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Research article

Influence of harvesting seasons on germination requirements and seed vigour of *Lasiurus sindicus* (Henr.)

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Abstract

Successful seed-based vegetation restoration and conservation efforts in arid sandy desert ecosystems rely heavily on the quality of seeds sourced from native plant species. This study examines how seasonal variation influences seed germination, dormancy, and ecological strategies in *Lasiurus sindicus*, an important desert-adapted grass. Findings indicate that seeds collected during the summer (new) possess greater seed mass, germination synchrony, and germination percentage compared to winter-collected seeds (old), which exhibited higher levels of dormancy. Physical structures, such as spikelets encasing the caryopsis (dispersal unit), were found to impede germination, while the removal of these structures (naked seeds) significantly enhanced germination rates. *L. sindicus* exhibited a neutral photoblastic response, though light sensitivity for germination was more pronounced at moderate temperatures. Overall, these results highlight the adaptive strategies employed by *L. sindicus* to regulate germination timing and improve seedling establishment under desert conditions. The study provides valuable insights for rangeland restoration and management, underscoring the need to understand seed dormancy mechanisms and germination behaviour to enhance ecological rehabilitation in arid ecosystems.

Keywords: Forage, Germination, Grass, Harvesting seasons, *Lasiurus sindicus*, Rangeland, Sustainable

Introduction

The Thar Desert is characterized by an extreme arid climate, where summer temperatures may soar up to 50°C and winter temperatures can fall to nearly 4°C (Climate and Weather in Thar Desert, 2020). Annual rainfall is notably low, ranging between 100 and 500 mm, resulting in severe water scarcity. Such harsh environmental conditions impose intense selective pressure, enabling only highly adapted plant species to survive and reproduce (Peacock *et al.*, 2003). Among the vegetation in these rangelands, perennial grasses play a pivotal role as a dependable source of fodder due to their resilience, palatability, and nutritional quality (Mansoor *et al.*, 2002). Remarkably, these grasses can initiate rapid growth within days of rainfall, even during peak summer heat. Seeds of dominant perennial grasses in arid ecosystems not only contribute to enhanced rangeland productivity but also support long-term ecological sustainability (Erfanzadeh *et al.*, 2025).

The environmental factors experienced by mother plants during seed development and maturation are known to influence seed germination behaviour and dormancy characteristics (Donohue *et al.*, 2008; Gorecki *et al.*, 2012). Photoperiod, in particular, has been identified as a key factor affecting germination responses (El-Keblawy & Al-Rawai, 2006). Consequently, seeds from the same species but produced in different seasons may exhibit significant variation in dormancy and germination traits (El-Keblawy *et al.*, 2009). Studies have also demonstrated that temperature regimes and moisture availability during seed development can impact dormancy strength, with seeds formed under lower water supply generally exhibiting reduced dormancy (Meyer and Allen, 1999; Luzuriaga *et al.*, 2006).

Lasiurus sindicus (Henrard) is a perennial, drought-hardy, and nutritionally rich grass species (Chowdhury *et al.*, 2009). It is extensively distributed across the sandy deserts of northwestern India (Thar Desert), as well as parts of the

Middle East and Africa, including Mali, Niger, Ethiopia, and Egypt (Goswami *et al.*, 2020). In dominating desert dunes, this species is valued for its immense potential in fodder production and ecological restoration (Mansoor *et al.*, 2002). Due to its high palatability and nutritional value, this grass serves as a valuable resource for livestock (Rani *et al.*, 2022). At maturity, it yields approximately 2.5 to 3.5 t ha⁻¹ of dry forage, containing around 93% dry matter, 4.6% crude protein, 31% crude fibre, and 4.5% ash. The carrying capacity of *L. sindicus*-based grazing lands ranges from 0.8 to 1.2 animal units per hectare under normal rainfall conditions (Ghosh *et al.*, 2022). Its ability to sustain forage production even when annual rainfall drops below 250 mm has earned it the reputation of being the "king of desert grasses."

This species demonstrates considerable promise for improving rangeland productivity through restoration and rehabilitation of severely degraded desert ecosystem where rangelands are important fodder resources and play a crucial role in ecological balance and biodiversity maintenance (Rani and Sanyal, 2024). Although *L. sindicus* can bloom throughout the year depending on moisture availability, seed formation primarily occurs during two favourable temperature windows: July to November and February to April (Rani and Sanyal, 2025). Understanding how seeds produced in different seasons differ in dormancy and germination behaviour is crucial for predicting seed performance, managing dormancy levels in the field, and ensuring successful use in rangeland development initiatives (Silva and Maciel, 2025). Such insights can further aid in selective breeding for reduced dormancy and inform improved seed storage practices.

We hypothesize that the environmental conditions prevailing during seed development, particularly temperature, salinity, and water availability, shape the dormancy and germination patterns of *L. sindicus*, thereby influencing its ecological resilience and persistence in both aerial and soil seed banks. Accordingly, the primary objective of this study is to examine how seasonal fluctuations in these factors affect seed dormancy and germination traits, with the ultimate aim of supporting strategies for sustainable *L. sindicus*–based rangeland rehabilitation and soil stabilization in arid desert ecosystems.

Materials and Methods

Seed collection and storage: *L. sindicus* blooms twice in a year, from July to November and from February to April. On the basis of seed maturity time, November-matured seeds were referred to as summer seed (Old), while seeds maturing in April were referred to as winter seed (New) in this study. Matured spikes were harvested from the plants growing in the grass nursery block at ICAR-Central Arid Zone Research Institute (ICAR-CAZRI), Jodhpur, in November (summer) and April (winter) during 2020-2022 (referred to as old and new seed, respectively). The seeds collected in November were stored for six months at room temperature (±25°C). In contrast, seeds collected in April were used immediately for experiments. The weather parameters, viz. atmospheric temperature, rainfall and relative humidity, were collected from the Agrometeorological station ICAR-CAZRI throughout the experimental period (Fig 1).

Seed viability: Seed viability was evaluated using the tetrazolium test, with four replicates of 25 pure seeds per harvest date. The seeds were laterally cut and placed in 9 cm diameter petri dishes containing 10 mL of 0.1% 2,3,5-triphenyl tetrazolium chloride solution to ensure proper contact with the reagent. The Petri dishes were then incubated at 30°C for 16 hours, following seed testing (ISTA, 2015) guidelines. After incubation, seeds were washed with distilled water and examined under a binocular stereo microscope. Seeds were considered viable when the embryo exhibited a red or purple coloration. Seed viability was calculated as the percentage of living seeds relative to the total number of pure seeds.

Seed germination assessment: The germination tests were conducted in double-chamber seed germinators set at different temperatures of 15, 20, 25, 30 and 35°C. A dark condition was achieved by wrapping the Petri dishes with two layers of aluminium foil. The germination was conducted in 9 cm tight-fitting Petri dishes containing one disk of Whatman No. 1 filter paper, moistened with 10 mL of distilled water. Four replicates of 25 seeds each were used for each treatment. For 28 days, the number of germinated seeds was counted. The experiment was stopped after 28 days because no new germination occurred for a consecutive five-day period. Seeds incubated in the dark were checked only once after 28 days. Therefore, they were not exposed to

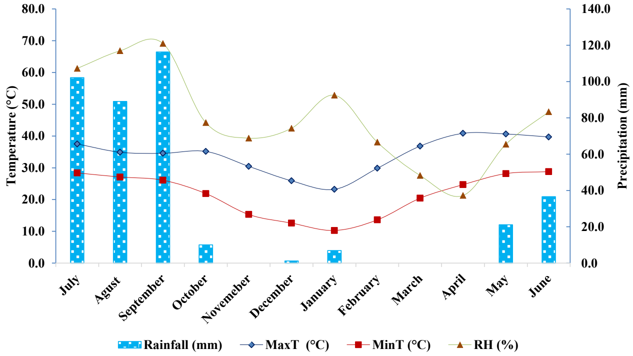

Fig 1. Mean Minimum (red) and maximum (blue) air temperature, mean relative humidity (green), and mean monthly rainfall (solid columns) recorded during growing seasons (2020-2022)

any light during the incubation period. The seedling vigour measurement was performed after the completion of the germination test by randomly selecting ten seedlings from each treatment. The dormant seeds (freshly ungerminated seed) were tested for viability for confirmation (Tetrazolium test).

Data analysis: These data were processed by MS Excel version 2016 to determine the seed mass, germinability, mean germination time (t), germination rate index (GRI), and seed Vigour (ISTA 2015). Relative light germination (RLG) expresses the light requirement for seed germination and was calculated according to Milberg *et al.* (2000) by dividing the germination percentage recorded in the light by the sum of the germination percentages observed in light and in darkness. The values varied from 0 (germination only in dark conditions) to 1 (germination only in light).

Results and Discussion

***Seed mass*:** The average seed mass of winter-harvested seeds (new) was higher (240.4 ± 21.74 mg) compared to old (summer-harvested) seeds (140.4 ± 3.74 mg; Fig 2). Seeds matured during different seasons have been reported to be responsible for variations in seed mass due to variations in the maternal environment. Seed germination, survival, and poor performance of lighter seeds have been related to their lower endosperm content (Harper, 1977).

***Seed viability*:** Seed viability was evaluated using the tetrazolium test. Harvesting season had a pronounced effect on the proportion of viable seeds within the seed lot. Seeds harvested in April (new seeds) exhibited 100% viability, as indicated by their intense staining during the incubation period. In contrast, seeds collected in November showed a reduction in viability of up to 30%. Seed bank dynamics also play a crucial role in the adaptation of desert plants (Sanyal and Rani, 2026). Soil seed banks help maintain seed viability and facilitate germination across varying environmental conditions. In species such as *Haloxylon iraqensis*, aerial seed banks replenish soil seed reserves during the spring season, ensuring a continuous supply of viable seeds. This complementary strategy is vital for persistence in arid ecosystems characterized by erratic and limited rainfall (Colville, 2017).

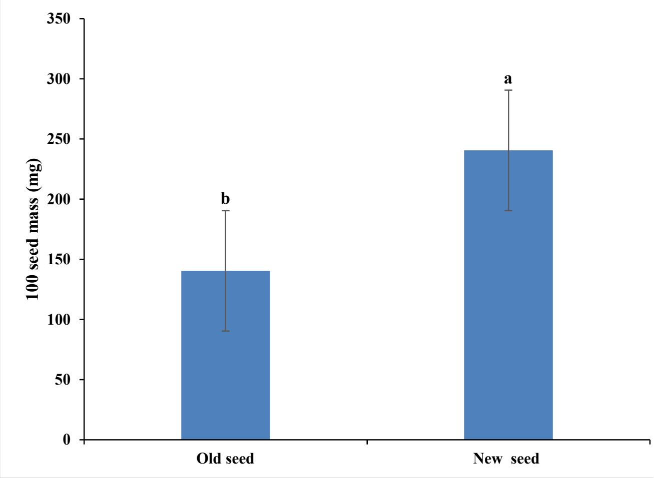

Fig 2. Seed mass (mean ± SE, mg (100 seeds)$^{-1}$ of *L. sindicus* harvested in winter and summer seasons. The values represent the mean (± SE) of eight replicates of 100 seeds each

***Seed structure*:** The germination performance of naked seeds (caryopsis) and the dispersal unit (spikelet enclosing the caryopsis) was evaluated under a range of temperature regimes (15, 20, 25, 30, and 35°C) in the presence of light (Fig 3a, c and e). Regardless of the collection period, naked seeds consistently exhibited higher germination percentages and superior germination traits compared to their dispersal units across all temperatures (Fig 3b, d and f). At 25°C, the germination percentage of naked seeds approached 100%, whereas the dispersal units showed only 53% germination. Mean germination time

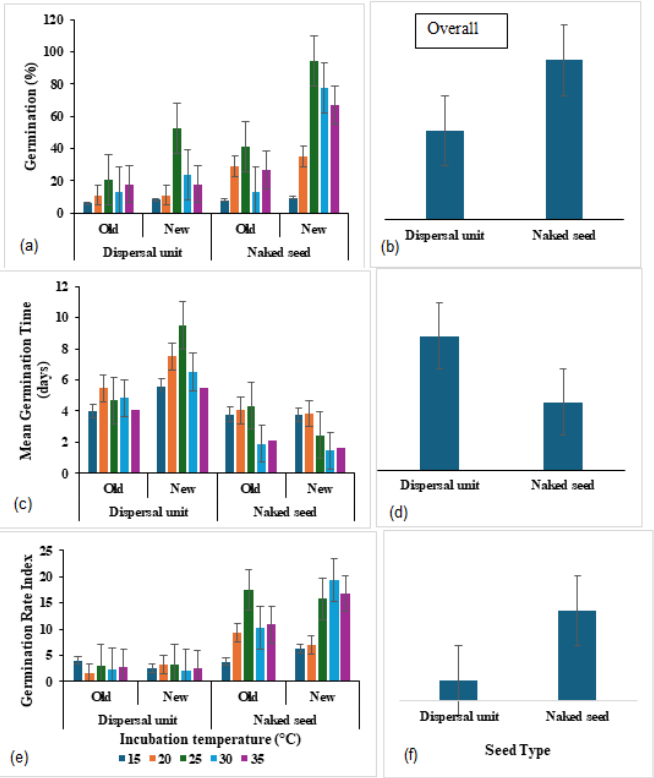

Fig 3. Effect of harvesting time and seed structure (seed type) on seed germination (a and b), mean germination time (c and d), and germination rate index (e and f) of *L. sindicus*. All values denote the mean (± SE) of four replicates

(MGT) showed a reverse trend with harvesting season, with seeds collected later exhibiting a longer MGT. The dispersal units required more time to germinate (5.76 days) compared to naked seeds, which germinated more rapidly and achieved 50% germination in just 2.92 days. Similarly, the germination rate index (GRI) was significantly higher for naked seeds (11.7) compared to dispersal units (2.7). Physical structures associated with the dispersal unit, such as winged perianths, florets, and other appendages, play an important role in regulating germination. In many arid species, these structures act as mechanical barriers that delay radicle emergence. Their removal markedly enhances germination, indicating that these features function as adaptive mechanisms that synchronize germination with favourable environmental conditions (El-Keblawy *et al.*, 2013). Comparable physical barriers in *Prosopis juliflora* seeds restrict water uptake, resulting in staggered germination and contributing to long-term population persistence (Miranda *et al.*, 2011).

***Germination*:** The effects of harvesting season ($p < 0.001$), temperature ($p < 0.001$), and light ($p < 0.001$) on germination traits in *L. sindicus* were found to be highly significant (Table 1). Seeds harvested in winter (new seeds) exhibited a higher germination percentage across all tested temperatures and light conditions compared to summer-harvested seeds (old seeds) (Fig 4). The maximum germination percentage for winter-harvested seeds was recorded at 25°C (82%), which was significantly higher than at other temperatures evaluated. Furthermore, germination under light conditions was markedly higher (>95%) than in darkness (69%) for winter-harvested seeds (Table 2). A similar trend was observed in summer-harvested seeds, although their overall germination percentage was considerably lower. The highest germination in these seeds was also achieved at 25°C (40%), and germination under light (41%) was slightly higher than in the dark (38%). Temperature requirements for germination differ among grass species. Warm-season grasses such as *Cenchrus virgata* require higher temperatures, whereas species like *C. ciliaris* perform better under moderate conditions. Such species-specific thermal responses enable plants to synchronize germination with seasonal rainfall patterns, ensuring successful seedling establishment during favourable periods (Jones, 1985). This temperature sensitivity reflects finely tuned ecological strategies that allow plants to persist under extreme desert environments (Mande *et al.*, 2025).

Winter-harvested seeds exhibited a higher cumulative germination percentage than summer-harvested seeds across all treatments (Fig 5). Germination in summer-harvested seeds continued for up to 10 days, whereas winter-harvested seeds completed germination within 6-8 days. Mean germination time (MGT), the period required for 50% of seeds to germinate, was significantly influenced by harvesting season ($p < 0.001$) and incubation temperature ($p < 0.001$). Summer-harvested seeds required less time to germinate at higher temperatures, while longer germination times were observed under lower and moderate temperature regimes (Fig. 3e). Although both seed lots exhibited a higher MGT at lower temperatures, winter-harvested seeds consistently germinated faster across all temperatures, with the shortest MGT recorded at 30°C. Similarly, the germination rate index (GRI) was significantly affected by harvesting season ($p < 0.001$) and incubation temperature ($p < 0.001$) in *L. sindicus*. Winter-harvested seeds showed markedly higher GRI values across temperature regimes compared to summer-harvested seeds, with the maximum mean GRI recorded at 25°C (16.3 ± 0.79). Pronounced differences were observed at 30°C, where GRI values reached 19.4 ± 0.79 for winter-harvested seeds compared to 10.8 ± 0.54 for summer-harvested seeds.

Seasonal environmental conditions during seed maturation strongly influence germination behaviour (Sanyal and Rani, 2026). Warmer temperatures enhance germination potential by inducing α-amylase and hydrolytic enzyme production, which facilitates reserve mobilization and accelerates seedling growth (Drew and Brocklehurst, 1990). In contrast, seeds maturing under cooler conditions germinate more slowly due

Table 1. Three-way ANOVA (F-values) showing interaction of environmental conditions with germination parameters

Parameters	Season (S)	Light (L)	Temperature (T)	S ×L × T	S × L	S × T	T × L
Seed mass	20.545**	-	-	-	-	-	-
G %	213.509**	46.676**	118.863**	9.935**	50.318**	30.133**	5.679*
FUS	18.473**	5.793	105.314*	30.536**	0.739	15.425**	62.006**
MGT	35.437**	-	46.783**	-	-	14.502**	-
GRI	13.799**	-	36.704**	-	-	9.75**	-
RLG	8.274*		40.32**				
VI	217.392**	0.386	73.986**	2.811*	13.942*	30.134**	1.351

*($p < 0.05$); **($p < 0.001$); G%: Germination; FUS: Freshly ungerminated seed; MGT: Mean germination time; GRI: Germination rate index; RLG: Relative light germination; VI: Vigour indices

Table 2. Influence of harvesting seasons, light and incubation temperature on germination in *L. sindicus*

Incubation temperature	**Winter-harvested seed (new)**		**Summer-harvested seed (old)**		
	Light	**Dark**	**Light**	**Dark**	**Overall mean**
15ºC	10 ± 0.957	14 ± 1.37	8 ± 1.633	11 ± 1.915	10.44
20ºC	36 ± 3.092	22 ± 2.021	29 ± 5.972	17 ± 3.416	25.69
25ºC	95 ± 0.866	69 ± 5.450	41 ± 4.726	38 ± 5.774	60.56
30ºC	78 ± 5.121	36 ± 0.946	13 ± 2.517	20 ± 2.828	36.50
35ºC	67 ± 2.021	39 ± 3.119	27 ± 2.517	34 ± 3.830	41.69
Overall mean	56.8	35.5	23.6	24.0	34.98
CD	9.699				
SE(m)	3.42				
SE(d)	4.837				
CV	19.558				

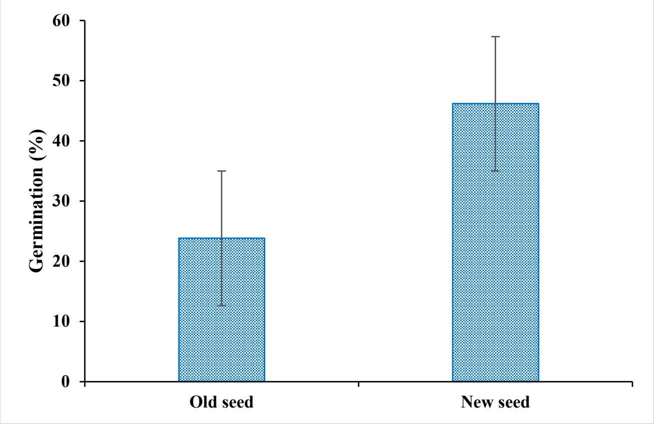

Fig 4. Overall germination percentage in *L. sindicus* seed in different harvesting seasons. The values represent the mean (± SE) of four replicates of 25 seeds each

to elevated abscisic acid (ABA) levels, which inhibit enzymatic activity (Huang *et al.*, 2014). The observed differences in germination percentage, MGT, and germination requirements between summer and winter seed lots likely represent ecological strategies that prevent simultaneous germination under unpredictable desert rainfall conditions (Gutterman, 2000). Seeds maturing in winter, when rainfall is minimal, may enter the soil seed bank, supported by their low germination synchrony, reduced GRI, and elevated MGT at lower temperatures (El-Keblawy, 2017).

***Dormancy*:** Dormancy, assessed through the percentage of freshly ungerminated seeds (FUS%), was significantly higher in summer-harvested (old) seeds than in winter-harvested (new) seeds, irrespective of light conditions (p <0.05) (Fig 6). Summer-harvested seeds exhibited clear signs of dormancy, whereas winter-harvested seeds showed little to no innate dormancy and germinated readily across all temperature regimes, as further confirmed by viability testing. Maternal environmental conditions, including temperature, photoperiod, and nutrient availability, strongly influence seed dormancy. Seeds maturing under cooler conditions often display deeper dormancy, as documented in *Cenchrus brevifolius*, where increased abscisic acid (ABA) levels during seed development contribute to reduced germination (Kendall *et al.*, 2011). Such dormancy mechanisms prevent premature germination, enabling seeds to

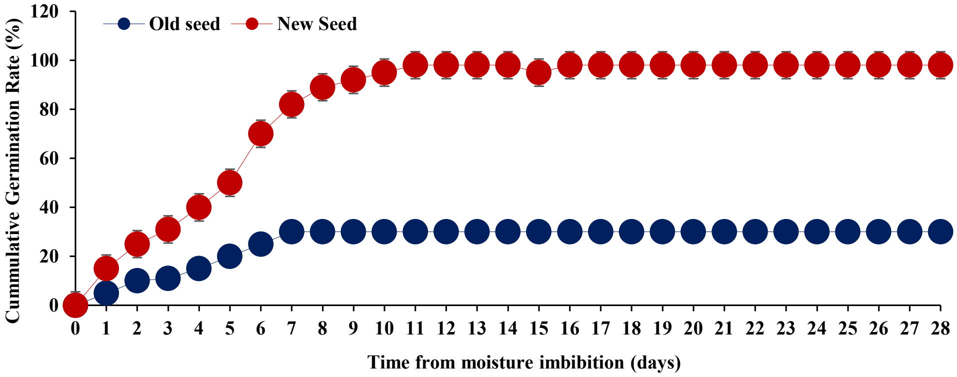

Fig 5. Effect of harvesting season on cumulative germination rate in the naked seed of *L. sindicus*

persist until favourable conditions emerge, an essential survival strategy in arid ecosystems characterized by unpredictable rainfall. Dormancy also facilitates temporal dispersal of germination, reducing competition among seedlings and enhancing the likelihood of establishment (Bewley *et al*., 2013). These findings align with El-Keblawy (2013), who reported high levels of innate dormancy in summer-produced seeds of *C. brevifolius*. The relatively higher dormancy and smaller size of summer-harvested seeds in *L. sindicus* may similarly function as ecological adaptations that allow seeds to avoid unfavourable conditions both temporally and spatially. In the desert environment, where germination opportunities are greatest during the monsoon followed by winter, such dormancy patterns enhance the probability of seedling survival and long-term species persistence.

***Vigour indices*:** Seed vigour indices (VI: G × SL) in *L. sindicus* were significantly influenced by harvesting season (p <0.001) and incubation temperature (p <0.001). Winter-harvested seeds (new seed) showed consistently higher vigour indices compared to summer-harvested seeds (old seed), irrespective of temperature and light conditions (Fig 7). Summer-harvested seeds exhibited maximum vigour at 25°C (306.7 ± 40.1) and minimum at 15°C (64.5 ± 6.3). Winter-harvested seeds displayed a similar trend, with the highest vigour index at 25°C (221.8 ± 24.1) and the lowest at 15°C (51.0 ± 13.3). Major differences in vigour were observed at higher temperatures, while differences at lower temperatures were minimal between the two seed lots. Seeds maturing in winter may therefore have a higher probability of successful seedling establishment, particularly during the onset of monsoon rains (El-Keblawy *et al*., 2017).

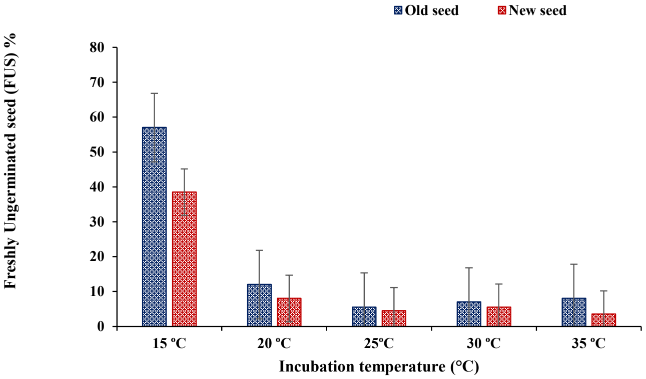

Fig 6. Influence of harvesting season on percentage of freshly ungerminated seed (FUS). The values represent the mean (± SE) of four replicates of 25 seeds each. Each value represents the mean value of the light and dark germination test

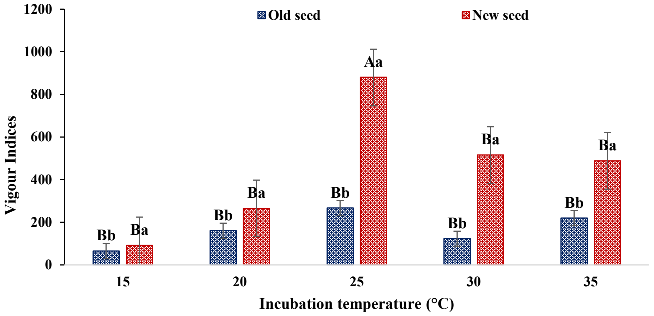

Fig 7. Effects of harvesting seasons, light and temperature on vigour indices in *L. sindicus*. The values represent the mean (± SE) of four replicates of 25 seeds each; Different capital letters denote significant differences between means for each parameter within each harvesting season; Different small letters denote significant differences for each parameter between means within each temperature (p <0.05, Newman-Keuls' test)

***Light sensitivity*:** *Lasiurus sindicus* exhibited significant sensitivity towards light for germination (p <0.001). Sensitivity to light, expressed as relative light germination (RLG), was significantly affected by harvesting season (p <0.05) and incubation temperature (p < 0.001) (Table 3). In winter-harvested seeds, RLG values were highest at moderate temperatures, peaking at 25°C (0.205 ± 0.01), and lowest at 15°C (0.021 ± 0.01). Summer-harvested seeds followed a similar pattern, with the greatest sensitivity at 25°C and reduced RLG values at both lower and higher temperatures. Photoperiod also shapes dormancy and germination responses. Longer day lengths during summer promote the development of seeds with reduced dormancy, as reported for *Aegilops ovata* and *Polypogon monspeliensis*. This highlights the complex interplay between environmental cues and seed physiology that enables plants to optimize germination timing for maximum survival (Gutterman, 2000).

Light requirements vary considerably among desert species. While some, such as *Panicum turgidum*, germinate equally well in light and darkness, others require light stimulus, a beneficial trait in sandy habitats where seed burial limits light exposure (Ye *et al*., 2019; Donohue *et al*., 2008). These adaptations enhance germination success under natural desert conditions.

Table 3. Relative light germination (RLG) in *L. sindicus* at different temperatures and harvesting seasons

Harvesting seasons	**Incubation temperature (°C)**				
	15ºC	**20ºC**	**25ºC**	**30ºC**	**35ºC**
Summer (new)	0.034 ± 0.007	0.123 ± 0.029	0.172 ± 0.017	0.054 ± 0.009	0.115 ± 0.015
Winter (old)	0.021 ± 0.015	0.076 ± 0.002	0.205 ± 0.003	0.169 ± 0.011	0.145 ± 0.006

The seasonal variation observed in seed dormancy and germination traits underscores the strong influence of the maternal environment. Seeds maturing under warmer temperatures generally possess lower dormancy and higher germination rates, as observed in *L. sindicus*, indicating its ecological resilience under changing environmental conditions.

Conclusion

This study elucidates key adaptive mechanisms that enable desert grasses, particularly *Lasiurus sindicus*, to survive and reproduce under arid climatic conditions. Maternal environmental factors, especially temperature and photoperiod, play decisive roles in regulating seed dormancy, germination timing, and physiological performance. Seeds maturing in summer were characterized by greater mass, higher synchrony, and faster germination, whereas winter-harvested seeds exhibited deeper dormancy, delaying germination until environmental conditions become favourable. Such seasonal dormancy patterns ensure that germination coincides with optimal periods of rainfall and moderate temperatures, thereby enhancing seedling establishment and long-term species persistence. The strong positive photoblastic response and broad temperature tolerance observed in *L. sindicus* suggest that this species is well adapted for germination and establishment during the early monsoon (May–July), making it a suitable candidate for rangeland rehabilitation and stabilization in loose sandy soils of arid regions.

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References

Bewley, J. D., H. W. M. Hilhorst, K. J. Bradford and H. Nonogaki. 2013. *Seeds: Physiology of Development, Germination and Dormancy*. Springer, New York.

Chowdhury, S. P., M. Schmid, A. Hartmann and A. K. Tripathi. 2009. Diversity of 16S-rRNA and nifH genes derived from rhizosphere soil and roots of an endemic drought tolerant grass, *Lasiurus sindicus*. *European Journal of Soil Biology* 45(1): 114-122.

Climate and weather in Thar desert (Average climate and weather records). 2020. https://www.timeanddate.com/weather/@1270835/climate

Colville, L. 2017. Seed storage. *Encyclopedia of Applied Plant Science* 1(1): 335-339.

Donohue, K., M. S. Heschel, C. M. Butler, D. Barua, R. A. Sharrock, G. C. Whitelam and G. C. Chiang. 2008. Diversification of phytochrome contributions to germination as a function of seed-maturation environment. *New Phytologist* 177(2): 367-379.

Drew, R. L. K. and P. A. Brocklehurst. 1990. Effects of temperature of mother-plant environment on yield and germination of seeds of lettuce (*Lactuca sativa*). *Annals of Botany* 66(1): 63-71.

El-Keblawy, A. 2013. Impacts of dormancy-regulating chemicals on innate and salinity-induced dormancy of four forage grasses native to Arabian deserts. *Grass Forage Science* 68: 288–296.

El-Keblawy, A. Ali, A. Bhatt and S. Gairola. 2013. Perianth colour affects germination behaviour in wind-pollinated *Salsola rubescens* in Arabian deserts. *Botany* 92(1): 69-75.

El-Keblawy, A. and A. Al-Rawai. 2006. Effects of seed maturation time and dry storage on light and temperature requirements during germination in invasive *Prosopis juliflora*. *Flora* 201: 135-143.

El-Keblawy, A., T. Kafhaga and T. Navarro. 2017. Live and dead shrubs and grasses have different facilitative and interfering effects on associated plants in arid Arabian deserts. *Journal of Arid Environments* 125: 127-135.

El-Keblawy, A., Y. M. Al-Sodany and F. A. Al-Hadad. 2009. Effects of time of seed maturation on dormancy and germination requirements of *Sporobolus spicatus* (Vahl) Kunth, a native desert grass of the United Arab Emirates. *Grassland Science* 55: 11-17.

El-Keblawy. A. 2017. Light and temperature requirements during germination of potential perennial grasses for rehabilitation of degraded sandy Arabian deserts. *Land Degradation and Development* 28(5): 1687-1695.

Erfanzadeh, R., T. Sabetpour, T. Amini and P. Török. 2025. Soil seed bank resilience after rangeland conversion: implications for restoring abandoned agricultural lands. *Science of The Total Environment* 997: 180209.

Ghosh, A., S. K. Mahanta, M. C. Manna, S. Singh, R. Bhattacharyya, V. C. Tyagi, J. B. Singh, S. N. Ram, R. Srinivasan, A. K. Singh and A. Gupta. 2022. Long-term grazing mediates soil organic carbon dynamics by reorienting enzyme activities and elemental stoichiometry in semi-arid tropical inceptisol. *Journal of Soil Science and Plant Nutrition* 22(2): 1422-1433.

Gorecki, M. J., R. L. Long, G. R. Flematti and J. C. Stevens. 2012. Parental environment changes the dormancy state and karrikinolide response of *Brassica tournefortii* seeds. *Annals of Botany* 109(7): 1369-1378.

Goswami, B., R. Rankawat and B. R. Gadi. 2020. Physiological and antioxidative responses associated with drought tolerance of *Lasiurus sindicus* Henr. endemic to Thar desert, India. *Brazilian Journal of Botany* 43(4): 761-773.

Gutterman, Y. 2000. Maternal effects on seeds during development. In *Seeds: the Ecology of Regeneration in Plant Communities*. CABI, Wallingford UK. pp. 59-84.

Harper, J. L. 1977. *Population Biology of Plants*. Academic Press Inc, London.

Huang, Z., S. Footitt and W. E. Finch-Savage. 2014. The effect of temperature on reproduction in the summer and winter annual *Arabidopsis thaliana* ecotypes Bur and Cvi. *Annals of Botany* 113(6): 921-929.

ISTA. International rules for seed testing. 2015. International Seed Testing Association ISTA, CH-8303 Bassersdorf, Switzerland. https://www.seedtest.org/en/publications/international-rules-seed-testing.html

Jones, C. A. 1985. *C_4 Grasses and Cereals: Growth, Development, and Stress Response*. Wiley, New York, USA. pp. 333-412.

Kendall, S. L., A. Hellwege, P. Marriot, C. Whalley, I. A. Graham and S. Penfield. 2011. Induction of dormancy in Arabidopsis summer annuals requires parallel regulation of DOG1 and hormone metabolism by low temperature and CBF transcription factors. *The Plant Cell* 23(7): 2568-2580.

Luzuriaga, A. L., A. Escudero and F. Pérez-García. 2006. Environmental maternal effects on seed morphology and germination in *Sinapis arvensis* (Cruciferae). *Weed Research* 46(2): 163-174.

Mande, M., A. A. Joshi, H. Paramjyothi, J. Ratnam and M. Sankaran. 2025. Patterns of grass (Poaceae) species distribution and richness across India. *Global Ecology and Conservation* 2025-05. https://doi.org/10.1016/j.gecco.2025.e03741.

Mansoor, U., M. Hameed, A. Wahid and A. R. Rao. 2002. Ecotypic variability for drought resistance in *Cenchrus ciliaris* L. germplasm from Cholistan desert in Pakistan. *International Journal of Agriculture and Biology* 4: 392-397.

Meyer, S. E. and P. S. Allen. 1999. Ecological genetics of seed germination regulation in *Bromus tectorum* L. II. Reaction norms in response to a water stress gradient imposed during seed maturation. *Oecologia* 120(1): 35-43.

Milberg, P., L. Andersson and K. Thompson. 2000. Large-seeded spices are less dependent on light for germination than small-seeded ones. *Seed Science Research* 10(1): 99-104.

Miranda, R. Q., M. T. Oliveira, R. M. Correia, J. S. Almeida-Cortez and M. F. Pompelli. 2011. Germination of *Prosopis juliflora* (Sw) DC seeds after scarification treatments. *Plant Species Biology* 26(2): 186-192.

Peacock, J. M., M. E. Ferguson, G. A. Alhadrami, I. R. McCann, A. Al Hajoj, A. Saleh and R. Karnik. 2003. Conservation through utilization: A case study of the indigenous forage grasses of the Arabian Peninsula. *Journal of Arid Environments* 54(1): 15-28. https://doi.org/10.1006/jare.2001.

Rani, R. and A. Sanyal. 2024. Reproductive biology of *Lasiurus sindicus*: a vital perennial fodder grass for arid ecosystem. *BMC Plant Biology* 24: 1159. https://doi.org/10.1186/s12870-024-05803-0.

Rani, R. and A. Sanyal. 2025. Phenology, pollination biology and breeding behavior of *Lasiurus sindicus*: an important forage species in arid climate of the Thar desert. *Range Management and Agroforestry* 46(2): 274-280.

Rani, R., J. P. Singh, A. Sanyal, M. P. Rajora and A. Trivedi. 2022. *Lasiurus sindicus* Henr., a key perennial fodder grass for desert ecosystem. *Arid Land Research and Management* 37(1): 1-19. https://doi.org/10.1080/15324982.2022.2060149.

Sanyal, A. and R. Rani. 2026. Morpho-physiology and seed quality attributes envisage physiological maturity in *Lasiurus sindicus* (Henr.): key perennial grass of arid ecosystem. *Discover Agriculture* 4(1): 6. https://doi.org/10.1007/s44279-025-00450-x.

Silva César da, J. and J. R. Maciel. 2025. Morphological and phenological shifts in semiarid grasses paralleled climate and land use changes. *Frontiers in Environmental Science* 13: 1625441. http://doi: 10.3389/fenvs.2025.1625441.

Ye, X., H. Wang, X. Cao, X. Jin, F. Cui, Y. Bu, H. Liu, W. Wu, T. Takano and S. Liu. 2019. Transcriptome profiling of *Puccinellia tenuiflora* during seed germination under a long-term saline-alkali stress. *BMC Genomics* 20(1): 589.