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Study of Different Rooting Media Compositions and Germination Rate of Papaya Seedlings var. Red Sun (Dwarf) under Prayagraj Agro-climatic Conditions

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

The experiment was conducted at the research field, Department of Horticulture, Naini Agricultural Institute (NAI), Faculty of Agriculture (FoA), Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, Uttar Pradesh (India), during the kharif season in 2025. The experiment was laid out in a Completely Randomized Block Design (CRD), consisting of a total of 16 different treatment combinations, including the control, with each treatment replicated thrice. Treatment T15: Soil + FYM + Vermicompost + Cocopeat (1:1:1:1) + GA3 (200 ppm seed treatment) recorded germination (96.67%), days taken for completion of germination (13.40 days), seedling height (28.51 cm), number of leaves per seedling

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(17.46), diameter of seedling (13.93 mm), leaf area (105.77 cm^2), chlorophyll content (SPAD value: 64.16), length of the longest tap root (7.55 cm), fresh weight of shoots (18.55 g), dry weight of shoots (2.51 g), fresh weight of root (5.54 g), dry weight of root (1.31 g), shoot:root ratio (0.52), Seed Vigour Index (I) (2756.53), Seed Vigour Index (II) (369.06), survival (94.4%), and mortality (5.5%), and was significantly superior overall to the other treatments. This study provides a practical approach to papaya seed germination and the production of healthy seedlings using suitable rooting media compositions with appropriate proportions of organic amendments, such as farmyard manure (FYM), vermicompost, and cocopeat, to improve nutrient availability, aeration, and moisture retention, together with GA_3 (200 ppm seed treatment). The findings may also provide a foundation for future research on rooting media, germination, and growth regulators for papaya and other horticultural crops under diverse agro-climatic conditions.

Keywords: Papaya; red sun; rooting media; biofertilizer; germination rate.

1. Introduction

Papaya (*Carica papaya L.*) is one of the most important tropical fruit crops belonging to the family Caricaceae. It is widely cultivated in tropical and subtropical regions because of its high nutritional value, rapid growth, early-bearing habit, and year-round fruit production. Papaya fruits are rich in vitamins A and C, along with minerals, antioxidants, and the proteolytic enzyme papain, which has significant medicinal and industrial applications. India is the largest producer of papaya in the world, contributing substantially to global production. Successful papaya cultivation depends largely on the availability of healthy and vigorous seedlings, which directly influence field establishment, growth, and fruit yield. Seed propagation remains the most common method of papaya multiplication; however, papaya seeds often exhibit slow and uneven germination because of seed dormancy, inhibitory substances present in the sarcotesta, and unfavourable environmental conditions (Mishra *et al.,* 2025; Voruganti *et al.,* 2022). Growing media for use in container nurseries are available in two basic forms: soil-based and organic-based. Compared with soil-based media, in which field soil is a major component, organic-based media (based on organic materials that may include compost, peat, coconut coir, or other organic materials mixed with inorganic ingredients) promote better root development. In temperate areas, nurseries can choose from a wide range of commercial products for their growing media, including peat moss, vermiculite, perlite, and premixed blends of these ingredients. Most nurseries in the tropics, however, do not have easy and affordable access to these materials, and even nurseries in temperate areas are seeking to replace some of these ingredients with more local and sustainable materials. In the tropics, growers often create their own media using locally available ingredients (Bhardwaj, 2014). Apart from growing media, seed treatment plays a crucial role in enhancing germination and seedling vigour. Biofertilisers such as Azotobacter and Phosphate Solubilizing Bacteria (PSB) have gained importance because of their ability to improve nutrient availability and plant growth. Azotobacter fixes atmospheric nitrogen and produces growth-promoting substances such as indole acetic acid, gibberellins, and cytokinin, which stimulate seed germination and root development. PSB converts insoluble phosphorus into forms available to plants, thereby improving root growth and nutrient uptake. Seed inoculation with these beneficial microorganisms has been reported to improve germination percentage, seedling vigour, and biomass accumulation in several horticultural crops (Mishra *et al*., 2025). Gibberellic acid (GA_3) is one of the most extensively studied plant growth regulators for improving papaya seed germination. GA_3 breaks seed dormancy by stimulating the synthesis of hydrolytic enzymes such as α-amylase, which mobilise stored food reserves required for embryo growth. Numerous studies have demonstrated that pre-sowing treatment of papaya seeds with GA_3 significantly increases germination percentage, reduces germination time, enhances seed vigour index, and improves subsequent seedling growth. GA_3 concentrations ranging from 150 to 200 ppm have been found to be particularly effective when combined with nutrient-rich growing media containing cocopeat and vermicompost (Ramteke *et al*., 2015; Bishnoi *et al*., 2024; Hazarika *et al*., 2023).

Recent papaya studies indicate that nursery substrate composition and plant growth regulator treatments can influence seed germination and early seedling establishment, supporting their joint evaluation in seedling production studies (Kumawat & Topno, 2024; Krishnanayak et al., 2024).

Evidence from another tropical fruit crop also shows that germination and early growth responses differ among nursery substrates, reinforcing the importance of selecting growing media according to their performance during seedling establishment (Sarwar et al., 2024).

Seed priming has likewise been evaluated directly in papaya, with germination and early seedling growth responding to the pre-sowing treatment used (Khajjak et al., 2022). Recent papaya seed-quality research further emphasises the relevance of seed viability and vigour when interpreting germination and early seedling performance (Limão et al., 2025).

Accordingly, within the context of the present study, a direct comparison of the tested rooting-media combinations and seed treatments under Prayagraj agro-climatic conditions is needed to determine their relative effects on germination and early seedling performance of papaya var. Red Sun (Dwarf).

1.1 Objective

The objective of the present study was to evaluate the effects of different rooting media compositions and selected seed treatments, including biofertiliser inoculation and GA_3 at 200 ppm, on germination, seedling growth, vigour, survival, and mortality of papaya var. Red Sun (Dwarf) under Prayagraj agro-climatic conditions.

2. Materials and Methods

The present investigation, entitled "Study of different rooting media compositions and germination rate of Papaya seedlings var. Red Sun(Dwarf) under Prayagraj Agro-climatic conditions", was carried out at the research field, Department of Horticulture, Naini Agricultural Institute (NAI), Faculty of Agriculture (FoA), SHUATS, Prayagraj. The experiment was laid out in a Completely Randomized Block Design consisting of 16 treatments, viz., T_0 Control, T_1 Soil + FYM (1:1), T_2 Soil + Vermicompost (1:1), T_3 Soil + Cocopeat (1:1), T_4 Soil + FYM + Vermicompost (1:1:1), T_5 Soil + FYM + Cocopeat (1:1:1), T_6 Soil + Vermicompost + Cocopeat (1:1:1), T_7 Soil + FYM + Vermicompost + Cocopeat (1:1:1:1), T_8 Soil + Poultry manure + Vermicompost (1:1:1), T_9 Soil + FYM + Sand + Vermicompost (1:1:1:1), T_{10} Soil + FYM + Cocopeat + Neem Cake (1:1:1:1), T_{11} Soil + FYM + Cocopeat + Biofertilizer (Azotobacter + PSB inoculation) (1:1:1:1), T_{12} Soil + FYM + Vermicompost + Cow Dung Slurry (1:1:1:1), T_{13} Soil + FYM + Vermicompost + Cocopeat + Poultry Manure (1:1:1:1:1), T_{14} Cocopeat + Vermicompost + Perlite (2:1:1) – soilless medium, and T_{15} Soil + FYM + Vermicompost + Cocopeat (1:1:1:1) + GA3 (200 ppm seed treatment), which were replicated thrice. Prayagraj falls within a subtropical climatic zone, with distinct winter and summer seasons. The seeds of papaya var. Red Sun were purchased from a reputed seed outlet, Prayag Seeds Bhandar, near Alopi Bagh, Prayagraj, Uttar Pradesh (India). In addition, polybags measuring 4 x 5 cm with a thickness of 150 gauge were purchased from the local market in Prayagraj. Perforated polybags of 4 x 5 cm (150 gauge thickness) were used for sowing. The bags were filled with mixtures of FYM, poultry manure, cocopeat, neem cake, cow dung slurry, perlite, soilless medium, and vermicompost at ratios of 1:1, 1:1:1, 2:1:1, 1:1:1:1, and 1:1:1:1:1, as applicable. Two seeds were sown in each polybag. Regular watering with a rose can was carried out gently in the morning and evening. A pre-sowing dip method was adopted for seed treatment. Sufficient quantities of growth regulators at the required concentrations were poured into labelled beakers. The treatments included soaking the seeds of papaya var. Red Sun (Dwarf) in GA_3 at 200 ppm, Azotobacter, and PSB for 24.00 hours, along with a control. Observations were recorded for germination (%), days required for completion of germination, seedling height (cm), number of leaves per seedling, seedling diameter (mm), leaf area (cm^2), chlorophyll content measurements (SPAD value), length of the longest tap root (cm), fresh weight of shoots (g), dry weight of shoots (g), fresh weight of root (g), dry weight of root (g), shoot:root ratio, seed vigour index-I, seed vigour index-II, and survival (%). The experiment was conducted using a Completely Randomized Block Design. The significance of the study was tested at the 5% level. The recorded data were statistically analysed using the method of Panse and Sukhatme (1967).

3. Results and Discussion

The data are presented in Tables 1 and 2. The effects of different rooting media compositions were significant for germination (%), days taken for germination, seedling height (cm), number of leaves per seedling, seedling diameter (mm), leaf area (cm^2), chlorophyll content (SPAD value), length of the longest tap root (cm), fresh weight of shoots (g), dry weight of shoots (g), fresh weight of root (g), dry weight of root (g), shoot:root ratio, seed vigour index (I), seed vigour index (II), survival (%), and mortality (%). The maximum germination (96.67%) was recorded in T_{15}: Soil + FYM + Vermicompost + Cocopeat (1:1:1:1) + GA_3 (200 ppm seed treatment), which was on par with Soil + FYM + Cocopeat + Biofertilizer (Azotobacter + PSB inoculation) (1:1:1:1), whereas the minimum germination (33.33%) was recorded in T_0 (Control). Similar results were reported by Parasana *et al.* (2013), Barche *et al.* (2010), Dhinesh Babu *et al.* (2010), and Mishra *et al.* (2017). The minimum number of days taken for completion of germination (13.40) was recorded in T_{15}: Soil + FYM + Vermicompost + Cocopeat (1:1:1:1) + GA_3 (200 ppm seed treatment), whereas the maximum number of days taken for completion of germination (23.40) was recorded in T_0 (Control). Gibberellic acid acts on the embryo and causes the synthesis of hydrolysing enzymes; the hydrolysed food is utilised for embryo growth, thereby enhancing germination. Similar findings were reported by Barche *et al.* (2010), Dhinesh Babu *et al.* (2010) in papaya, and Mishra *et al.* (2017). This might be because media containing organic manures possess organic acids. Therefore, greater moisture availability and the presence of some acids may have contributed to fewer days to germination and a better germination percentage. Similar results were reported by Parasana *et al.* (2013) in mango. At 90 days after germination, the maximum seedling height was observed in T_{15}: Soil + FYM + Vermicompost + Cocopeat (1:1:1:1) + GA_3 (200 ppm seed treatment) at 28.51 cm, whereas the minimum seedling height (16.38 cm) was observed in T_0 (Control). The increased height in seeds treated with GA_3 at 200 ppm may be attributed to the possibility that the endogenous levels of GA_3 synthesised by the papaya seedlings were insufficient and that external application of GA_3 enhanced growth by increasing cell multiplication and cell elongation, resulting in better plant growth (Mishra *et al.*, 2017). A growing medium not only provides a growing environment but also serves as a source of nutrients for plant growth. At 90 days after germination, the maximum number of leaves per seedling was observed in T_{15}: Soil + FYM + Vermicompost + Cocopeat (1:1:1:1) + GA_3 (200 ppm seed treatment) at 17.46, whereas the minimum number of leaves per seedling (9.19) was observed in T_0 (Control). The increase in the number of leaves might be because GA_3 helps invigorate physiological processes in the plant and has a stimulatory effect on the formation of new leaves at a faster rate (Mishra *et al.*, 2017). A growing medium not only provides a growing environment but also serves as a source of nutrients for plant growth. The media composition used influences seedling quality (Wilson *et al.*, 2001). Humic acids (vermicompost) applied in the medium increased plant height, leaf area, and dry weight of peppers, tomatoes, and marigolds (Arancon *et al.*, 2003). At 90 days after germination, the maximum seedling diameter was observed in T_{15}: Soil + FYM + Vermicompost + Cocopeat (1:1:1:1) + GA_3 (200 ppm seed treatment) at 13.93 mm, whereas the minimum seedling diameter (4.54 mm) was observed in T_0 (Control). Similar results were also recorded by Barche *et al.* (2010), Mishra *et al.* (2017), Bhardwaj (2014), and Bishnoi *et al.* (2024). At 90 days after germination, the maximum leaf area was observed in T_{15}: Soil + FYM + Vermicompost + Cocopeat (1:1:1:1) + GA_3 (200 ppm seed treatment) at 105.77 cm2, whereas the minimum leaf area (51.15 cm2) was observed in T_0 (Control). The increase in the number of leaves might be because GA_3 helps invigorate physiological processes in the plant and has a stimulatory effect on the formation of new leaves at a faster rate (Mishra *et al.*, 2017). A growing medium not only provides a growing environment but also serves as a source of nutrients for plant growth. The media composition used influences seedling quality (Wilson *et al.*, 2001). The maximum chlorophyll content (SPAD value) (64.16) was recorded in T_{15}: Soil + FYM + Vermicompost + Cocopeat (1:1:1:1) + GA_3 (200 ppm seed treatment), whereas the minimum chlorophyll content (SPAD value) (39.41) was recorded in T_0 (Control). This may be due to the mobilisation of water and nutrients at a higher rate, which might have promoted greater production of photosynthetic products and their translocation to

Table 1. Effect of different rooting media compositions on germination and seedling growth of papaya seedlings var. red sun (dwarf) under prayagraj agro-climatic conditions

Treatments No.	Germination (%)	Days taken for germination	Seedling height (cm)	Number of leaves per seedling	Diameter of seedling (mm)	Leaf area (cm^2)	Chlorophyll content (SPAD Value)	Length of longest tap root (cm)	Fresh weight of shoots(g)	Dry weight of shoots(g)
T_0	33.33	23.40	16.38	9.19	4.54	51.15	39.41	3.48	8.36	0.81
T_1	53.33	21.47	20.17	13.35	7.69	78.01	44.43	5.63	10.20	1.14
T_2	56.67	20.99	20.52	13.60	8.07	80.85	46.11	5.75	10.84	1.23
T_3	56.67	21.56	19.66	13.07	7.14	76.65	42.23	5.39	10.06	1.02
T_4	53.33	19.46	22.61	15.23	8.62	85.78	47.38	6.12	12.34	1.37
T_5	56.67	20.33	21.59	15.02	8.11	82.94	45.63	5.83	12.08	1.32
T_6	56.67	18.43	25.20	15.11	9.37	87.41	48.54	6.24	12.51	1.44
T_7	56.67	16.91	26.14	15.84	12.07	92.18	53.75	6.72	13.80	1.78
T_8	53.33	16.33	26.36	15.92	12.24	94.15	56.03	6.83	14.14	1.91
T_9	63.33	17.10	24.86	15.74	10.54	91.19	51.35	6.59	13.10	1.66
T_{10}	66.67	17.24	24.52	15.63	10.34	89.17	50.52	6.44	12.86	1.53
T_{11}	83.33	13.70	28.40	17.07	13.72	102.74	61.54	7.44	18.29	2.27
T_{12}	63.33	14.30	27.58	16.09	12.52	97.07	57.38	7.11	15.81	2.02
T_{13}	73.33	13.91	28.28	16.58	13.55	101.30	60.52	7.34	17.55	2.19
T_{14}	66.67	14.05	28.09	16.26	12.90	97.76	59.08	7.25	17.05	2.10
T_{15}	96.67	13.40	28.51	17.46	13.93	105.77	64.16	7.55	18.55	2.51
F-Test	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
C.D.	**13.427**	**0.240**	**0.745**	**0.146**	**0.219**	**1.106**	**0.974**	**0.082**	**0.190**	**0.051**
SE(m)	**4.640**	**0.083**	**0.257**	**0.050**	**0.076**	**0.382**	**0.337**	**0.028**	**0.066**	**0.018**
SE(d)	**6.562**	**0.117**	**0.364**	**0.071**	**0.107**	**0.541**	**0.476**	**0.040**	**0.093**	**0.025**
C.V.	**12.988**	**0.811**	**1.834**	**0.579**	**1.270**	**0.749**	**1.126**	**0.776**	**0.837**	**1.874**

Table 2. Effect of different rooting media compositions on germination and seedling growth of Papaya seedlings var. Red Sun (Dwarf) under Prayagraj Agro-climatic conditions

Treatments No.	Fresh weight of root (g)	Dry weight of root (g)	Shoot:Root ratio	Seed vigour index (I)	Seed vigour index (II)	Survival (%)	Mortality (%)
T_0	1.04	0.20	0.247	545.567	33.700	31.111	68.889
T_1	1.24	0.33	0.289	1075.667	78.633	55.556	44.444
T_2	2.28	0.37	0.304	1162.833	90.467	57.778	42.222
T_3	1.17	0.27	0.265	1114.067	73.367	53.333	46.667
T_4	2.53	0.50	0.362	1205.767	99.733	61.111	38.889
T_5	2.42	0.41	0.314	1223.900	98.000	56.667	43.333
T_6	2.72	0.55	0.382	1431.160	112.433	64.444	35.556
T_7	3.91	0.75	0.421	1481.367	143.267	74.444	25.556
T_8	4.05	0.84	0.438	1406.167	146.467	75.556	24.444
T_9	3.51	0.65	0.393	1574.333	146.100	70.000	30.000
T_{10}	2.86	0.61	0.400	1633.967	143.000	66.667	33.333
T_{11}	5.03	1.20	0.530	2366.433	289.533	86.667	13.333
T_{12}	4.23	0.96	0.475	1747.933	188.800	76.667	23.333
T_{13}	4.58	1.12	0.512	2074.200	243.233	80.000	20.000
T_{14}	4.38	1.02	0.485	1872.600	208.267	75.556	24.444
T_{15}	5.54	1.31	0.522	2756.533	369.067	94.444	5.556
F-Test	**S**	**S**	**S**	**S**	**S**	**S**	**S**
C.D.	**0.082**	**0.042**	**0.032**	**331.559**	**29.590**	**7.998**	**7.998**
SE(m)	**0.028**	**0.015**	**0.011**	**114.577**	**10.226**	**2.764**	**2.764**
SE(d)	**0.040**	**0.021**	**0.015**	**162.036**	**14.461**	**3.909**	**3.909**
C.V.	**1.522**	**3.663**	**4.779**	**12.870**	**11.500**	**7.092**	**14.730**

various plant parts, resulting in better seedling growth and, consequently, greater fresh and dry weight. These findings are in agreement with the results obtained by Ramteke *et al.* (2016) in papaya. The different levels of GA3 did not significantly affect chlorophyll content. The maximum length of the longest tap root (7.55 cm) was recorded in $T_{15:}$ Soil + FYM + Vermicompost + Cocopeat (1:1:1:1) + GA_3 (200 ppm seed treatment), whereas the minimum length of the longest tap root (3.48 cm) was recorded in T_0 (Control). This might be because GA_3 increases somatic uptake of nutrients, causing cell elongation and thus increasing the length of the tap root and the number of secondary roots (Mishra *et al.*, 2017). The maximum fresh and dry weights of shoots (18.55 and 2.51 g, respectively) were recorded in $T_{15:}$ Soil + FYM + Vermicompost + Cocopeat (1:1:1:1) + GA_3 (200 ppm seed treatment), which was on par with Soil + FYM + Cocopeat + Biofertilizer (Azotobacter + PSB inoculation) (1:1:1:1). The minimum fresh and dry weights of shoots (8.36 and 0.81 g, respectively) were recorded in T_0 (Control). The findings of the present study are in agreement with those of Ramteke *et al.* (2015), Choudhary ***et** al.* (2018), Choudhary *et al.* (2022), Hossain *et al.* (2023), and Bishnoi *et al.* (2024). The maximum fresh and dry weights of root (5.54 and 1.31 g, respectively) were recorded in $T_{15:}$ Soil + FYM + Vermicompost + Cocopeat (1:1:1:1) + GA_3 (200 ppm seed treatment), whereas the minimum fresh and dry weights of root (1.04 and 0.20 g, respectively) were recorded in T_0 (Control). The present findings are in close agreement with the observations of Ramteke *et al.* (2015), Hossain *et al.* (2023), and Choudhary *et al.* (2022). The maximum shoot:root ratio (0.530) was recorded in $T_{11:}$ Soil + FYM + Cocopeat + Biofertilizer (Azotobacter + PSB inoculation) (1:1:1:1), whereas the minimum shoot:root ratio (0.247) was recorded in T_0 (Control). These findings are in close agreement with those of Bhardwaj (2014) and Ramteke *et al.* (2015). The maximum seed vigour indices I and II (2756.533 and 369.067, respectively) were recorded in $T_{15:}$ Soil + FYM + Vermicompost + Cocopeat (1:1:1:1) + GA_3 (200 ppm seed treatment), whereas the minimum seed vigour indices I and II (545.567 and 33.700, respectively) were recorded in T_0 (Control). Seed vigour indices were interpreted with reference to Abdul-Baki and Anderson (1973), and the findings agree with Bhardwaj (2014), Ramteke *et al.* (2015), Mishra *et al.* (2017), and Bishnoi *et al.* (2024). The maximum survival (94.444%) and minimum mortality (5.556%) were recorded in $T_{15:}$ Soil + FYM + Vermicompost + Cocopeat (1:1:1:1) + GA_3 (200 ppm seed treatment), whereas the minimum survival (31.111%) and maximum mortality (68.889%) were recorded in T_0 (Control). This might be due to GA_3, which may weaken the seed coat so that the emergence of the radicle and plumule positively influences root and shoot initiation. Besides this, GA_3 also helps in cell expansion and elongation, resulting in better root and shoot growth, which supports and encourages better seedling survival (Ramteke *et al.,* 2015; Deb *et al.,* 2010; Choudhary *et al.,* 2018; Choudhary *et al.,* 2022; Hazarika *et al.,* 2023).

4. Conclusion

The present study showed that rooting-media composition combined with seed treatment influenced the germination and early seedling performance of papaya var. Red Sun (Dwarf) under Prayagraj agro-climatic conditions. Among the 16 treatments, T15, consisting of soil + FYM + vermicompost + cocopeat (1:1:1:1) with GA_3 at 200 ppm, performed best for most of the measured traits. It recorded the highest germination (96.67%), seedling height (28.51 cm), number of leaves per seedling (17.46), seedling diameter (13.93 mm), leaf area (105.77 cm^2), chlorophyll content (64.16 SPAD value), shoot and root biomass, Seed Vigour Index I (2756.53), Seed Vigour Index II (369.06), and survival (94.44%), while requiring 13.40 days for completion of germination and recording 5.56% mortality. The control showed the lowest performance for most measured parameters. Within the conditions of this experiment, the combination used in T15 may therefore be considered suitable for raising vigorous papaya seedlings. The findings are specific to the tested cultivar, treatment combinations, and Prayagraj agro-climatic conditions.

5. Limitations

The study on rooting media compositions and the germination rate of papaya var. Red Sun was constrained by the agro-climatic conditions of Prayagraj, where intense summer heat exceeding 40 degrees Celsius and low winter temperatures may affect uniform germination and normal growth. In addition, erratic monsoon rainfall creates a risk of waterlogging. This evaluation was limited to a single location over a short time frame. Therefore, the findings may not be directly applicable to other agro-climatic regions and conditions.

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Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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