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SUBSTRATE-MEDIATED STORAGE MICROENVIRONMENTS REGULATE DEHYDRATION DECAY TRADE-OFFS AND PLANTING PERFORMANCE OF GLADIOLUS CORMS UNDER AMBIENT CONDITIONS

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ABSTRACT

Physiology under ambient conditions is controlled by a microenvironment that controls the storage of gladiolus corms storage substrates that alter humidity and aeration and consequently, regulate the dehydration injury, decay pressure and dormancy stability. The influence of storage media on deterioration indices and subsequent post-storage planting of two gladiolus cultivars were tested in this paper in reference to cold storage (4 ^{o}C). Storage media had a significant influence on physiological weight loss, shrinkage, rotting and storage sprouting with the trade-off between moisture conservation and decay suppression showing a clear trade-off scheme. The moisture-buffered microenvironment created by cocopeat reduced the effects of dehydration in storage at ambient temperature (PLW 9.63%; diameter reduction 6.85%), similar to cold storage (PLW 9.89%; diameter reduction 5.33%). Conversely, the sawdust minimized microbial decay (rotting 9.39%), and retarded early sprouting (4.86%), at the expense of high costs of dehydration (PLW 17.64%) and reduction in diameter (14.41%). Maximum rotting was observed with sawdust with sand (18.16%), and maximum storage sprouting was observed with sand (18.86%). The effects of these storage when subjected planting showed the greatest carry-over effects on field sprouting (92.23%), plant height (93.45 cm), and cocopeat was the most suitable ambient choice (field sprouting 82.45); plant height 87.64 cm). On the other hand, the driest aerated substrate diluted establishment (field sprouting 66.14; plant height 62.06 cm. In general, substrate-mediated control of dehydration-decay interactions leads to ambient storage results and deterioration indices are good predictors of the future planting performance.

***Keywords* :** *Gladiolus*, corm, ambient storage, microenvironment, dehydration, decay, dormancy.

Introduction

One of the most commercially significant bulbous ornamentals used in cut spikes is Gladiolus (*Gladiolus grandiflorus* L.) due to its broad appeal to consumers, variety and flexibility across the agro-climatic regions. Propagation of the crop mainly takes place via corms; therefore, the physiological status of stored planting material is a key determinant in the consistency of establishments, early vegetative activity and consequent flowering results (Tomiozzo *et al.*, 2019). Storage in production areas where the corm harvest is not directly succeeded by new planting makes it inevitable and tends to be the most important step with regard to the quality of propagules and the successfulness of crops (Halevy and Shilo, 1979; Amingad *et al.*, 2013). The physiology of storing gladiolus is complicated in that corms are active metabolic organs, with relations of moisture, regulation of dormancy, maintenance of reserves and resistance to diseases combined to determine overall planting values (Halevy and Shilo, 1979).

Gladiolus growing and planting are often done in subtropical environments, including the North Indian plains, where corm holding in non-refrigerated conditions is mostly necessary because of the low availability of cold-chain and high cost of operation, and therefore low-cost ambient storage strategies are of interest (Dhiman *et al*., 2022; Spadaro & Droby, 2016). The Ambient storage conditions are typified by fluctuations in temperature and relative humidity, which may aggravate physiological weight loss by raising the evaporative demand, accelerate the depletion of the reserves by increasing the respiration rate, and disrupt dormancy control resulting in untimely sprouting (Halevy and Shilo, 1979; Amingad *et al*., 2013; Tsukamoto & Yagi, 1960). Simultaneously, warm and humid microclimates enhance microbial stress and leave corm tissues vulnerable to rotting and colloquial degeneration, thus reducing the value of planting and predetermining the rise in quantitative loss (Shillo & Simchon, 1973). Therefore, two partially independent but operating simultaneously deterioration pathways, namely; (i) dehydration-associated physiological deterioration and (ii) microclimate-induced microbial deterioration, need to be controlled in order to sustain corm viability and performance in ambient subtropical storage.

To overcome this problem, growers tend to use inexpensive storage media including sand, sawdust, rice husk, cocopeat and mixtures of the above. The substrates are also able to adjust the immediate microenvironment in to which stored organs are stored by changing the humidity of the boundary-layers, aeration status and moisture buffering capacity, and thus the vapour pressure gradient causing water loss and pathogen proliferation potential. There is a well-known ability of cocopeat /coir-based material to retain high water-holding capacity and moisture buffering ability that can attenuate dehydration stress in changing ambient RH conditions, but more porous substrates like sawdust and rice husk may enhance aeration and possibly diminish the retention of residual moisture promoting microbial growth (Abad *et al*., 2002; Awang *et al*., 2009). But the physiological consequences of storage by using substrates are not consistent and may depend on cultivar dormancy behaviour, tissue vulnerability to dehydrating injury and natural predisposition by storage pathogens (Halevy and Shilo, 1979; Amingad *et al*., 2013). Furthermore, physiology-based evidence has strengthened the view that postharvest storage responses in gladiolus are closely interrelated with physiological integrity preservation under specific microenvironment conditions (Jhanji *et al*., 2024), which substantiates the importance of the ambient storage media approach to be viewed not so much as a handling aid but as a physiological regulator of the dormancy stability and storage quality.

Although the application of ambient storage media in tropical areas has been widely practiced, there is a lack of comparative physiological data in literature concerning the balance of moisture conservation and decay inhibition in different substrates and the relation between these results of storage and subsequent post-storage colonization and early development. This knowledge gap is especially crucial in the case of subtropical systems where cold storage is not always present and the quality of planting material defines the uniformity and economic yields of crops (Dhiman *et al*., 2022). Thus, the current research compared the influence of various low-cost ambient storage media and combinations of them on the deterioration indices (physiological weight loss, shrinkage, rotting, and sprouting), the dormancy-related behaviour and the following field establishment performance of two gladiolus cultivars under subtropical conditions using cold storage as the control. The hypothesis was that the storage media have variable influence due to their moisture buffering and aeration characteristics, which produce dehydration-decay trade-off resulting in ultimate physiological quality and planting performance.

Materials and Methods

Plant material and experimental site

This experiment was carried out during the year 2024-2025 using the gladiolus (*Gladiolus grandiflorus* L.) corms of two varieties namely Punjab Glance and Punjab Dawn provided by the department of Floriculture and Landscaping, PAU, Ludhiana. The experiment was conducted at the Research Farm of the Department of Floriculture and Landscaping, Punjab Agricultural University (PAU), Ludhiana, India (30°54′ N, 75°48′ E; 247 m a.m.s.l.). Before storing, corms were thoroughly washed and dried in shade and broken or conspicuously infected ones were removed.

Storage treatments, experimental design.

The study was designed as a two-factor factorial experiment that comprised of variety (V1, V2) at two levels, and seven storage treatments with five replications. Storage commenced in May 2024 and was ended during the first week of October 2024.

Seven storage treatments were evaluated in T1 sand + cocopeat (1:1 v/v), T2 sawdust + cocopeat (1:1), T3 sawdust + sand (1:1), T4 sand, T5 cocopeat, T6 sawdust, T7 cold storage (4 °C)**.** Variety used: V1- Punjab Glance, V2- Punjab Dawn

In the case of ambient storage treatments (T1-T6), the corms were packed in plastic crates (10 kg capacity) with a layered packing. The storage medium used was in a form of a basal layer which was put in the crate, then the corms were placed in a single layer and covered with the same medium; this was repeated until the crates were full. The crates were kept in ambient conditions of the laboratory. In the case of control treatment, storage of the corms was made under refrigeration at 4^oC cold storage is commonly used as a benchmark postharvest strategy in gladiolus to regulate dormancy behavior and improve uniformity of sprouting and subsequent performance (Ramos-García *et al*., 2009). Periodic monitoring of ambient storage temperature and relative humidity was done by the use of a digital thermo-hygrometer.

Evaluation of corm physical characteristics.

Corm weight (g)

The mass of Corm before and after storage (initial and final weight) was measured with a calibrated electronic balance (+-0.01 g), on the basis of the principles of the standard gravimetric measurements (AOAC International, 2019).

Corm diameter (cm)

The diameter of the corm was evaluated at the widest equatorial area both before and after storage with a digital Vernier caliper (least count 0.01 cm), as with other standard morphological measurement protocols in descriptions based on the descriptors (UPOV, 2015).

Physiological indices of deterioration caused by storage

Physiological loss in weight (PLW, percent).

The weight loss was calculated physiologically via the use of the following equation:

$$PLW (\%) = [(W_i - W_f) / Wi] \times 100$$

W_i = starting fresh weight (g) and W_f = ending fresh weight (g).

Reduction in diameter (%)

Shrinkage in diameter was calculated as:

$$\text{Reduction in diameter } (\%) = [(D_i - D_f)/ D_i] \times 100$$

in which D_i is the initial diameter (cm) and D_f is the final diameter (cm).

Rotting percentage (%)

At the end of storage incidence of rotting was determined. Corms that softened, disintegrated, discolored or showed evident microbial growth were considered rotten. Rotting percentage was calculated with the following:

$$\text{Rotting } (\%) = (\text{rotten corms}/ \text{total corms stored}) \times 100$$

The classification of decay was done according to the standard postharvest pathological symptom assessment procedures (Droby *et al*., 2016).

Post-storage establishment and storage sprouting.

Storage sprouting (%)

Corms with apparent emergence of sprouts at end of the storage period were counted. Storage sprouting percentage was determined:

$$\text{Storage sprouting } (\%)= (\text{Number of sprouted corms} / \text{Total corms stored}) \times 100.$$

Sprouting evaluation and emergence counts were done on standard principles used in propagule quality assessment (ISTA, 2023).

Field planting

In October 2024, after storage, non-rotted corms were planted in the Floriculture Research Farm, PAU, Ludhiana, on raised beds at a spacing of 30 cm x 20 cm under the same agronomic management practice.

Days to sprouting

Sprouting days were set to record how many days it took to emerge above the surface of the soil. Frequently, the principles of emergence recording were adjusted to procedures of emergence evaluation based on ISTA (ISTA, 2023).

Field sprouting (%)

The percentage of sprouting of the fields was computed as:

$$\text{Field sprouting } (\%) = (\text{Number of plants emerged}/ \text{Total corms planted}) \times 100$$

Plant height (cm)

The height of the plants was taken at the onset of vegetative development and measured between the soil surface and the end of the tallest leaf in centimeters.

Statistical analysis

All statistical analyses were performed using R software. Data were analyzed using two-way ANOVA with variety and storage treatment as fixed factors. Assumptions of normality of residuals and homogeneity of variance were tested prior to analysis. Treatment means were separated using Tukey’s honestly significant difference (HSD) test at $p \leq 0.05$. When the variety × treatment interaction was non-significant, treatment means were pooled across varieties; however, for parameters showing significant interaction (Table 1B), mean comparisons were performed separately within each variety.

Pearson correlation coefficients were determined between storage deterioration indices (PLW, diameter reduction, rotting percentage, storage sprouting) and post-storage establishment characteristics (field sprouting, days to sprouting, plant height). PCA was conducted on the standardized variables (z-scores) to assess the multivariate correlations and clusters of treatments and analyzed through PCA biplots.

Table S1: Initial physical characteristics of gladiolus corms before storage

Treatment	Initial Weight	Initial Diameter
T1	36.23 ± 0.88^{c}	4.65 ± 0.11^{ab}
T2	39.68 ± 1.12^{b}	4.94 ± 0.08^{a}
T3	38.56 ± 2.74^{bc}	4.68 ± 0.13^{ab}
T4	39.59 ± 1.32^{b}	4.87 ± 0.04^{ab}
T5	37.69 ± 1.10^{bc}	4.66 ± 0.19^{ab}
T6	46.80 ± 1.08^{a}	4.85 ± 0.09^{ab}
T7	37.00 ± 0.23^{bc}	4.56 ± 0.07^{b}
Mean V1	38.91 ± 1.03	4.86 ± 0.06
Mean V2	39.81 ± 0.77	4.62 ± 0.05
CV(%)	5.03	4.74

Footnote (Table S1): Values represent mean ± SE. Means followed by different superscript letters within a column differ significantly according to Tukey's HSD test at $p \leq 0.05$.

Results

Storage media effect on deterioration related to dehydration

Storage treatments significantly affected physiological loss in weight (PLW) and reduction in diameter (Table 1A). Cocopeat (T$_5$) stored at ambient temperature had the lowest PLW (9.63%) and was not significantly different between cold-storage control (T7; 9.89%). The maximum PLW was under sawdust (T$_6$; 17.64%) and sawdust + cocopeat (T2; 17.40%), which is about 1.8 times higher than the one of the control. A similar trend was observed for reduction in diameter. The lowest shrinkage was observed under T7 (5.34%), followed by T5 (6.85%), whereas T6 recorded the highest shrinkage (14.41%). The concordant trends between PLW and diameter reduction indicate a strong treatment effect on dehydration-related deterioration during ambient storage.

Rotting incidence and sprouting behaviour during storage

There was significant difference in the percentage of rotting among storage treatments (Table 1A). Cold storage resulted in the lowest rotting incidence of (2.86%). Among ambient media, sawdust (T6; 9.40%) recorded the lowest rotting incidence followed by sawdust + cocopeat (T2; 12.55%). There was high rotting incidence in sand + cocopeat (T1; 18.16%), cocopeat (T5; 17.20%) and sand (T4; 16.86%) (Table 1A). In T1 Rotting was more than six-fold higher than the control.

Storage treatments significantly influenced sprouting percentage during storage (Table 1A). Storage sprouting was strongly suppressed under cold storage (0.95 percent). Sawdust (T6) possessed the lowest sprouting (4.86 percent), whereas sand (T4) had the highest sprouting percentage of 18.86, and sand and cocopeat (T1) had the middle between (13.28 percent). Sand had a 17.9 percentage point higher effect on storage sprouting than the control (Table 1A).

Table 1A : Effect of storage treatments on physiological deterioration and sprouting during storage of gladiolus corms (pooled across varieties)

Treat-ment	PLW (%)	Reduction in diameter (%)	Rotting (%)	Storage sprouting (%)
T1	12.55 ± 1.26^{ab}	8.45 ± 1.56^{bcd}	18.16 ± 0.98^{a}	13.28 ± 1.25^{b}
T2	17.40 ± 1.43^{a}	9.92 ± 0.44^{bc}	12.55 ± 1.05^{bc}	8.16 ± 1.29^{cd}
T3	14.34 ± 2.10^{ab}	10.52 ± 0.48^{b}	16.06 ± 0.92^{ab}	8.76 ± 0.59^{c}
T4	13.44 ± 1.63^{ab}	8.09 ± 0.55^{bcd}	16.86 ± 1.12^{a}	18.86 ± 0.81^{a}
T5	9.63 ± 1.90^{b}	6.85 ± 0.68^{cd}	17.20 ± 0.88^{a}	10.14 ± 0.96^{bc}
T6	17.64 ± 1.91^{a}	14.41 ± 0.97^{a}	9.39 ± 1.35^{c}	4.86 ± 0.54^{d}
T7	9.89 ± 1.23^{b}	5.33 ± 0.45^{d}	2.86 ± 0.29^{d}	0.95 ± 0.30^{e}
mean V1	16.88 ± 0.78	8.63 ± 0.45	12.59 ± 0.95	8.21 ± 0.94
mean V2	10.23 ± 0.86	9.53 ± 0.76	14.01 ± 1.07	10.37 ± 1.07
CV(%)	28.25	28.3	23.41	26.8

Footnote (Table 1A): Values are means ± SE (pooled across varieties). Different superscript letters within a column indicate significant differences among treatments based on Tukey's honestly significant difference (HSD) test at $p \leq 0.05$

Days to sprouting response-variety (interaction effect)

The time to sprout reflected a strong variety x treatment synergy (Table 1B). The earliest sprouting was recorded in Punjab Glance (V1), and it was under cold storage (T7; 13.13 days) and statistically comparable to cocopeat (T5; 13.33 days). The V1 sprouting lasted the most under sawdust (T6; 16.73 days). Cold storage (T7), in Punjab Dawn (V2) also gave rise to early sprouting (16.20 days) and sawdust (T6) to last sprouting (20.20 days) (Table 1B). In all treatments, V2 took longer days to sprouting as compared to V1.

Table 1B : Interaction effect (variety × storage treatment) on days to sprouting in gladiolus

Treatment	Days to sprouting (V1: Punjab Glance)	Days to sprouting (V2: Punjab Dawn)
T1	14.27 ± 0.13^{bc}	18.13 ± 0.17^{h}
T2	15.20 ± 0.08^{cd}	17.93 ± 0.44^{gh}
T3	16.00 ± 0.15^{de}	18.40 ± 0.07^{h}
T4	14.87 ± 0.08^{c}	17.80 ± 0.25^{gh}
T5	13.33 ± 0.11^{ab}	17.00 ± 0.18^{fg}
T6	16.73 ± 0.13^{ef}	20.20 ± 0.31^{i}

T7	13.13 ± 0.08^{a}	16.20 ± 0.17^{ef}
Mean	14.79 ± 0.21	17.95 ± 0.22
CV(%)	2.66	

Footnote (Table 1B): Values represent mean ± SE. Means followed by different superscript letters within a column differ significantly according to Tukey's HSD test at $p \leq 0.05$.

Emergence of post-storage field and vegetative growth

Storage treatments had significant difference in field sprouting percentage and the height of the plants (Table 2). The greatest field sprouting (92.23%) and maximum plant height (93.45 cm) were obtained when cold storage control (T7) was used. Cocopeat (T5) among ambient storage treatments had relatively high field sprouting (82.45), and height of plants (87.64 cm). The lowest establishment was registered in sawdust (T6) whereby the field sprouting was 66.14 percent with a plant height of 62.06 cm (Table 2). Cold storage improved field sprouting by 26.1 percentage points relative to the poorest-performing ambient treatment with an increase in plant height by an average of 31.4 cm (Table 2). There were generally treatments that had lower deterioration during storage followed by enhanced emergence and early development after planting.

Table 2 : Effect of storage treatments on post-storage establishment of gladiolus (pooled across varieties)

Treatment	Field sprouting (%)	Plant height (cm)
T1	78.69 ± 1.08^{bc}	79.88 ± 2.31^{c}
T2	73.56 ± 0.73^{d}	71.48 ± 1.63^{e}
T3	69.12 ± 0.60^{e}	66.32 ± 1.85^{f}
T4	77.80 ± 0.89^{c}	76.49 ± 2.21^{d}
T5	82.45 ± 1.19^{b}	87.64 ± 2.13^{b}
T6	66.14 ± 1.52^{e}	62.06 ± 1.83^{g}
T7	92.23 ± 0.80^{a}	93.45 ± 2.02^{a}
Mean V1	78.71 ± 1.44	82.46 ± 1.87
Mean V2	75.57 ± 1.47	71.06 ± 1.77
CV (%)	3.7	2.68

Footnote (Table 2): Values represent mean ± SE pooled across varieties. Means followed by different superscript letters within a column differ significantly according to Tukey's HSD test at $p \leq 0.05$

Pearson Correlation between indices of storage deterioration and post-storage performance (Correlation analysis)

The correlation analysis performed by Pearson revealed that there was a high degree of association between after storage emergence and the initial growth of vegetation (Fig. 1). The field sprouting demonstrated positive relationship with plant height (r = 0.89). Days to sprouting showed a high level of negative relationships with the establishment traits, which are negatively correlated with field sprouting (r = - 0.67) and plant height most of all (r = - 0.87). Final corm weight was weak to moderate (r = 0.38 with days to sprouting and negative with plant height (r = - 0.36) and PLW (r = - 0.37) (Fig. 1). PLW and rotting percent had an insignificant relationship between them (r = - 0.02), and the extent of variation in dehydration-linked loss and decay incidence were largely independent in the sampled dataset.

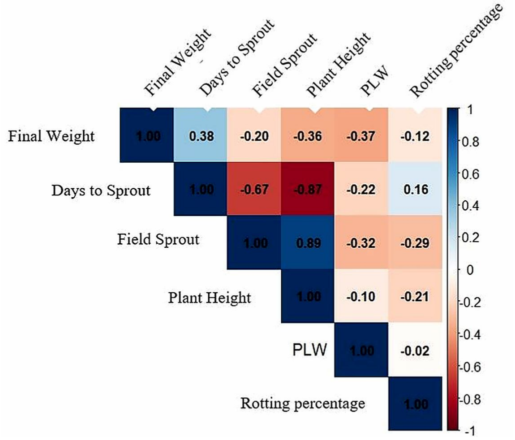

Fig. 1: Storage deterioration indices and post-storage performance Correlation analysis

Principal component analysis and Multivariate discrimination of treatments

The multivariate results of deterioration indexes and post-storage establishment characteristics were summarized using principal component analysis (PCA) (Fig. 2). The two former attributes explained 72.1% of the overall variance (PC1: 47.4; PC2: 24.7). The PCA biplot segregated the treatments in accordance with the establishment- and dormancy associated gradients: the vectors of field sprouting and height of the plant loaded simultaneously whereas days to the sprouting loaded in another direction in accordance with their strong negative correlations in the correlation matrix (Fig. 1). The positioning of treatment also favoured the control (T7) and cocopeat (T5) over the area linked to better establishment performance whereas sawdust (T6) fitted better with delayed sprouting behaviour (Fig. 2). The other combinations of ambient storage (T1-T4) were intermediate in nature due to their moderate multivariate responses of the traits studied.

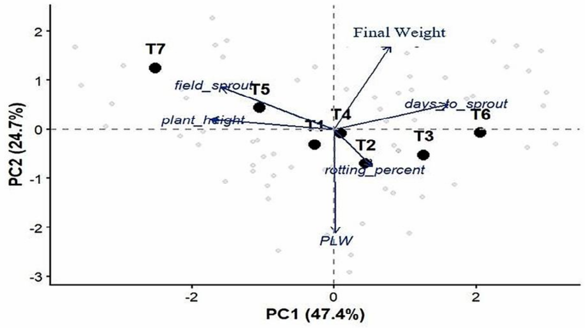

Fig. 2: Multivariate discrimination of treatments (Principal component analysis)

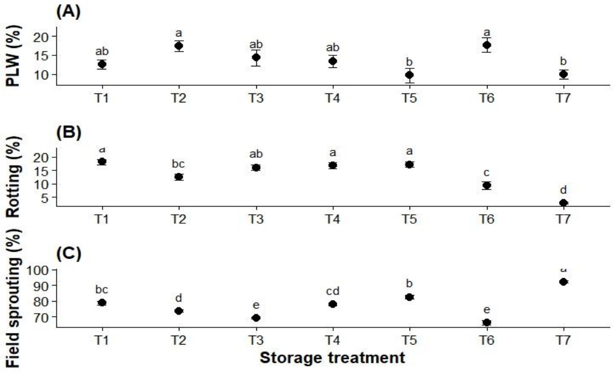

Fig 3: Effect of different storage treatments on **(A)** physiological loss in weight (PLW, %), **(B)** rotting (%), and **(C)** field sprouting (%) of gladiolus corms.

Discussion

A key limitation to maintaining gladiolus corms ambiently at subtropical temperatures is physiological degradation since propagules are subjected to changing temperature and relative humidity which concurrently enhance moisture loss, disrupt dormancy control, and increase the risk of microbial degradation. The current research proved that storage substrates had a great impact on deterioration indices in storage and were able to produce strong carry-over effects after planting, meaning that low-cost media change the corm microenvironment and, as such, control tissue hydration, infection pressure and physiological activation. The most common limitation in ambient storage was dehydration-related degradation, which was indicated by significant differences in physiological weight loss (PLW) and shrinkage of substrates. Cocopeat (T5) was found to have the lowest PLW during ambient storage (9.63%), which was similar to cold storage (T7: 9.89%), but sawdust + rice husk (T6) had the highest dehydration stress (PLW 17.64%). Patterns of shrinkage corroborated this observation whereby the lowest shrinkage percentage was observed during cold storage (5.33%), and the highest percentage was observed during T6 (14.41%). These findings are in line with the known effect of the physical properties of the substrate on the humidity of the boundary-layer, vapour pressure deficit and evaporative demand at the organ surface, in which moisture-buffering media lessen net water loss by sustaining a higher local humidity microclimate (Abad *et al.*, 2002; Awang *et al.*, 2009). Cold storage is also credited to slow down physiological ageing by lowering respiration as well as metabolic turnover, thus limiting the reserves depletion as well as moisture-loss related tissue degradation; this is especially applicable in gladiolus where dormancy behaviour and planting value are highly affected by storage temperature and storage duration (Halevy and Shilo, 1979; Amingad *et al.*, 2013). Therefore, the relative good performance of cocopeat in ambient storage conditions is probably due to its large moisture-holding capacity and buffering ability that has been commonly reported in coir/cocopeat-based substrates (Abad *et al.*, 2002; Awang *et al.*, 2009).

It is interesting to note that the rate of decay was not directly dependent on the trends of dehydration, which suggests that rotting is controlled by other factors, especially by aeration and humidity conditions that support the growth of microorganisms. Rotting was least when stored in cold (2.86%), as one would anticipate because low temperatures inhibit the growth of microbes and decelerate the process of breaking down tissue. In ambient conditions, the highest rotting was observed in the control (T1; 18.16%), and the lowest rotting was observed in sawdust + rice husk (T6) despite having the highest PLW, which indicated that the higher-aerated and drier microenvironment decreased the pressure of decay. This is consistent with the principles of postharvest pathology that the success of infections and the development of symptoms are greatly dependent on microclimate humidity and aeration, and disease progression is facilitated by conditions that extend the surface wetness and reduce ventilation around tissues (Spadaro and Droby, 2016; Droby *et al.*, 2016). Conversely, cocopeat decreased dehydration but displayed a comparatively higher rotting (17.20%), which suggests that moisture-buffering substrates can enhance local humidity and extend wetness, thereby increasing the risk of decay. Taken together, these findings prove a definite physiological trade-off during ambient storage: the conservation of moisture leads to hydration and vigour, and too much moisture conservation may increase microbial degradation (Spadaro and Droby, 2016; Droby *et al.*, 2016). The gladiolus corm storage patterns have been observed to be similar to substrate-mediated patterns in applied studies where the media properties affect the dynamics of dehydration and rotting (Dudhat *et al.*, 2021).

The stability of dormancy and the sprouting responses also supported this trade-off framework and emphasised the interaction between the environment and the genotype x. Premature sprouting in storage is not desirable as it indicates the loss of dormancy and the use of reserves before planting and thus lowering the quality of propagules; ABA-GA antagonism in the regulation of bud activation has been commonly linked to this (Li *et al.*, 2021). Cold storage (0.95%), verified the effectiveness of low temperature in preserving dormancy in gladiolus planting material by strongly suppressing storage sprouting (Amingad *et al.*, 2013).

The physiological basis of cultivar-dependent sprouting behaviour has been supported by the reports of differential ABA- and GA-mediated responses during dormancy maintenance and release in gladiolus corm systems (Goyal *et al*., 2024). The sprouting under ambient media was not consistent with the highest sprouting in sand (T4; 18.86) and the lowest in T6 (4.86). Sand probably offers smaller buffering of humidity and allows more daily variation in temperature and RH around corms, and thus favours physiological activation and sprout development. Sawdust-based storage, on the other hand, could reduce sprouting by reducing humidity of the microenvironment and enhancing aeration, but the large dehydration penalty suggests that suppression of sprouting is not sufficient to characterise a successful storage. The interaction of the variety x treatment days to sprouting reveals that the responsiveness of dormancy to storage cues is genetically controlled, which is in line with ABA-related regulatory signalling pathways involved in the regulation of dormancy (Wu *et al*., 2015). Punjab Dawn typically exhibited a late sprouting relative to Punjab Glance which showed that there are cultivar variations in the dormancy persistence and activation threshold in different ambient conditions. Even though the present study did not determine sugars or hormones, cultivar-specific differences in the kinetics of dormancy are compatible with the physiology of gladiolus dormancy and temperature-dependent regulation of dormancy break and subsequent sprout development (Halevy and Shilo, 1979; Amingad *et al*., 2013), and similar genotype-dependent responses to storage have been observed in controlled conditions (Jhanji *et al*., 2024).

The observed carry-over effects into field establishment support the fact that the indices of deterioration of storage are biologically significant and directly influence the further growth performance. The cold storage produced the best field sprouting (92.23%) and maximum plant height (93.45 cm), which was also in line with its overall control of dehydration (PLW 9.89%), decay (2.86%) and premature sprouting (0.95%). Cocopeat had one of the highest establishment (82.45% field sprouting) and plant height (87.64 cm), presumably because of better preservation of tissue hydration (PLW 9.63%), and diminished shrinkage, among the ambient media. On the other hand, sawdust + rice husk (T6) had the lowest establishment (66.14% field sprouting; 62.06 cm plant height) even though it had favourable decay and suppression of the sprouting, which was caused by severe dehydration damage during storage that inhibited physiological vigour and restricted rapid emergence and early growth. This trend is physiologically realistic since initial post-planting development using corms is mainly heterotrophic and relies on the amount of reserves and tissue integrity; stress on dehydration and metabolic loss can limit the mobilisation of reserves and establishment despite comparatively low levels of microbial decay (Halevy and Shilo, 1979; Ramos-Garcia *et al*., 2009). The strong association between storage deterioration indices and performance traits (as indicated by correlation and PCA trends) further supports the conclusion that ambient storage media govern planting value through integrated effects on water relations, dormancy stability and tissue health.

Collectively, these findings indicate that ambient storage systems for gladiolus in subtropical regions should be optimized not only to reduce visible loss but to preserve key physiological quality determinants that drive establishment. Cocopeat appears most suitable for dehydration suppression and planting vigour among low-cost substrates, consistent with the moisture-buffering performance of coir-based media (Abad *et al*., 2002; Awang *et al*., 2009), while sawdust-based storage provides strong decay and sprouting suppression but induces unacceptable dehydration penalties. Therefore, a practical approach may involve designing storage systems that combine humidity buffering with adequate aeration to avoid prolonged local wetness thereby balancing moisture conservation against microbial suppression under non-refrigerated conditions (Spadaro and Droby, 2016; Dudhat *et al*., 2021). This trade-off framework is particularly relevant for regions where cold storage infrastructure is limited, and optimizing ambient storage will support uniform establishment and productivity of gladiolus as a high-value ornamental crop (Dhiman *et al*., 2022; CABI, 2024).

Conflict of Interest

The authors declare that they do not have any known competing financial interests or personal connections that might have manifested itself in the work they report in this paper.

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