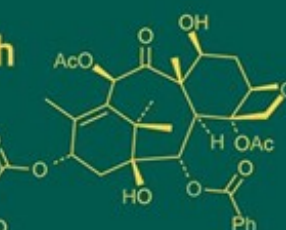
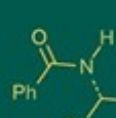
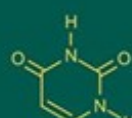


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
 ISSN Online: 2617-4707
 NAAS Rating (2026): 5.29
 Indexing: Embase
 IJABR 2026; SP-10(10): 437-442
www.biochemjournal.com
 Received: 11-08-2026
 Accepted: 21-09-2026
 Published: 06-10-2026

The names and affiliations of all authors are provided below, following the references.

Palynological variability study among strawberry (*Fragaria* × *ananassa* Duch.) cultivars for pollination and breeding

Sukjai Dhar¹, AS Sundouri², Amit Kumar³, Khalid Masoodi⁴, Gowhar Ali⁵, Parmeet Singh⁶, RP Phanbah⁷

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i10Sf.10318>

ABSTRACT

Reproductive performance in strawberry is influenced by pollen fertility and stigma receptivity, which may vary among cultivars. The present palynological study was conducted to evaluate key reproductive traits in six strawberry (*Fragaria* × *ananassa* Duch.) cultivars, viz., Chandler, Kimberly, Larson, Sweet Charlie, Winterdawn and *Selva*, during the 2024–25 and 2025–26 growing seasons at SKUAST-Kashmir, Shalimar, India. Significant cultivar differences were observed for pollen viability, pollen germination and stigma receptivity. Based on pooled means, Chandler recorded the highest pollen viability (78.97%), which was statistically at par with Winterdawn (77.50%), whereas Larson exhibited the lowest viability (63.92%). Pollen germination was highest in *Selva* (68.67%), followed by Sweet Charlie (66.00%), while Larson recorded the lowest germination (53.00%). Stigma receptivity was highest in Winterdawn (90.83%), followed by Kimberly (88.83%), whereas Sweet Charlie showed the lowest receptivity (71.67%). No single cultivar exhibited superior performance for all three traits, indicating cultivar-specific variation in male and female reproductive attributes. Winterdawn exhibited a favourable combination of relatively high pollen viability and stigma receptivity, indicating its potential as parental material in strawberry breeding programmes. The findings highlight the importance of evaluating multiple reproductive traits for characterizing strawberry cultivars and identifying suitable parents for controlled hybridization and breeding programmes.

Keywords: *Fragaria* × *ananassa*, Palynology, Reproductive biology, Cultivar variation

1. Introduction

Strawberry (*Fragaria* × *ananassa* Duch.) is a high-value commercial fruit cultivated extensively in temperate, subtropical, and protected production systems, prized for its sensory quality, nutritional profile, and dual suitability for fresh and processed markets. Despite advances in protected cultivation and breeding technologies, sustaining high marketable yields and consistent fruit quality remains a primary production challenge (Hernández-Martínez *et al.*, 2023). Productivity is uniquely constrained by pollination and fertilization dynamics due to the plant's aggregate floral biology. The commercial "fruit" develops from an enlarged receptacle whose expansion is directly governed by surrounding true fruits the achenes each derived from an individually fertilized ovary. Post-fertilization, developing achenes synthesize key phytohormones, notably auxin, which trigger and coordinate early receptacle hypertrophy (Tian *et al.*, 2022). Consequently, sub-optimal or spatially heterogeneous fertilization across the carpellary collective leads to localized developmental arrest, yielding misshapen or unmarketable fruit.

Fertilization success requires mutual functional competence of the staminate and pistillate structures. Pollen viability and *in vitro* germination capacity determine male gametophytic fitness and pollen-tube elongation rates toward the ovule, while stigma receptivity defines the temporal window permitting pollen adhesion, hydration, and style penetration. Recent evidence confirms that floral architecture, pollen load, and viability are directly proportional to the percentage of fertilized achenes and final fruit mass (Lee *et al.*, 2026). Genotypic variation in male fertility and female receptivity is therefore a principal driver of divergence in reproductive efficiency and yield architecture among cultivars.

While cultivated strawberry is generally considered self-compatible, autonomous self-pollination often fails to deliver adequate, uniform pollen across the numerous pistils of a receptacle, directly limiting fruit set and commercial quality. Klatt *et al.* (2014) showed that insect pollination significantly reduces malformation while enhancing fruit mass and market grade relative to wind- or self-pollination. This is corroborated by Wietzke *et al.* (2018), who linked efficient pollination to increased fertilized achene set and physiological improvements during receptacle development. Furthermore, Lee *et al.* (2026) demonstrated that pollen load

Corresponding Author: Sukjai Dhar

Division of Fruit Science,
 Sher-e-Kashmir University
 of Agricultural Sciences
 and Technology of
 Kashmir, Srinagar, Jammu
 and Kashmir, India

and viability directly govern achene fertilization rates and ultimate fruit weight. Collectively, these data confirm that floral reproductive efficiency is a critical physiological determinant of marketable yield. Pollen viability and germination are strongly governed by microclimatic conditions during microsporogenesis and post-anthesis exposure. Ambient temperature and relative humidity modulate pollen longevity, germination capacity, and tube elongation kinetics, with the magnitude of susceptibility varying genotypically. Leech *et al.* (2000) observed cultivar-dependent declines in strawberry pollen germination under prolonged post-anthesis exposure, which were exacerbated by concurrent thermal and hygric stress. Similarly, elevated temperatures suppressed pollen germination and tube growth in everbearing genotypes, ultimately reducing yield (Karapatzak *et al.*, 2012). Because male gametophytic fitness represents a genotype-by-environment interaction, multi-season phenotyping is essential to reliably characterize reproductive stability across cultivars.

Successful fertilization requires strict coordination between pollen quality and pistillate competence. Effective pollen adhesion, hydration, and germination demand that viable pollen deposition coincides with peak stigma receptivity, a primary determinant of reproductive success and optimal timing for controlled hybridization. Stigmatic receptivity is functionally marked by surface physiological alterations and elevated enzymatic activity (Dafni and Maués, 1998). In strawberry, this receptivity window is highly transient, Lata *et al.* (2018) identified peak receptivity at anthesis, followed by a rapid post-anthesis decline. Consequently, temporal asynchronous overlap between viable pollen release and stigma receptivity risks incomplete fertilization, regardless of pollen load.

Pollen viability, *in vitro* germination capacity, and stigma receptivity represent distinct yet functionally complementary components of floral reproductive performance. Evaluating any single parameter in isolation provides an incomplete assessment of overall reproductive competence. While previous investigations documented cultivar-specific variation in pollen viability (Zebrowska, 1997), environmental modulation of pollen germination (Leech *et al.*, 2000; Karapatzak *et al.*, 2012), and floral phenology (Lata *et al.*, 2018), substantial knowledge gaps remain. Specifically, data are limited regarding the temporal stability of these traits across consecutive field seasons and the extent to which superior male gametophytic traits correlate with high stigma receptivity within a given genotype. Resolving these relationships is critical for breeding programs, where optimizing parental selection and cross-synchronization dictates hybridization efficiency. Accordingly, this study evaluated six strawberry cultivars (Chandler, Kimberly, Larson, Sweet Charlie, Winterdawn, and *Selva*) over two consecutive seasons (2024–25 and 2025–26) under the temperate conditions of Kashmir to quantify genotypic variation in pollen viability, *in vitro* germination, and stigma receptivity. Specifically, we examined the concordance among these reproductive components to determine whether high performance in a single floral trait predicts overall reproductive competence. These findings aim to establish reliable reproductive benchmarks for parental selection and targeted hybridization in strawberry improvement programs.

2. Materials and Methods

2.1. Experimental site and study period

The investigation was conducted during two consecutive strawberry-growing seasons, 2024–25 and 2025–26, at the Strawberry Germplasm Block, Division of Fruit Science, Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K), Shalimar, Srinagar, Jammu and Kashmir, India. The experimental site is located at approximately 34°09'22" N latitude and 74°52'55" E longitude, at an elevation of 1685 m above mean sea level. The same experimental site and observational procedures were used during both seasons.

2.2. Plant material and experimental design

Six strawberry (*Fragaria × ananassa* Duch.) cultivars, namely Chandler, Kimberly, Larson, Sweet Charlie, Winterdawn and *Selva*, maintained in the Strawberry Germplasm Block of SKUAST-K, were used in the study. The experiment was conducted in a randomized complete block design (RCBD), with cultivar considered as the treatment. Plants were maintained following the recommended cultural practices for strawberry cultivation under local conditions. Freshly opened, healthy and morphologically normal flowers were selected at anthesis for assessment of pollen viability, pollen germination and stigma receptivity. Flowers showing visible injury, disease symptoms or abnormal development were excluded from sampling. Observations were recorded separately for each cultivar and replication during both cropping seasons.

2.3. Pollen viability

Pollen viability was determined using the 0.1% erythrosin B staining test, following the general staining procedure used for strawberry pollen assessment (Lata *et al.*, 2018). A 0.1% erythrosin B solution was prepared by dissolving 100 mg erythrosin B in distilled water and making the final volume to 100 mL.

Fresh pollen grains collected from flowers at anthesis were dusted onto clean glass slides. One to two drops of erythrosin B solution were added and the preparation was covered with a coverslip. The slides were allowed to stand for approximately 5 min to permit staining and were subsequently examined under a microscope. With erythrosin B, pollen grains that remained unstained or colourless were considered viable, whereas grains that absorbed the stain and appeared red or pink were considered non-viable, following the criterion used in previous pollen studies (Sharma *et al.*, 2025; Lata *et al.*, 2018). Pollen grains were counted for each replication and cultivar, and pollen viability was calculated as:

$$\text{Pollen viability (\%)} = \frac{\text{Number of viable (unstained) pollen grains}}{\text{Total number of pollen grains examined}} \times 100 \quad (\text{A1})$$

Pollen germination was assessed *in vitro* using a sucrose-boric acid medium, following the general procedure described for strawberry pollen germination by Lata *et al.* (2018), with appropriate modification. Freshly collected pollen grains were placed in small drops of 15% sucrose solution supplemented with 0.01 g boric acid on cavity slides. The preparations were covered carefully with coverslips.

The margins of the coverslips were sealed with a thin layer of petroleum jelly (Vaseline) to reduce evaporation of the germination medium. The prepared slides were placed in Petri dishes lined with moist filter paper to maintain a uniformly high relative humidity during incubation. The slides were maintained at room temperature and pollen germination was examined microscopically after 24, 48 and 72 h.

A pollen grain was considered germinated when the length of its pollen tube exceeded the diameter of the pollen grain. The numbers of germinated and non-germinated pollen grains were recorded for each cultivar and replication. Pollen germination was calculated as:

$$\text{Pollen germination (\%)} = \frac{\text{Number of germinated pollen grains}}{\text{Total number of pollen grains examined}} \times 100 \quad (\text{A2})$$

Previous work in strawberry has shown that sucrose concentration and incubation period influence *in vitro* pollen germination, with 15% sucrose providing favourable germination in several cultivars (Lata *et al.*, 2018).

2.5. Stigma receptivity

Stigma receptivity was evaluated using the hydrogen peroxide (H₂O₂) test, based on the principle described by Dafni and Maués (1998) and the scoring procedure subsequently employed by Crispim *et al.* (2017) [1]. This test is based on the reaction of hydrogen peroxide with enzymes, particularly peroxidases, present on receptive stigmatic surfaces; visible effervescence is therefore used as an indicator of re

ceptivity. The H₂O₂ method and its relationship with stigmatic enzymatic activity have been widely used for rapid assessment of stigma receptivity.

For each cultivar and replication, ten freshly opened flowers at anthesis were selected. A 3% H₂O₂ solution was applied directly to the stigmatic surface, and the resulting reaction was examined under a stereoscopic microscope. Stigma receptivity was assessed according to the intensity and extent of bubble formation on the stigmatic surface. Following Crispim *et al.* (2017) [1], receptivity was scored on a

scale of 0-3, corresponding to the approximate proportion of the stigmatic surface showing bubbling: 0 = 0%, 1 = 30%, 2 = 60%, and 3 = 100% bubble coverage.

This scoring system is consistent with the hydrogen-peroxide-based assessment reported by Crispim *et al.* (2017) [1]. Greater bubble formation was interpreted as greater stigmatic receptivity. For each cultivar, the percentage value corresponding to the score of each stigma was recorded, and mean stigma receptivity was calculated as:

$$\text{Stigma receptivity (\%)} = \frac{\sum \text{bubble-coverage values of the stigmas examined}}{\text{Total number of stigmas examined}}$$

(A3)

2.6. Statistical analysis

Data recorded during the two cropping seasons were subjected to analysis of variance (ANOVA) appropriate to a randomized complete block design. Cultivar effects were tested for each reproductive trait, and the data from the two seasons were subsequently used to obtain pooled estimates. Statistical analyses were performed using OPSTAT, a statistical software package developed by the Department of Mathematics and Statistics, CCS Haryana Agricultural University, Hisar, India. OPSTAT is commonly used for analysis of agricultural experiments based on randomized experimental designs. Where the cultivar effect was significant, treatment means were compared using the critical difference (CD) at the 5% probability level ($P \leq 0.05$). Results are presented as cultivar means together with the corresponding measures of variability.

3. Results and Discussion

3.1. Pollen fertility

3.1.1. Pollen viability

Pollen viability varied significantly ($P < 0.05$) among the evaluated strawberry cultivars across both growing seasons (Table 1). During 2024–25, viability ranged from 63.50% in Larson to 78.80% in Chandler; Chandler was statistically at par with Winterdawn (76.33%) and Sweet Charlie (74.93%). A consistent genotypic pattern emerged in 2025–26, where Chandler maintained the highest viability (79.17%), followed closely by Winterdawn (78.67%) and Sweet Charlie (75.67%), with no significant differences among these three top performing cultivars ($CD = 4.291$). Representative light micrographs illustrating differential stain uptake by viable versus non-viable pollen grains following 0.1% erythrosin B staining are presented in Figure 1.

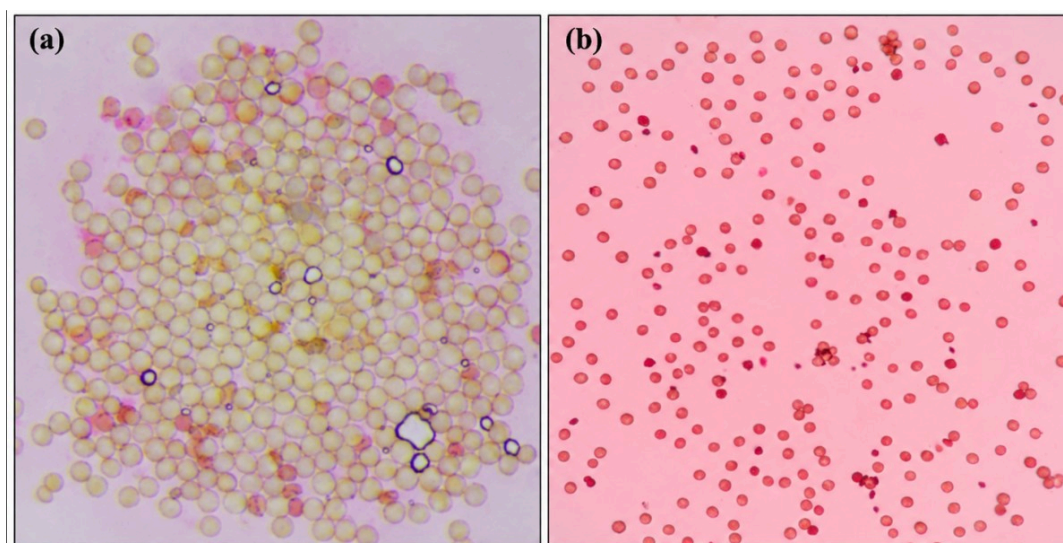


Figure 1. Representative micrographs of pollen viability in strawberry cv. Chandler assessed using 0.1% erythrosin B staining: (a) predominantly viable, unstained pollen grains; (b) stained pollen grains showing viable and non-viable grains.

Pooled analysis provided clearer statistical resolution among cultivars (pooled $CD = 2.880$). Chandler recorded the highest overall pollen viability (78.97%), which was statistically comparable to Winterdawn (77.50%). Sweet Charlie exhibited intermediate viability (75.30%), remaining statistically on par with Winterdawn but significantly lower

than Chandler. Conversely, Larson consistently exhibited the lowest pollen viability (pooled mean of 63.92%), followed by Selva (67.33%). The stable genotypic ranking across both consecutive seasons highlights strong genetic control and low inter-annual plasticity in strawberry pollen viability under these conditions.

Table 1. Season-wise and pooled pollen viability and pollen germination of six strawberry (*Fragaria × ananassa* Duch.) cultivars

Cultivar	Pollen viability (%)		Pooled	Pollen germination (%)		
	2024-25	2025-26		2024-25	2025-26	Pooled
Chandler	78.800 ± 0.709	79.167 ± 1.618	78.970	63.000 ± 0.577	66.333 ± 0.882	64.670
Kimberly	71.333 ± 1.856	72.833 ± 1.878	72.080	57.667 ± 0.882	57.667 ± 2.333	57.670
Larson	63.500 ± 0.866	64.333 ± 1.202	63.920	51.000 ± 1.528	55.000 ± 2.082	53.000

(continued on next page)

Cultivar	Pollen viability (%)			Pollen germination (%)		
	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled
Sweet Charlie	74.933 ± 0.581	75.667 ± 1.202	75.300	64.333 ± 1.202	67.667 ± 1.202	66.000
Winterdawn	76.333 ± 0.882	78.667 ± 0.882	77.500	61.667 ± 3.930	62.667 ± 2.028	62.170
<i>Selva</i>	66.000 ± 2.082	68.667 ± 0.882	67.330	67.667 ± 1.453	70.333 ± 2.186	68.670
CD ($P \leq 0.05$)	4.4061	4.2906	2.880	5.3502	5.5025	3.726

Values are mean ± SE. CD, critical difference at $P \leq 0.05$.

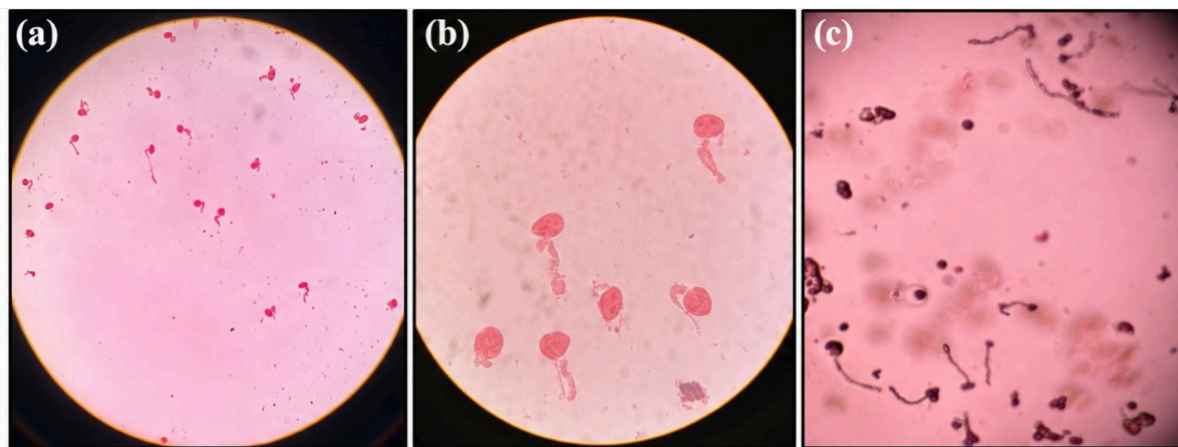


Figure 2. Representative micrographs of *in vitro* pollen germination in strawberry (*Fragaria × ananassa* Duch.) at 12 and 24 h of incubation: (a, c) 12 h and (b) 24 h.

These genotypic differences in pollen viability corroborate earlier reports demonstrating significant intra-specific variation in strawberry staminate fertility. Żebrowska (1997) documented wide variation in pollen viability among genotypes, linking these differences to anther morphology and microsporogenesis. Using an identical erythrosin B staining protocol across 16 strawberry cultivars, Lata *et al.* (2018) reported viability ranges of 60.05% to 78.35%. Our pooled findings (63.92% to 78.97%) align closely with these benchmarks, with Chandler and Winterdawn defining the upper threshold of previously reported values.

Divergence in pollen viability is driven by intrinsic genetic architecture interacting with microclimatic conditions during microsporogenesis and anthesis. Male gametophytic tissues are particularly vulnerable to thermal and hygric fluctuations, and genotypes differ markedly in buffering capacity against such stresses. Leech *et al.* (2000) observed marked cultivar-dependent differences in pollen longevity across varying temperature and relative humidity regimes, a pattern further validated under controlled thermal treatments by Sturzeanu *et al.* (2020). Maintaining high pollen viability carries direct agronomic significance: Lee *et al.* (2026) demonstrated that sustained staminate viability directly increases the proportion of fertilized achenes and final receptacle mass, establishing pollen competence as a functional determinant of commercial fruit grade.

Across both study years, Chandler and Winterdawn maintained superior viability, whereas Larson consistently exhibited inferior performance with minimal inter-annual numerical fluctuation. However, because multi-factor analysis of variance was not performed to formally partition the season and cultivar × times and season interaction effects, these cross-year trends remain descriptive rather than statistically confirmed benchmarks of phenotypic stability.

3.1.2. Pollen germination

In vitro pollen germination varied significantly ($P < 0.05$) among the evaluated cultivars across both cropping seasons (Table 1). In 2024–25, germination ranged from 51.00% in Larson to 67.67% in *Selva*; *Selva* was statistically comparable to Sweet Charlie (64.33%) and Chandler (63.00%). A similar pattern occurred in 2025–26, with *Selva* maintaining the highest germination capacity (70.33%), followed closely by Sweet Charlie (67.67%) and Chandler (66.33%), with no significant divergence among these top three performers. Larson exhibited the lowest germination capacity in both seasons (51.00% and

55.00%, respectively). Representative light micrographs illustrating *in vitro* pollen germination and subsequent tube elongation are presented in Figure 2.

Pollen grains were scored as germinated when pollen tube length exceeded grain diameter. Pooled analysis resolved clear genotypic distinctions (pooled CD = 3.726): *Selva* achieved the highest overall germination (68.67%), which was statistically comparable only to Sweet Charlie (66.00%). Chandler (64.67%) and Winterdawn (62.17%) displayed intermediate germination, whereas Kimberly (57.67%) and Larson (53.00%) exhibited the lowest performance. Consequently, the genotypic hierarchy for germination diverged from that observed for viability.

A notable physiological discordance emerged between *Selva* and Chandler. Although Chandler produced the highest proportion of viable pollen, it did not maximize germination; conversely, *Selva* yielded lower stainability yet achieved the highest *in vitro* germination. This discrepancy underscores that cytochemical staining and functional germination are not interchangeable proxies for male gametophytic fitness. Staining reflects cellular integrity and membrane intactness, whereas *in vitro* germination functionally evaluates physiological activation, metabolic competence, and tube emergence kinetics under specific osmotic and nutritional conditions.

These genotypic differences align with Lata *et al.* (2018), who observed significant variation in strawberry pollen germination using a standard 15% sucrose medium. Moreover, functional germination is highly sensitive to microclimatic conditions during microsporogenesis and anthesis. Leech *et al.* (2000) showed that pollen germination drops precipitously following post-anthesis exposure to elevated temperature and humidity. Similarly, thermal stress suppressed pollen tube growth and subsequent yield in everbearing strawberries (Karapatzak *et al.*, 2012), while Sturzeanu *et al.* (2020) demonstrated genotype-dependent germination responses across thermal regimes. Thus, *in vitro* germination represents an integrated output of genotypic potential, pre-anthesis physiological status, and the immediate ambient environment.

Although relative cultivar rankings remained consistent across both years, with *Selva* and Sweet Charlie consistently superior and Larson inferior most cultivars exhibited numerically higher germination in 2025–26 than in 2024–25. In the absence of a factorial ANOVA partitioning the environment and genotype-by-environment interaction

terms, these inter-annual differences remain descriptive rather than statistically verified.

3.2. Stigma receptivity

Stigma receptivity varied significantly ($P < 0.05$) among the evaluated cultivars across both cropping seasons (Table 2). In 2024–25, receptivity ranged from 69.00% in Sweet Charlie to 89.33% in Winterdawn. Winterdawn was statistically comparable to Kimberly (87.33%), while the remaining cultivars exhibited significantly lower values. During 2025–26, Winterdawn maintained the highest receptivity (92.33%), followed by Kimberly (90.33%) and Chandler (87.00%), with no significant divergence among these top three cultivars ($CD = 6.305$). Across both seasons, numerical pooled means ranked in descending order, Winterdawn (90.83%), Kimberly (88.83%), Chandler (83.67%), Larson (78.50%), Selva (72.50%), and Sweet Charlie (71.67%). Because a pooled critical difference was not computed for this parameter, these pooled values are reported descriptively to delineate overall cross-season trends without formal mean separation.

Table 2. Season-wise and pooled stigma receptivity of six strawberry (*Fragaria × ananassa* Duch.) cultivars

Cultivar	Stigma receptivity (%)		
	2024-25	2025-26	Pooled
Chandler	80.333 ± 0.882	87.000 ± 1.155	83.667
Kimberly	87.333 ± 1.453	90.333 ± 0.882	88.833
Larson	77.333 ± 1.453	79.667 ± 1.453	78.500
Sweet Charlie	69.000 ± 2.082	74.333 ± 2.333	71.667
Winterdawn	89.333 ± 1.202	92.333 ± 1.453	90.833
Selva	70.000 ± 1.155	75.000 ± 2.887	72.500
CD ($P \leq 0.05$)	4.385	6.3054	-

Values are mean ± SE. CD, critical difference at $P \leq 0.05$. Pooled means are presented descriptively because a pooled CD was not computed.

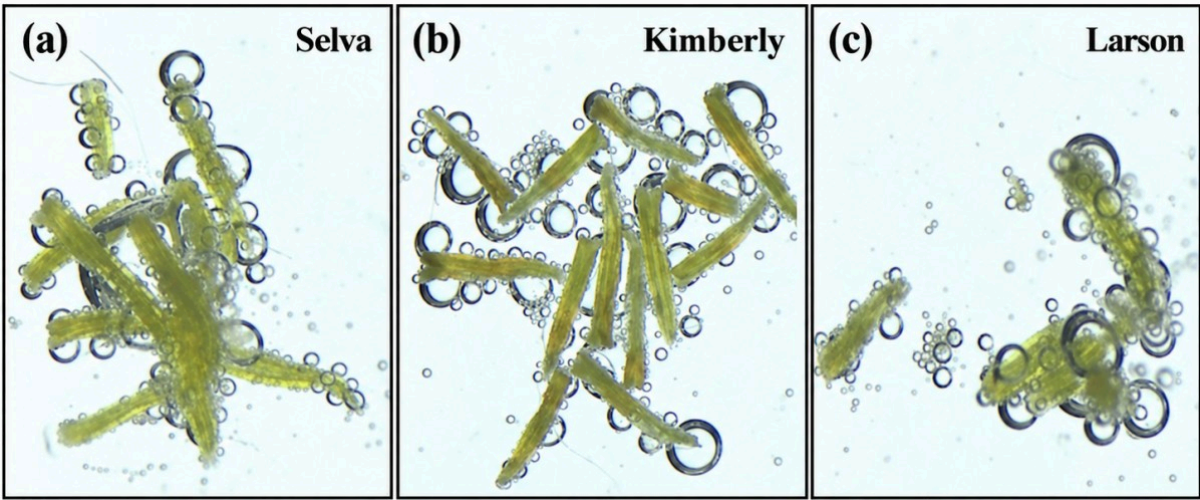


Figure 3. Representative micrographs showing stigma receptivity in strawberry (*Fragaria × ananassa* Duch.) cultivars: (a) Selva, (b) Kimberly and (c) Larson, as assessed by the hydrogen peroxide (H₂O₂) test. Stigma receptivity was inferred from the extent of bubble formation on the stigmatic surface.

Genotypic variation in stigma receptivity is biologically critical because fertilization kinetics require that viable pollen deposition coincides precisely with a physiologically receptive stigmatic surface capable of supporting hydration, germination, and style penetration. Our findings corroborate Lata *et al.* (2018), who identified marked cultivar differences in strawberry stigma receptivity with a distinct peak at anthesis. The present data confirm substantial genotypic divergence in pistillate competence when evaluated at this critical developmental stage. Representative light micrographs illustrating stigmatic surface peroxidase/esterase activity and receptive morphology across selected cultivars are presented in Figure 3. The hydrogen peroxide bubble assay detects endogenous peroxidase activity on the receptive stigmatic surface, providing a rapid qualitative and semi-quantitative proxy for pistillate competence (Dafni and Maués, 1998). However, stigma receptivity is temporally dynamic, the stigmatic papillae undergo marked developmental transitions and can remain capable of supporting pollen germination for several days post-anthesis depending on genotype and microclimate (Zini *et al.*, 2026). Thus, the cultivar differences documented here reflect relative pistillate competence specifically at the anthesis stage. The elevated receptivity of Winterdawn and Kimberly contrasted sharply with their respective staminate performance profiles. Winterdawn combined superior pollen viability with high stigma receptivity, yet exhibited intermediate pollen germination. Kimberly displayed high stigma receptivity alongside moderate pollen viability and germination. Conversely, Selva maximized pollen germination despite lower viability and stigma receptivity, while Sweet Charlie

exhibited high germination coupled with the lowest pooled stigma receptivity. These divergent genotypic rankings confirm that pollen viability, *in vitro* germination capacity, and stigma receptivity represent decoupled physiological components of reproductive competence that cannot serve as reciprocal proxies. This physiological divergence carries direct implications for cultivar characterization and breeding strategy. Recent investigations demonstrate that achene fertilization, fruit set, and receptacle enlargement are governed by multi trait floral interactions, including absolute pollen load, gametophytic longevity, and pistil architecture (Sharma *et al.*, 2025; Lee *et al.*, 2026). Phenotyping both staminate and pistillate attributes concurrently provides a far more robust predictive framework for parental selection and cross-compatibility than isolated male-fertility assays. Overall, pollen viability exhibited narrow within-cultivar dispersion, whereas *in vitro* germination displayed greater variability. Stigma receptivity followed an independent genotypic hierarchy, with Winterdawn and Kimberly consistently superior and Sweet Charlie and Selva inferior. Although receptivity was numerically elevated in 2025–26 across all cultivars, the functional independence or co-segregation of these traits warrants formal validation through multivariate and correlation analyses.

4. Conclusion

The evaluated strawberry cultivars exhibited significant genotypic divergence across pollen viability, *in vitro* germination capacity, and stigma receptivity. Chandler and Winterdawn demonstrated superior

pollen viability, *Selva* and Sweet Charlie maximized pollen germination, and Winterdawn and Kimberly displayed the highest stigmatic receptivity; conversely, Larson consistently underperformed across both male gametophytic traits.

No single cultivar maximized all three reproductive attributes, demonstrating that pollen viability, germination capacity, and pistillate receptivity are physiologically uncoupled traits that cannot serve as reciprocal proxies for reproductive competence. However, Winterdawn emerged as the most balanced genotype, combining high pollen viability with peak stigma receptivity, underscoring its high potential as a parental candidate for controlled hybridization schemes. Collectively, these findings demonstrate that multi-trait phenotyping encompassing both staminate and pistillate fitness parameters is critical for accurately characterizing strawberry floral biology, identifying elite parental material, and optimizing reproductive success in temperate breeding programs.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

AI Declaration: The authors used artificial intelligence (AI)-assisted tools solely to improve the grammar, spelling, and language clarity of

the manuscript and to enhance the quality and resolution of the figures. All scientific statements, interpretations, and conclusions were developed, verified, and approved by the authors, who take full responsibility for the accuracy and integrity of the manuscript.

References

1. Crispim JG, Rêgo ER, Rêgo MM, Nascimento NFF, Barroso PA. Stigma receptivity and anther dehiscence in ornamental pepper. *Horticultura Brasileira*. 2017;35(4):609-612.
2. Areia M, Crispim JG. Stigma receptivity and anther dehiscence in ornamental pepper. *Horticultura Brasileira*. 2017;35:609-612.

How to cite this article: Dhar S, Sundouri A, Kumar A, Masoodi K, Ali G, Singh P, et al. Palynological variability study among strawberry (*Fragaria* × *ananassa* Duch.) cultivars for pollination and breeding. *International Journal of Advanced Biochemistry Research*. 2026;SP-10(10):437-442. doi: <https://www.doi.org/10.33545/26174693.2026.v10.i10Sf.10318>

Authors

Sukjai Dhar

Division of Fruit Science, Sher-e- Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India

AS Sundouri

Division of Fruit Science, Sher-e- Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India

Amit Kumar

Division of Fruit Science, Sher-e- Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India

Khalid Masoodi

Division of Plant Biotechnology, Sher-e- Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India

Gowhar Ali

Division of Plant Breeding, Sher-e- Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India

Parmeet Singh

Associate Director Research, Sher-e- Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India

RP Phanbah

Division of Vegetable Science, Sher-e- Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India