Seed Res. 53 (2): 183-189, December, 2025
doi: https://doi.org/10.56093/SR.v53i2.13

Studies on Stigma Receptivity and Pollen Viability in Parental Lines of Phule Aadishakti Hybrid of pearlmillet as Affected by Different Seasons

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(Received July 2025; Revised August 2025; Accepted September 2025)

ABSTRACT: Stigma receptivity and pollen viability are critical determinants of successful hybrid seed production in pearl millet (*Pennisetum glaucum* (L.) R. Br.), particularly in male-sterility–based hybrid breeding systems. The present investigation was undertaken to study the effect of seasons on stigma receptivity and pollen viability in parental lines of the Phule Aadishakti pearl millet hybrid during *Kharif* and summer seasons. The experimental material comprised the male-sterile line DHLB-8A (female parent), the maintainer line DHLB-8B, and the restorer line DHLB-967 (male parent). Stigma receptivity was evaluated under six starvation interval treatments (0, 1, 2, 3, 4, and 5 days), while pollen viability was assessed at six pollination intervals (0, 2, 4, 6, 8, and 10 hours). Seed set percentage, number of seeds per earhead, seed weight per earhead, and 1000-seed weight were recorded to assess reproductive success. Results revealed that both stigma receptivity and pollen viability were significantly influenced by season, with superior performance observed during the *Kharif* season compared to the summer season. Higher seed set and yield attributes in *Kharif* indicated more favorable environmental conditions for reproductive processes. The findings highlight the importance of optimizing season-specific flowering synchronization and pollination timing for efficient hybrid seed production. This study provides valuable insights for improving seed yield and quality in pearl millet hybrid breeding and commercial seed production programs.

Keywords: Pearl millet, stigma receptivity, pollen viability, seasons

INTRODUCTION

Pearl millet (*Pennisetum glaucum* (L.) R. Br.), a highly cross-pollinated crop, has witnessed remarkable success in the commercial exploitation of hybrid vigour. The development of hybrid technology in pearl millet became feasible following the discovery of cytoplasmic male sterility (CMS) systems and fertility-restoring genes. Although cytoplasmic male sterility in pearl millet had been identified earlier, this information was initially not effectively utilized for harnessing hybrid vigour [1]. It was only after the discovery of the cytoplasmic–genetic male sterile line Tift 23A and its corresponding maintainer line by scientists in the USA that male sterility was successfully exploited for the development of high-yielding pearl millet hybrids [2].

In hybrid seed production, the female parent used in foundation and certified seed production is a male-sterile line, which depends entirely on viable pollen from the male parent for successful seed set. Under such conditions, adequate pollen viability of the male line, coupled with prolonged and effective stigma receptivity of the male-sterile line, becomes a critical prerequisite for achieving optimum seed set and seed yield. In addition to genetic factors, reproductive success in pearl millet is strongly influenced by environmental and edaphic conditions, particularly variations associated with different planting seasons.

Considering the pivotal role of male-sterile lines in hybrid development and seed production, the present investigation entitled *“Studies on receptivity and pollen viability in parental lines of pearl millet as affected by different seasons”* was undertaken to study the duration of stigma receptivity of the seed parent and to assess pollen viability of the restorer and maintainer lines during the *Kharif* and summer seasons.

MATERIALS AND METHODS

The experiment was conducted in a Factorial Randomized Block Design (FRBD) with four replications. The experimental material comprised three parental lines of the Phule Aadishakti pearl millet hybrid (Table 1), namely the male-sterile line DHLB-8A (female parent),

Table 1. Effect of season, starvation period and their interaction on seed setting %, number of seed per ear head, seed weight per ear head, 1000 seed weight at different starvation period in DHLB -8A (Male sterile)

Season × Starvation period	Seed setting %	Number of Seed per ear head	Seed weight per ear head	1000 seed weight
S1T0	93.98 (76.05)	1046.50 (32.35)	11.47	11.22
S1T1	86.50 (68.64)	953.75(30.89)	10.33	10.86
S1T2	64.28 (53.32)	585.00(24.13)	7.88	10.28
S1T3	17.12 (24.38)	178.75(13.25)	2.30	8.80
S1T4	0.00 (0.00)	0.00(0.71)	0.00	0.00
S1T5	0.00 (0.00)	0.00(0.71)	0.00	0.00
S2T0	96.82 (80.75)	1238.50(35.19)	12.91	12.51
S2T1	91.58 (73.22)	1033.25(32.15)	11.20	11.11
S2T2	76.47 (61.02)	827.50(28.77)	8.50	10.69
S2T3	24.73 (29.78)	221.50(14.90)	2.16	9.60
S2T4	0.00 (0.00)	0.00(0.71)	0.00	0.00
S2T5	0.00 (0.00)	0.00(0.71)	0.00	0.00
SE (m) ±	1.33	0.50	0.18	0.27
CD at 5%	3.82	1.44	0.51	NS
C.V. (%)	5.78	5.60	6.35	7.76

	Seed setting %	Number of Seed per ear head	Seed weight per ear head	1000 seed weight
Season				
S1 (Summer)	43.64 (37.06)	460.67(17.01)	5.33	6.86
S2 (*Kharif*)	48.26(40.80)	553.46(18.74)	5.80	7.32
SE (m) ±	0.51	0.20	0.07	0.11
C.D.at 5%	1.46	0.59	0.21	0.32
Starvation Period (days)				
T_0 (0 days)	95.40(78.40)	1142.50(33.77)	12.19	11.86
T_1 (1 day)	89.04(70.93)	993.50(31.52)	10.77	10.99
T_2(2 days)	70.37(57.17)	706.25(26.45)	8.19	10.49
T_3(3 days)	20.92 (27.08)	200.13(14.08)	2.23	9.20
T_4(4 days)	0.00(0.00)	0.00(0.71)	0.00	0.00
T_5(5 days)	0.00(0.00)	0.00(0.71)	0.00	0.00
SE (m) ±	0.88	0.35	0.12	0.19
C.D. at 5%	2.53	1.02	0.36	0.56

the maintainer line DHLB-8B, and the restorer line DHLB-967 (male parent). Seeds of these parental lines were obtained from the All India Coordinated Research Project (AICRP) on Pearl Millet, College of Agriculture, Dhule.

For the assessment of stigma receptivity, six starvation interval treatments were imposed, viz., 0, 1, 2, 3, 4, and 5 days after stigma emergence. Pollen viability was evaluated under six pollination interval treatments, namely 0, 2, 4, 6, 8, and 10 hours after pollen collection. The male-sterile line DHLB-8A was used as the female parent for stigma receptivity studies, while the maintainer line DHLB-8B and the restorer line DHLB-967 served as male parents for pollen viability assessment.

RESULT AND DISCUSSION

Effect of Starvation Period and Season on Seed Set and Yield Attributes in Male-Sterile Line DHLB-8A

Seed set percentage

Effect of season

Mean seed set percentage of the male-sterile line DHLB-8A differed significantly between seasons (Table 1). Averaged across starvation periods, seed set was significantly higher during the *Kharif* season (48.26%) compared to the summer season (43.64%), indicating a favorable reproductive environment during *Kharif*.

Effect of starvation period

Starvation period had a pronounced effect on seed set percentage. Pollination immediately after stigma emergence (T_0) resulted in the highest seed set (95.40%), followed by one day of starvation (T_1; 89.04%). Seed set declined significantly with each successive delay in pollination, with a sharp reduction observed at three days of starvation (T_3; 20.92%). No seed set was recorded when pollination was delayed beyond three days (T_4 and T_5).

Season × starvation period interaction

The interaction between season and starvation period was significant. The highest seed set was recorded when pollination was carried out at zero-day starvation (T_0), registering 96.82% in *Kharif* and 93.98% in summer, followed by one-day starvation (T_1) with 91.58% and 86.50% seed set in *Kharif* and summer, respectively. These results indicate that stigma receptivity in the male-sterile line remained effective for up to two days in both seasons, with higher seed set consistently observed during *Kharif*. The enhanced performance during *Kharif* may be attributed to relatively higher humidity and moderate temperatures, whereas high temperature and low humidity during summer adversely affected seed set. Similar observations on limited duration of stigma receptivity in pearl millet have been reported earlier [3–6].

Number of seeds per earhead

Effect of season

The mean number of seeds per earhead differed significantly between seasons (Table 1). The male-sterile line DHLB-8A produced a higher number of seeds per earhead during *Kharif* (553.46) compared to summer (460.67).

Effect of starvation period

Pollination at zero-day starvation (T_0) resulted in the maximum number of seeds per earhead (1142.50), followed by one-day starvation (T_1; 993.50). A significant and progressive decline in seed number was observed with increasing starvation period, with the lowest number recorded at three days of starvation (T_3; 200.13). No seeds were formed when pollination was delayed beyond three days due to complete failure of seed set.

Season × starvation period interaction

The interaction effect was significant. The highest number of seeds per earhead was recorded under T_0 during *Kharif* (1238.50) and summer (1046.50), followed by T_1 with 1033.25 and 953.75 seeds, respectively. Overall, seed number was consistently higher in *Kharif* than in summer across all starvation periods. Similar reductions in seed number with delayed pollination have also been reported in sorghum [7].

Seed weight per earhead (g)

Effect of season

Seed weight per earhead differed significantly between seasons, with higher mean values recorded during *Kharif* (5.80 g) than summer (5.33 g) (Table 1).

Effect of starvation period

Pollination immediately after stigma emergence (T_0) resulted in the highest seed weight per earhead (12.91 g), followed by one-day starvation (T_1; 10.77 g). Seed weight declined significantly with increasing starvation period, reaching a minimum at three days of starvation (T_3; 8.19 g). No seed formation occurred beyond this period.

Season × starvation period interaction

The interaction effect was significant. Maximum seed weight per earhead was recorded at T_0 during *Kharif* (12.91 g) and summer (11.47 g), followed by T_1 with 11.20 g and 10.33 g, respectively. Across starvation periods, seed weight per earhead was consistently higher during *Kharif*.

1000-seed weight (g)

Effect of season

The mean 1000-seed weight was significantly higher during *Kharif* (7.32 g) compared to summer (6.86 g) (Table 1).

Effect of starvation period

Significantly higher 1000-seed weight was observed when pollination was carried out at zero-day starvation (T_0; 11.86 g). A gradual and significant decline was observed with increasing starvation period, with the lowest 1000-seed weight recorded at three days of starvation (T_3; 9.20 g). No seed formation was observed beyond this period.

Season × starvation period interaction

The interaction between season and starvation period was non-significant for 1000-seed weight. However, higher values were consistently recorded under T_0 in both *Kharif* (12.51 g) and summer (11.22 g). The decline in 1000-seed weight with increasing starvation period may be attributed to reduced seed size resulting from impaired fertilization and grain filling, as reported earlier [8].

Pollen Viability Studies in Maintainer Line (DHLB-8B)

Pollen viability was assessed by pollinating receptive stigmas with pollen collected at different time intervals after anthesis, and its effect on seed set and yield attributes was evaluated under *Kharif* and summer seasons.

Seed set percentage

Effect of season

Mean seed set percentage in the maintainer line DHLB-8B differed significantly between seasons (Table 2). Averaged over pollination intervals, higher seed set was recorded during the *Kharif* season (49.03%) compared to the summer season (40.73%), indicating more favourable conditions for pollen viability and fertilization during *Kharif*.

Table 2. Effect of season, starvation period and their interaction on seed setting %, number of seed per ear head, seed weight per ear head, 1000 seed weight at different pollination period of B line i.e. DHLB -8B (Maintainer line)

Season ×Pollination period interval (hrs.) weight(g)	Seed setting	Number of seed percentage(%)	Seed weight per ear head	1000 seed per ear head(g)
S1T0	94.13(76.12)	1057.00(32.52)	12.48	12.18
S1T1	83.40(66.04)	956.50(30.93)	10.61	11.75
S1T2	59.75(52.40)	680.00(26.07)	8.90	10.98
S1T3	6.00(14.15)	170.00(13.04)	1.25	10.19
S1T4	1.13(6.56)	12.25(3.49)	0.14	0.00
S1T5	0.00(0.00)	0.00(0.71)	0.00	0.00
S2T0	98.28(82.60)	1196.75(34.60)	12.84	12.50
S2T1	95.22(77.67)	1048.75(32.39)	11.98	12.45
S2T2	72.38(58.32)	903.75(30.07)	9.13	11.68
S2T3	21.58(24.59)	329.00(18.14)	2.75	10.58
S2T4	5.33(13.22)	61.25(7.85)	0.68	0.00
S2T5	1.40(6.69)	13.75(3.73)	0.17	0.00
SE (m) ±	1.02	0.31	0.18	0.20
C.D. at 5%	2.93	0.89	0.52	NS
C.V.(%)	5.12	3.18	6.07	5.25

	Seed setting percentage (%)	Number of seed per ear head	Seed weight per ear head(g)	1000 seed weight(g)
Season				
S1 (Summer)	40.73(35.88)	479.26(17.79)	5.79	7.52
S2 (*Kharif*)	49.03(43.85)	592.21(21.13)	6.19	7.87
S.E.(m)±	0.42	0.13	0.07	0.08
C.D.at 5%	1.20	0.36	0.21	0.24
Pollination period interval (hrs.)				
T_0(0 hrs. interval)	96.20(79.36)	1126.88(33.56)	12.66	12.34
T_1(2 hrs. interval)	89.31(71.86)	1002.63(31.66)	11.79	12.10
T_2(4 hrs. interval)	66.06(55.36)	791.88(28.07)	9.01	11.33
T_3(6 hrs. interval)	13.79(19.37)	249.50(15.59)	2.00	10.38
T_4(8 hrs. interval)	3.23(9.89)	36.75(5.67)	0.41	0.00
T_5(10 hrs. interval)	0.70(3.34)	6.88(2.22)	0.09	0.00
SE (m) ±	0.72	0.22	0.13	0.14
C.D. at 5%	2.07	0.63	0.37	0.41

(Note: Figures in brackets are arcsine and square root transform values)

Effect of pollination interval

Pollination interval had a significant effect on seed set percentage. Pollination carried out immediately after pollen collection (T_0) resulted in the highest seed set (96.20%), followed by pollination after 2 hours (T_1; 89.31%). Seed set declined significantly with increasing delay in pollination, with a sharp reduction observed at 6 hours after pollen collection (T_3; 13.79%). Very low seed set was recorded at 8 and 10 hours due to loss of pollen viability.

Season × pollination interval interaction

The interaction between season and pollination interval was significant. The highest seed set was recorded under T_0 during *Kharif* (98.28%) and summer (94.13%), followed by T_1 with 95.22% and 83.40%, respectively. The results indicate that pollen collected at 08:00 h remained viable for up to 4 hours in both seasons, with superior viability during *Kharif*. Similar diurnal patterns of pollen viability in pearl millet and related crops have been reported earlier [9–11].

Number of seeds per earhead

Effect of season

The mean number of seeds per earhead differed significantly between seasons (Table 2). The maintainer line DHLB-8B produced a higher number of seeds per earhead during *Kharif* (592.21) than during summer (479.26).

Effect of pollination interval

Maximum seed number per earhead was obtained when pollination was carried out immediately after pollen collection (T_0; 1126.88), followed by 2-hour interval (T_1; 1002.63). Seed number declined significantly with increasing pollination interval, reaching the lowest value at 6 hours (T_3; 249.50). Very few or no seeds were formed when pollination was delayed beyond this period.

Season × pollination interval interaction

The interaction effect was significant. The highest number of seeds per earhead was recorded under T_0 during *Kharif* (1196.75) and summer (1057.00), followed by T_1 with 1048.75 and 903.75 seeds, respectively. Overall, seed number was consistently higher during *Kharif* across all pollination intervals. These results confirm that higher pollen viability directly contributes to increased seed number, as also reported earlier [7,11].

Seed weight per earhead (g)

Effect of season

Seed weight per earhead differed significantly between seasons, with higher mean values recorded during *Kharif* (6.19 g) compared to summer (5.79 g) (Table 2).

Effect of pollination interval

Pollination immediately after pollen collection (T_0) resulted in the highest seed weight per earhead (12.66 g), followed by T_1 (11.79 g). A significant decline in seed weight was observed with increasing pollination interval, with minimal seed weight recorded at 6 hours (T_3; 2.00 g). Very low or no seed weight was recorded beyond this interval due to poor seed set.

Season × pollination interval interaction

The interaction effect was significant. The maximum seed weight per earhead was recorded under T_0 during *Kharif* (12.84 g) and summer (12.48 g), followed by T_1 with 11.98 g and 10.61 g, respectively. The results indicate that seed weight is strongly influenced by pollen viability and timely pollination [6,12,13].

1000-seed weight (g)

Effect of season

The mean 1000-seed weight was significantly higher during *Kharif* (7.87 g) than summer (7.52 g) (Table 2).

Effect of pollination interval

The highest 1000-seed weight was observed when pollination was carried out immediately after pollen collection (T_0; 12.34 g), followed by T_1•(12.10 g). A gradual decline in 1000-seed weight was observed with increasing pollination interval, with the lowest value recorded at 6 hours (T_3; 10.38 g). No measurable 1000-seed weight was recorded at longer intervals due to lack of seed set.

Season × pollination interval interaction

The interaction between season and pollination interval was non-significant for 1000-seed weight. Nevertheless, higher values were consistently observed under *Kharif* conditions, and a declining trend was evident with delayed pollination.

Influence of temperature and relative humidity on seed set

During the *Kharif* season, the maximum and minimum

Table 3. Effect of temperature and relative humidity on seed setting percentage (%) in male sterile line DHLB-8A and maintainer line DHLB-8B

Season	Average Temperature (°C)		Average relative humidity (%)		Seed setting % in male sterile line DHLB-8A and maintainer line DHLB-8B	
	Maximum	Minimum	Morning	Evening	Stigma receptivity in male sterile line DHLB-8A	Pollen viability maintainer line DHLB-8B
Summer 2023	32.62	18.18	71.75	27.01	43.64	40.73
Kharif 2023	30.77	23.12	83.18	54.58	48.26	49.03

temperatures during flowering ranged from 30.77°C to 23.12°C, with morning and evening relative humidity of 83.18% and 54.58%, respectively. In contrast, the summer season recorded higher temperature fluctuations (32.62°C to 18.18°C) and lower relative humidity, particularly during the evening (27.01%).

Higher seed set during *Kharif* in both the male-sterile line DHLB-8A and the maintainer line DHLB-8B can be attributed to comparatively lower temperatures and higher relative humidity during flowering, which favoured both stigma receptivity and pollen viability. In summer, reduced relative humidity and elevated temperatures adversely affected pollen viability and fertilization efficiency. These observations are in agreement with earlier reports highlighting the sensitivity of reproductive processes in pearl millet to environmental conditions [14].

CONCLUSION

The present study clearly demonstrated that reproductive efficiency and seed quality in pearl millet are strongly influenced by both pollination timing and seasonal conditions. In the male-sterile line, a progressive decline in seed quality parameters was observed with increasing starvation period, indicating a rapid loss of stigma receptivity following stigma emergence. Similarly, in the maintainer and restorer lines, delayed use of pollen after collection resulted in a marked reduction in pollen viability, which in turn adversely affected seed set and associated yield attributes.

Seed setting percentage, number of seeds per earhead, seed weight per earhead, and 1000-seed weight were consistently higher when pollination was carried out immediately after stigma emergence or pollen collection, emphasizing the importance of timely pollination for successful hybrid seed production. Across all parental lines, these parameters were significantly superior during the kharif season compared to the summer season. The favourable environmental conditions prevailing during kharif, particularly moderate temperatures and higher relative humidity during the flowering period, enhanced stigma receptivity and pollen viability, thereby improving fertilization and seed development.

Overall, the findings indicate that kharif season is more suitable for pearl millet hybrid seed production than summer season under the conditions studied. For achieving higher seed yield and better seed quality, pollination should be synchronized to ensure minimal stigma starvation and immediate use of freshly collected pollen. These results provide practical guidelines for optimizing planting season, pollination timing, and hybrid seed production efficiency in pearl millet breeding and seed production programmes.

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