	0.49	0.11	0.15	0.19	0.12	0.13
Species	0.36	0.30	0.14	0.18	0.31	0.37	0.25	0.09	0.71	0.91	0.44	0.10	0.13	0.17	0.11	0.12
Treatments × Species	0.80	0.66	0.31	0.42	0.70	0.83	0.56	0.21	1.64	2.10	0.98	0.22	0.29	0.38	0.24	0.26

Stolon internodal length

The results revealed that the application of gamma irradiation had an impact on stolon internodal length with 00 Gy (control) exhibiting the maximum length followed by 30 Gy and minimum value was exhibited by 120 Gy as presented in (Fig 4). The individual effect of species was found significant with Crowfoot grass showing maximum length and Bermuda grass exhibiting minimum length. While the combine effect has no notable significance at 6,12 and 18 WAP, but at 20 WAP longest stolon was realized in Crowfoot grass (control), small stolon was in Bermuda grass at 120 Gy.

Stolon internodal diameter

The individual effect of species was found significant for internodal diameter with Crowfoot grass indicating maximum and Bermuda grass indicating the minimum

internodal diameter, however the significance observed when analyzed combine effect where Crowfoot (control) shows a wide stolon and Bermuda grass at 120 Gy has thin stolon. Maximum internodal diameter was reported with 00 Gy which was followed by 30 Gy and minimum diameter was reported with 120 Gy, clearly seen in (Fig 4).

SPAD

SPAD value significantly decreased with higher gamma irradiation doses. Maximum value was presented by 30 Gy at 6 weeks but at later stages of growth 00 Gy was recorded with maximum value. Whereas, minimum value was presented with 120 Gy. Interaction shows the similar trend of decrease in SPAD value with increased dose with Crowfoot had maximum chlorophyll content in control treatment. While, Mexican at 120 Gy appeared rather less green (Fig 5).

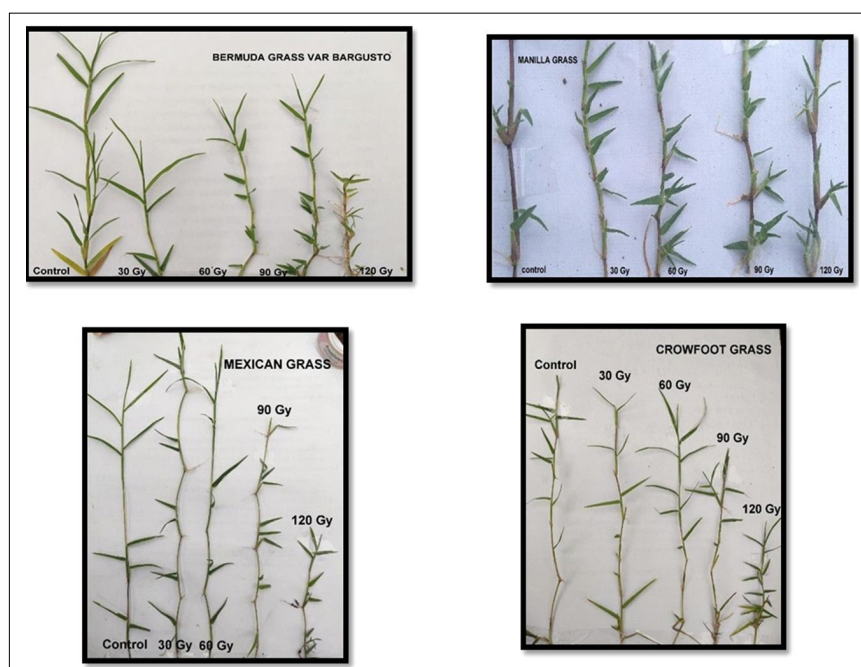


Fig 4: Effect of gamma irradiation on stolons of Bermuda grass var Bargusto, Manilla grass, Crowfoot grass, mexican grasses.

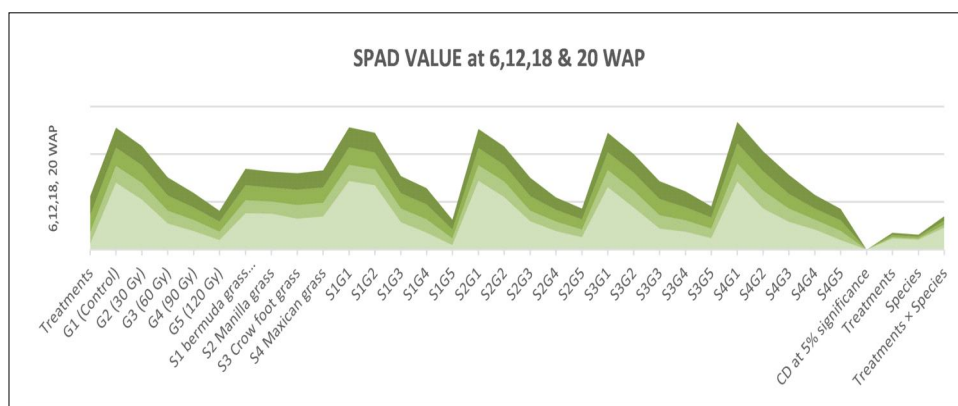


Fig 5: Effect of gamma irradiation on SPAD values of Bermuda grass var Bargusto, Manilla grass, Crowfoots grass, Mexican grasses.

Number of stolons

Treatment of Gamma irradiation significantly affected the respective but combine effect was non-significantly influenced. Maximum number of stolons was observed in Manilla grass and minimum was observed with Bermuda grass var Burgasto for 12 weeks after planting and Crowfoot grass showing minimum value for 18 and 20 WAP. For gamma irradiation the maximum number of stolons was observed in 00 Gy followed by 30 Gy for 12 WAP although 30 Gy was leading in later stages of growth. However minimum value was observed with 120 Gy.

Leaf blade width

The leaf blade width decreased with increase in gamma irradiation where minimum value was observed with 120 Gy though maximum value was obtained with 00 Gy following by 30 Gy. Significant difference was observed with species where Crowfoot grass was recorded with widest leaves and Manilla grass was found with narrowest leaves. The difference between leaf blade width of various genotypes was non-significant (Fig 6).

Leaf blade length

The smallest leaf blade length as mentioned in Table 2, was observed by higher dose of gamma radiation viz. 120 Gy while the largest leaf blade was observed with 00 Gy followed by 30 Gy. The individual effect of species was found significant with Mexican grass was recorded with highest value followed by Crowfoot grass and lowest value was recorded with Manilla grass. The leaf blade width and length when analyzed at interaction of two factors showed non-notable effect at earlier stages. The difference in visual quality can be noted with (Fig 6).

Canopy height

Among the observed species, Mexican grass showed the highest canopy height, while Manilla grass exhibited the lowest canopy height. The control having the tallest recorded canopy followed by 30 Gy on the other hand, the irradiation dose with the lowest observed canopy height was 120 Gy. Non-significant variation observed among interaction (Table 2).

The variation observed in cell elongation and abnormalities in cell wall development seem to be closely

related with the disparity in morphology of treatment with increasing dose of gamma irradiation (Reynolds *et al.*, 2009). Where gamma rays are known to cause DNA damage, disrupting normal cell division and elongation. As a result, they alter important metabolic processes, which together affect plant morphology and growth patterns leading to compact growth habit and deviation from control treatment (Borrill *et al.*, 2022; Zhang *et al.*, 2020 ; Hong *et al.*, 2002; Li *et al.*, 2010; Takahashi *et al.*, 1995 and Reiter *et al.*, 1993). According to Kiani *et al.* (2022), chromosomal abnormalities/ alteration brought on by radiation exposure also impede growth and development. The leaf morphology of the various turf grass species under study varied noticeably may be the attributed to negative impact of radiation to vegetative propagules where higher doses hinder normal leaf development (Burton, 1985). In addition to structural changes, gamma irradiation can affect hormonal pathways. Irradiation can interfere with perception of gibberellin and brassinosteroid biosynthesis (Graeff *et al.*, 2020), which can further disrupt growth-promoting signals, leading to stunted growth and reduced stem elongation, contributing to a dwarf phenotype. (Miao *et al.*, 2024; Castorina and Consonni, 2020; Cakir *et al.*, 2017; Azahar *et al.*, 2019 ; Ross *et al.*, 1997 and Noguchi *et al.*, 1999).

The altered SPAD values reflects the impact of gamma irradiation on photosynthetic efficiency of the treated plants. While the Environmental stressors such as intense light, nutrient deficiencies and limited water availability further affected the plants' photosynthetic efficiency, indicating changes in chlorophyll content (Talebzadeh and Valeo, 2022; Janakiram *et al.*, 2015 and Ross *et al.*, 1997). Interestingly, patterns of shoot regeneration were also changed under radiation exposure. Suggesting increased assimilate allocation toward stolon development. Which, could account for the increased number of stolons seen across treatments (Cakir *et al.*, 2017 and Azahar *et al.*, 2019).

Overall, each turfgrass species' genetic background played a significant role in determining its response to gamma irradiation. This genetic diversity affects each species' ability to adapt to stress in addition to its growth and morphology. These discoveries may play a key role in the future breeding of turf grass cultivars that are more

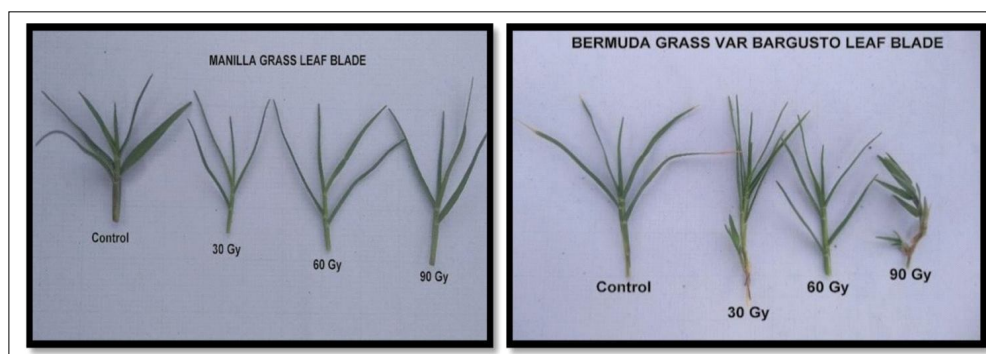


Fig 6: Effect of gamma irradiation on stolons of Bermuda grass var Burgusto, Manilla grass, Crowfoot grass, Mexican grasses.

Table 2: Effect of gamma irradiation on SPAD value, leaf blade length (cm), leaf blade width (mm), number of stolon, canopy height(cm).

Treatments	No. of stolon			Leaf blade width			Leaf blade length			C.H	
	12	18	20	12	18	20	12	18	20	20	20
Gamma Irradiation											
G ₁ (Control)	5.09	5.38	5.38	2.25	2.46	2.56	2.33	2.70	2.81	37.06	
G ₂ (30 Gy)	4.97	5.60	5.41	2.13	2.28	2.31	2.23	2.63	2.70	30.87	
G ₃ (60 Gy)	4.79	5.11	5.20	1.79	2.18	2.21	1.94	2.25	2.22	30.17	
G ₄ (90 Gy)	4.49	4.93	5.09	1.61	1.92	1.97	1.68	2.02	2.05	32.53	
G ₅ (120 Gy)	4.08	4.48	4.93	1.02	1.16	1.28	1.12	1.33	1.61	22.24	
Species											
S ₁ Bermuda grass var Bargusto	4.21	4.78	4.95	1.64	1.88	1.94	1.57	1.65	1.73	23.76	
S ₂ Manilla grass	5.21	5.59	5.72	1.28	1.76	1.83	1.30	1.67	1.75	20.52	
S ₃ Crow foot grass	4.38	4.54	4.72	2.15	2.29	2.39	2.23	2.99	3.05	38.65	
S ₄ Maxican grass	4.94	5.27	5.42	1.97	2.07	2.11	2.32	2.43	2.59	39.37	
Interaction											
S ₁ G ₁	1.84	1.98	2.14	2.30	2.41	2.44	4.56	5.23	5.37	20.70	
S ₁ G ₂	1.82	1.94	2.11	2.14	2.15	2.17	4.51	5.11	5.22	23.32	
S ₁ G ₃	1.79	1.82	1.84	1.60	2.16	2.16	4.48	4.76	4.83	29.89	
S ₁ G ₄	1.77	1.81	1.82	1.55	1.97	2.00	4.46	4.65	4.67	29.76	
S ₁ G ₅	0.61	0.68	0.72	0.57	0.71	0.94	3.00	4.13	4.66	15.10	
S ₂ G ₁	1.78	2.11	2.33	1.81	2.18	2.19	5.70	5.90	5.91	24.03	
S ₂ G ₂	1.59	2.04	2.09	1.65	2.00	2.10	5.50	5.82	5.86	21.32	
S ₂ G ₃	1.28	2.00	2.06	1.19	1.98	2.00	5.16	5.66	5.73	20.53	
S ₂ G ₄	1.16	1.49	1.54	1.17	1.82	1.86	4.86	5.50	5.62	28.06	
S ₂ G ₅	0.66	0.71	0.73	0.58	0.78	0.96	4.82	5.01	5.43	8.47	
S ₃ G ₁	3.07	3.93	3.96	2.52	2.65	2.95	4.56	4.80	5.03	47.51	
S ₃ G ₂	2.94	3.82	3.83	2.46	2.58	2.61	4.41	4.79	4.94	39.21	
S ₃ G ₃	2.28	2.74	2.82	2.17	2.30	2.39	4.38	4.55	4.63	32.67	
S ₃ G ₄	1.69	2.64	2.72	2.12	2.29	2.33	4.33	4.46	4.52	37.81	
S ₃ G ₅	1.24	1.81	1.92	1.47	1.62	1.64	4.20	4.11	4.40	36.06	
S ₄ G ₁	2.61	2.74	2.80	2.34	2.60	2.63	5.53	5.58	5.60	55.92	
S ₄ G ₂	2.54	2.72	2.77	2.26	2.37	2.39	5.43	5.51	5.58	39.59	
S ₄ G ₃	2.39	2.42	2.45	2.16	2.26	2.31	5.11	5.66	5.52	37.77	
S ₄ G ₄	2.07	2.13	2.26	1.59	1.62	1.67	4.31	5.10	5.22	34.48	
S ₄ G ₅	1.96	2.10	2.13	1.46	1.51	1.55	4.30	4.66	4.78	29.05	
CD(P=0.05)											
Treatments	0.51	0.31	0.33	0.39	0.29	0.21	0.43	0.22	0.25	7.20	
Species	0.45	0.28	0.30	0.34	0.26	0.18	0.39	0.20	0.22	6.44	
Treatments×Species	1.02	1.63	0.67	0.79	0.62	0.45	0.87	0.44	0.50	14.41	

resilient to environmental stressors and better adapted to environments of different region.

CONCLUSION

Gamma irradiation induced favorable morphological characters changes in grass species. Low doses (30 and 60 Gy) enhanced indices such as shoot density, fine growth, shorter internodes and improved color retention, particularly in Manilla grass and Bermuda grass var Bargusto. Whereas, higher doses (90 Gy and 120 Gy) negatively influenced grass species, leading to reduced survival and mortality. Overall, gamma irradiation improved qualitative aspects in Bermuda grass var Bargusto and Manilla grass, while quantitative parameters favored Crowfoot and Mexican grass. To conclude, gamma irradiation is an effective way of inducing genetic variation in turf grass species but its effectiveness is dose dependent. Where, higher dose causes mortality and low doses ranging from 30 Gy to below 100 Gy can be effectively used. However, optimal dose of gamma rays may depend on the species and desired trait improved.

ACKNOWLEDGEMENT

The authors thankfully acknowledge the received support from all participating researchers, facilities provided by COH, Mandsaur and funding from Rajmata Vijayaraje Scindhia Krishi VishwaVidyalaya, Gwalior. We also acknowledge IARI facility for treatment of grass sprigs with gamma rays.

Conflict of interest

All authors declared that there is no conflict of interest.

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