Refining Harvest Timing and Physiological Maturity for Optimal Seed Yield in *Stylosanthes hamata*

ABSTRACT

Aims:

The aim of the study was to standardize cutting schedules and determine the physiological maturity of *Stylosanthes hamata* to improve seed production.

Study Design: The study was carried out during the Kharif season of 2022-23 at the ICAR-Indian Grassland and Fodder Research Institute, SRRS, Dharwad, Karnataka, India.

Place and Duration of Study: The study was conducted at the ICAR-Indian Grassland and Fodder Research Institute, SRRS, Dharwad, Karnataka, India, during the Kharif season of 2022-23.

Methodology: Flower phenology studies were conducted to estimate pollen viability using the baker method. Mulching was applied to study its effect on growth, flowering parameters, seed yield, and quality. Various growth parameters were measured at different days after sowing (DAS), By 90 DAS, several parameters were recorded for plants in the mulching (M2) plots compared to the non-mulching (M1) plots. These parameters included plant height, days to 50% flowering, number of branches, days to maturity, seed yield, seed germination, shoot length, root length, seedling vigor index, seeds on plant, physical purity, test weight, and the minimum number of seeds fallen on the ground.

Results: Flower phenology studies revealed that the baker method was effective for estimating pollen viability. It was noted that *Stylosanthes* exhibited protandry, with a total of 10 stamens, where the development of 5 long anthers preceded the remaining 5 short anthers by 1-2 days.

The highest pollen viability was observed during the morning hours on the day of anthesis, reaching a maximum of 67.05%. The main flowering period for *Stylosanthes* was from September to December, with an additional minor blooming period observed during April-May. After anthesis, *Stylosanthes* flowers lasted for a maximum of 8-9 hours before wilting. The use of mulching significantly improved various growth and flowering parameters, as well as seed yield and quality. At 60 days after sowing (DAS), initial plant height was similar for plots without mulch (M1) and those with mulch (M2) at around 30.85cm and 30.68cm respectively. However, by 90 DAS, plants in the M2 plots had significantly greater height (66.65cm) compared to those in M1. Similarly, various other parameters such as days to 50% flowering (88.35), number of branches (6.25), days to maturity (159.18), seed yield (771.98kg/ha), seed germination (35.65%), shoot length (7.30cm), root length (6.55cm), seedling vigor index (494.91), seeds on plant (5.83%), physical purity (82.33%), test weight (3.24g), and minimum seeds fallen on the ground (78.18%) were also significantly improved with mulching. These results were consistent across different stages of harvesting at 170-180 days after sowing, indicating physiological maturity.

Conclusion:

The study successfully optimized cutting schedules and determined the physiological maturity of *Stylosanthes hamata* to enhance seed production. For optimal growth, seed yield, and quality in *Stylosanthes hamata*, mulching should be used, and seeds should be harvested at 170-180 DAS. Mulching significantly improved plant growth, flowering, and seed yield, with better results in parameters such as plant height, flowering time, and seed quality. The flower phenology study also confirmed the effectiveness of the Baker method for estimating pollen viability. These findings provide valuable insights for improving seed production practices for *Stylosanthes hamata*.

Keywords: Flower phenlogy, Cutting schedule, physiological maturity, *S. hamata*

Introduction

Caribbean stylo, scientifically known as *Stylosanthes hamata*, belongs to the *Fabaceae* family and is indigenous to the Caribbean islands and nearby mainland regions. This plant encompasses both diploid and tetraploid cultivars, with tetraploids demonstrating higher drought tolerance and frequently utilized for pasture purposes.

Stylosanthes hamata emerges as a promising crop with notable nutritional attributes. Green leaf crude protein (CP) content ranges from 17 to 24%, while stems contain 6-12%, influenced by regrowth age and environmental factors. In Vitro Dry Matter Digestibility (IVDMD) ranges from 60–65%, with green foliage contributing 66-72% and stems 33-57%. Forage phosphorus (P) levels vary with soil P status and regrowth age, potentially from 0.08-0.3%. Despite declining nutritional value during the dry season, Caribbean stylo remains palatable and non-toxic (Stace and Edye, 1984). Dry matter yields up to 17 t/ha DM under ideal conditions, with animal liveweight gains ranging from 140 to 160 kg/hd/yr (Maass and Sawkins, 2004).

The identification of physiological maturity in *Stylosanthes hamata* holds significant importance in agricultural practices. It serves as a cornerstone for optimizing seed production, enhancing crop management strategies, promoting sustainability in agriculture, improving forage quality, and driving research and development efforts in crop science.

Effective cutting management is pivotal for sustaining a healthy plant stand (Guay, 2001). In grass stands, cutting intervals are often too frequent, leading to stand deterioration due to inadequate energy reserves for regrowth. Conversely, infrequent cutting can weaken the stand further by reducing seedling and tiller survival, mainly due to overshadowing by the forage canopy (Jung et al., 1994). Extensive research has underscored the benefits of incorporating legumes into grass stands (Guay, 2001; Casler and Walgenbach, 1990). Maintaining legumes in pastures is crucial for the sustainability of mixed-species ecosystems (Turner et al., 1998).

Expertise in seed generation is predominantly focused on the tetraploid variant of *Stylosanthes hemihamata* nom. nud. Seed harvesting methods typically involve manual collection or mechanical extraction through direct heading, with or without subsequent suction harvest. Generally, seed collection occurs post-flowering when seeds are predominantly brown rather than green. While total seeding potential can reach 1,750-2,000 kg/ha, practical harvest yields from suction harvesting operations typically fall within the 300-600 kg/ha range (Edye and Maass, 1997). Thus, forage cutting and collection of seeds plays prime role on seed quality.

Mulching is necessary in this crop as it plays a significant role in enhancing plant growth by boosting root activity, soluble sugar content, and chlorophyll a levels, while also providing favorable moisture conditions and nutrient availability in the root zone (Xue et al., 2016). Moreover, mulches aid in soil moisture conservation, improve soil nutrient status, mitigate erosion, suppress weed growth, and alleviate residual effects of pesticides, fertilizers, and heavy metals (Iqbal et al., 2020).

Thus, understanding cutting schedules and physiological maturity in *Stylosanthes hamata* is essential for optimizing seed production and maintaining sustainable pasture ecosystems. Keeping this in view the present experiement was carried out on standardization of cutting schedules and identification of physiological maturity of *Stylosanthes hamata* to enhance seed production.

The standardization of cutting schedules and identification of physiological maturity of *Stylosanthes hamata* is a crucial area of research aimed at improving seed production. This research focuses on determining the optimal timing for cutting or harvesting the plants to maximize seed yield. By identifying key physiological indicators of maturity, such as flower phenology and pollen viability, researchers aim to develop guidelines for farmers to enhance the efficiency and effectiveness of seed production methods. Ultimately, this work contributes to the sustainable cultivation of *Stylosanthes hamata*, supporting livestock feed and agricultural systems in these regions.

Materials and methods

Study location:

The experiment focused on standardizing cutting schedules and identifying the physiological maturity of *Stylosanthes hamata* to improve seed production. It was conducted at the ICAR-Indian Grassland and Fodder Research Institute, SRRS, Dharwad, Karnataka, India, during the Kharif season of 2022-23. The study utilized a two-factorial Randomized Complete Block Design and a two-factorial Completely Randomized Design with three replications. The factors investigated were Mulching (M) with two levels: M1 (Control) and M2 (Mulching with polythene cover), and Harvesting methods (H) with four levels: H1 (Harvesting at 150 days after sowing), H2 (Harvesting at 160 days after sowing), H3 (Harvesting at 170 days after sowing), and H4 (Harvesting at 180 days after sowing).

Data collection encompassed various aspects including growth parameters such as plant height (measured in centimeters) at 60 and 90 days after sowing (DAS), number of branches per plant, and flowering pattern. Additionally, observations were made on flowering parameters such as days to 50% flowering and days to maturity. Seed yield and its attributing parameters were also recorded, including seed yield per plant (in grams), seed yield per plot (in grams), seed yield per hectare (in kilograms per hectare), and test weight (in grams). Furthermore, seed quality parameters such as seed germination percentage, shoot length (measured in centimeters), root length (measured in centimeters), seedling dry weight (measured in milligrams per 10 seedlings), and seedling vigor index were assessed.

Seed quality of Stylosanthes hamata

Germination:

To assess germination, one hundred seeds were methodically chosen from each plot, ensuring representation, and replicated four times for robustness. The germination protocol adhered to the guidelines outlined by the International Seed Testing Association (ISTA), specifically utilizing the top-of-the-paper method. Seeds were meticulously arranged in Petri dishes and incubated within a controlled environment, maintaining a constant temperature of 25±1°C and 95% relative humidity, to simulate optimal germination conditions. After 28 days, the final germination count was conducted, and the germination rate was calculated as a percentage, providing insights into seed viability and performance.

Root Length:

Ten healthy seedlings were randomly selected from the germination test on the 28th day to measure root length, ensuring a representative sample. Root length was meticulously measured from the collar region to the tip of the primary root, employing precise techniques to ensure accuracy. The obtained measurements were then averaged to determine the mean root length, expressed in centimeters. This parameter serves as a vital indicator of seedling vigor and root development, essential for nutrient uptake and overall plant growth.

Shoot Length:

Similarly, ten well-developed seedlings were randomly chosen on the 28th day for assessing shoot length, maintaining consistency in sampling methodology. Shoot length was carefully measured from the tip of the primary leaf to the base of the hypocotyl, employing standardized procedures to ensure precision. The averaged measurements provided valuable insights into shoot growth and development, crucial for assessing seedling health and vigor.

Seedling Vigour Index-I:

The seedling vigor index, a composite measure of germination and seedling growth, was calculated using the formula proposed by Abdul Baki and Anderson (1973). This index integrates both germination percentage and mean seedling length, providing a comprehensive assessment of seedling vigor. By multiplying the germination percentage by the mean seedling length, the index offers a quantitative measure of overall seedling performance, facilitating comparisons between treatments and aiding in the evaluation of seed quality and viability.

Seedling Vigour Index I = Germination % × Mean seedling length (cm).

Data analysis

The experiment was meticulously analyzed employing two distinct statistical approaches to ensure robustness and accuracy in the interpretation of results. For the field data, a two-factorial randomized completely block design (RCBD) was utilized, enabling systematic evaluation of treatment effects while controlling for potential sources of variation. This design was implemented using the Statistical Package for the Social Sciences (SPSS) software, a widely recognized and reliable tool for statistical analysis in research settings.

In contrast, the laboratory experiment underwent analysis using a completely randomized design (CRD). This approach, commonly employed in controlled laboratory settings, allowed for the assessment of treatment effects with random allocation of experimental units to different treatment groups. The significance of observed differences between treatments was determined at a predetermined confidence level of 5% ($P < 0.05$), adhering to established statistical conventions for hypothesis testing and inference.

The methodology outlined in Snedecor and Cochran's seminal work from 1967 served as the theoretical foundation for the statistical analyses conducted in this study. By adhering to established statistical principles and employing rigorous experimental designs, the validity and reliability of the findings were ensured, thereby enhancing the credibility and trustworthiness of the research outcomes.

Results

The flower phenology studies indicated that the baker method is suitable for estimation of pollen viability in case of *Stylosanthes* species. The results are presented in table 1 and figure 1. It was observed that in *Stylosanthes* pollen is viable before the anthesis of flower and under bud stage also (>2 days before anthesis) hence, *stylosanthes* is protandry in nature. There are total 10 stamens but the development of the 5 long anthers occurs 1-2 days earlier than remaining 5 short anthers. Which provide the continuous mature pollens to stigma and ensure the self-pollination. The highest pollen viability was observed during morning hours on day of anthesis. The maximum pollen viability of 67.05 % was observed in *S. hamata*.

The major flowering period is during september to december but one more minor blooming period is observed during April-May. The flowering and vegetative growth are simultaneous process resulting into seed shattering loss. The longevity of stylosanthes flowers is maximum 8-9 hours after anthesis followed by shriveling and withering of flowers. The anthesis of flowers occurs during the morning hours and it ranges from 6 AM to 12 Noon. The maximum anthesis in all species was taking place during 8.00 am. The stigma receptivity was measured and it was observed that in all species of *stylosanthes* stigma is receptive 1 day before anthesis of flower. In *Stylosanthes hamata* stigma is receptive for longer duration compared to other species.

Table 1: Morphometric features S*tylosanthes hamata*

Morphometric features	***S. hamata***
Flowering period	Sept-Dec/April
Flower longevity (hrs)	9.56
Flower colour	Yellow
Flower odour	Not
Anthesis time (Max.)	8.00 AM
Pre anthesis bud (L) um	3589.26 ± 156.62
Pre anthesis bud (w) um	963.22 ± 88.02
Flower (L) um	6190.47 ± 244.56
Style length (um)	2131.85 ± 121.34
Style width (um)	119.56 ± 8.86
Anther Filament length (um)	1336.41 ± 84.14
Anther lobe length (um)	521.66 ± 48.90
Anther lobe width (um)	280.78 ± 19.15
Matured seed (L) um	4726.60 ± 621.73

Matured seed (w) um	1894.95 ± 111.28
No of pollen/anther	257.84 ± 46.77
No of pollen/flower	2656.95 ± 514.63

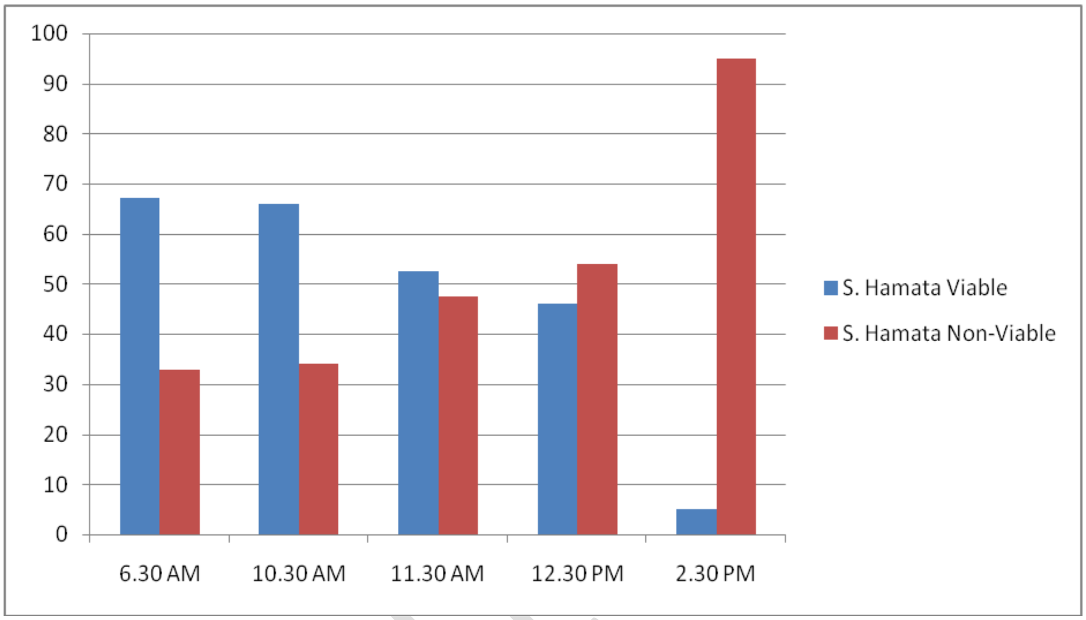

Fig. 1. Pollen viability of *Stylosanthes hamata*

Non significant differences were recorded for plant height at 60 and 90 DAS except for mulching treatment at 90 DAS (Table 2). In mulching treatments plant height (cm) at 60 DAS was maximum in M1 (30.85) and minimum in M2 (30.68), among harvesting stages it was high in H2 (31.80) and low in H3 (30.15). Among interaction it was maximum in M1H2 (32.90) and minimum in M1H4 (29.40). Whereas, plant height (cm) at 90 DAS was signifacantly maximum in M2 (66.65) and minimum in M1 (64.45) in mulching treatments, among harvesting stages it was high in H3 (66.85) and low in H2 (64.80). It was observed that among interaction maximum plant height was in M2H3 (68.80) and minimum in M1H1 (63.70).

Table 2: Effect of mulching and harvesting stages on plant height at 60 and 90 days after sowing in *S. hamata* (Pooled data)

Factors (M & H)	Plant height (cm) at 60 DAS	Plant height (cm) at 90 DAS	Interaction (MXH)	Plant height (cm) at 60 DAS	Plant height (cm) at 90 DAS
M1	30.85	64.45	M1H1	31.40	63.70
M2	30.68	66.65	M1H2	32.90	64.20
S.Em+	0.81	0.71	M1H3	29.70	64.90
C.D at 5 %	NS	2.97	M1H4	29.40	65.00
H1	30.60	64.95	M2H1	29.80	66.20
H2	31.80	64.80	M2H2	30.70	65.40
H3	30.15	66.85	M2H3	30.60	68.80
H4	30.50	65.60	M2H4	31.60	66.20
S.Em+	1.14	1.00	**S.Em+**	0.54	0.47
C.D at 5 %	NS	NS	**C.D at 5 %**	NS	NS

Factor I: Mulching (M) *viz*., M1: Control, M2: Mulching with polythene cover, **Factor II**: Harvesting stages (H) *viz*., H1: Harvesting at 150 days after sowing, H2: Harvesting at 160 days after sowing, H3: Harvesting at 170 days after sowing, H4: Harvesting at 180 days after sowing.

Table 3: Effect of mulching and harvesting stages on number of branches and days to 50 % flowering in *S. hamata* (Pooled data)

FACTORS (M & H)	Days to 50 % flowering	Number of branches	Interaction (MXH)	Days to 50 % flowering	Number of branches
M1	85.80	5.83	M1H1	84.60	5.70
M2	88.35	6.25	M1H2	85.30	5.60
S.Em+	0.72	0.79	M1H3	88.10	5.70
C.D at 5 %	3.02	3.33	M1H4	85.20	6.30
H1	86.10	5.85	M2H1	87.60	6.00
H2	86.80	5.81	M2H2	88.30	6.10
H3	88.35	6.15	M2H3	88.60	6.60
H4	87.05	6.30	M2H4	88.90	6.30
S.Em+	1.01	1.12	S.Em+	0.48	0.53
C.D at 5 %	NS	4.71	C.D at 5 %	NS	2.22

Factor I: Mulching (M) *viz*., M1: Control, M2: Mulching with polythene cover, **Factor II**: Harvesting stages (H) *viz*., H1: Harvesting at 150 days after sowing, H2: Harvesting at 160 days after sowing, H3: Harvesting at 170 days after sowing, H4: Harvesting at 180 days after sowing.

In mulching treatments days to 50 % flowering was signifacantly maximum in M2 (88.35) and minimum in M1 (85.80) as depicted in table 3 among harvesting stages it was high in H3 (88.35) and low in H1 (86.10). Among interaction it was maximum in M2H4 (88.90) and minimum in M1H1 (84.60). Signifacantly maximum number of branches were in M2 (6.25) and minimum in M1 (5.83), among harvesting stages it was high in H4 (6.30) and low in H2 (5.81). Among interaction it was maximum in M2H3 (6.60) and minimum in M1H2 (5.60).

Table 4: Effect of mulching and harvesting stages on days to maturity and seed yield in *S. hamata* (Pooled data)

FACTORS (M & H)	Days taken to maturity	Seed yield (kg/ha)	Interaction (MXH)	Days taken to maturity	Seed yield (kg/ha)
M1	155.88	755.88	M1H1	155.90	751.00
M2	159.18	786.98	M1H2	158.40	755.40
S.Em+	0.70	0.66	M1H3	154.50	758.10
C.D at 5 %	2.95	2.78	M1H4	154.70	759.00
H1	157.00	758.70	M2H1	158.10	766.40
H2	158.95	767.90	M2H2	159.50	780.40
H3	156.15	783.45	M2H3	157.80	785.80
H4	158.00	760.65	M2H4	161.30	762.30
S.Em+	0.99	0.93	S.Em+	0.47	0.44
C.D at 5 %	4.18	3.93	C.D at 5 %	1.97	1.85

Factor I: Mulching (M) *viz*., M1: Control, M2: Mulching with polythene cover, **Factor II**: Harvesting stages (H) *viz*., H1: Harvesting at 150 days after sowing, H2: Harvesting at 160 days after sowing, H3: Harvesting at 170 days after sowing, H4: Harvesting at 180 days after sowing.

In mulching days taken to maturity was signifacantly maximum in M2 (159.18) and minimum in M1 (155.88), among harvesting stages it was high in H2 (158.95) and low in H3 (156.15). Among interaction it was maximum in M2H4 (161.30) and minimum in M1H3 (154.50).In mulching seed yield (kg/ha) was signifacantly maximum in M2 (771.98) and minimum in M1 (755.88), among harvesting stages it was high in H3 (768.45) and low in H1 (758.70). Among interaction it was maximum in M2H2 (780.40) and minimum in M1H1 (751.00).

Table 5: Effect of mulching and harvesting stages on seed germination and shoot length in *S. hamata* (Pooled data)

FACTORS (M & H)	Seed germination (%)	Shoot length (cm)	Interaction (MXH)	Seed germination (%)	Shoot length (cm)
M1	30.44	7.54	M1H1	26.54	7.52
M2	35.65	7.30	M1H2	28.33	7.20
S.Em+	0.63	0.75	M1H3	31.25	7.54
C.D at 5 %	2.66	3.17	M1H4	35.64	7.48
H1	28.72	7.24	M2H1	30.89	6.95
H2	31.00	7.21	M2H2	33.66	7.21
H3	38.11	7.72	M2H3	40.58	7.89
H4	34.36	7.51	M2H4	37.47	7.54
S.Em+	0.89	1.07	S.Em+	0.42	0.50
C.D at 5 %	3.76	4.49	C.D at 5 %	1.77	2.12

Factor I: Mulching (M) *viz*., M1: Control, M2: Mulching with polythene cover, **Factor II**: Harvesting stages (H) *viz*., H1: Harvesting at 150 days after sowing, H2: Harvesting at 160 days after sowing, H3: Harvesting at 170 days after sowing, H4: Harvesting at 180 days after sowing.

In mulching treatment signifacantly influenced seed germination (%), was maximum in M2 (35.65) and minimum in M1 (30.44), among harvesting stages it was high in H4 (38.11) and low in H1 (28.72). Among interaction it was maximum in M1H4 (7.89) and minimum in M2H1 (6.95). In mulching shoot length (cm) was signifacantly maximum in M1 (7.54) and minimum in M2 (7.30), among harvesting stages it was high in H4 (7.72) and low in H2 (7.21). Among interaction it was maximum in M2H4 (40.58) and minimum in M1H1 (26.54).

Table 6: Effect of mulching and harvesting stages on root length and seedling vigour index in *S. hamata* (Pooled data)

FACTORS (M & H)	Root length (cm)	Seedling vigour index	Interaction (MXH)	Root length (cm)	Seedling vigour index
M1	6.26	421.36	M1H1	6.12	362.01
M2	6.55	494.91	M1H2	6.00	373.96
S.Em+	0.82	0.73	M1H3	6.34	433.75
C.D at 5 %	3.47	3.06	M1H4	6.58	501.11
H1	6.19	384.88	M2H1	6.25	407.75
H2	6.27	418.39	M2H2	6.54	462.83
H3	6.68	480.85	M2H3	6.78	595.31
H4	6.48	548.41	M2H4	6.61	530.20
S.Em+	1.17	1.03	S.Em+	0.55	0.48
C.D at 5 %	4.91	4.33	C.D at 5 %	2.31	2.04

Factor I: Mulching (M) *viz*., M1: Control, M2: Mulching with polythene cover , **Factor II**: Harvesting stages (H) *viz*., H1: Harvesting at 150 days after sowing, H2: Harvesting at 160 days after sowing, H3: Harvesting at 170 days after sowing, H4: Harvesting at 180 days after sowing.

In Table 6 it was noticed that root length (cm) was significantly maximum in M2 (6.55) and minimum in M1(6.26), among harvesting stages it was high in H4 (6.68) and low in H1 (6.19). Among interaction it was maximum in M2H4 (6.78) and minimum in M1H2 (6.00). Similarly, in mulching seedling vigour index was significantly maximum in M2 (494.91) and minimum in M1 (421.36), among harvesting stages it was high in H4 (548.41) and low in H1 (384.88). Among interaction it was maximum in M2H4 (581.11) and minimum in M1H1 (362.01).

Table 7: Effect of mulching and harvesting stages on seeds on plant and seeds fallen on ground in *S. hamata* (Pooled data)

FACTORS (M & H)	Seeds on plant (%)	Seeds fallen on ground (%)	Interaction (MXH)	Seeds on plant (%)	Seeds fallen on ground (%)
M1	5.17	94.84	M1H1	6.14*	93.86
M2	5.83	78.18	M1H2	5.63	94.37
S.Em+	0.78	0.61	M1H3	5.11	94.89
C.D at 5 %	3.30	2.58	M1H4	3.78	96.22
H1	6.52	88.33	M2H1	6.89	82.80
H2	6.10	87.14	M2H2	6.56	79.90
H3	5.26	85.40	M2H3	5.41	75.90
H4	4.12	85.16	M2H4	4.45	74.10
S.Em+	1.11	0.87	S.Em+	0.52	0.41
C.D at 5 %	4.67	3.65	C.D at 5 %	2.20	1.72

*Seeds retained on polythene sheet

Factor I: Mulching (M) *viz*., M1: Control, M2: Mulching with polythene cover, **Factor II**: Harvesting stages (H) *viz*., H1: Harvesting at 150 days after sowing, H2: Harvesting at 160 days after sowing, H3: Harvesting at 170 days after sowing, H4: Harvesting at 180 days after sowing.

The seed retention percentage exhibited significant differences for harvesting stages, as the harvesting stage increases the seed retention percentage on plant decreases (Table 7). Seeds on plant (%) was significantly maximum in M2 (5.83) and minimum in M1 (5.17), among harvesting stages it was high in H1 (6.52) and low in H4 (4.12). Among interaction it was maximum in M2H1 (6.89) and minimum in M1H4 (3.78). In mulching treatments seeds fallen on ground (%) was significantly maximum in M1 (94.84) and minimum in M2 (78.18), among harvesting stages it was high in H2 (87.14) and low in H4 (85.16). Among interaction it was maximum in M1H4 (96.22) and minimum in M2H4 (74.10).

Table 8: Effect of mulching and harvesting stages on physical purity and test weight in *S. hamata* (Pooled data)

FACTORS (M & H)	Physical purity (%)	Test weight (g)	Interaction (MXH)	Physical purity (%)	Test weight (g)
M1	73.84	3.15	M1H1	70.41	3.05
M2	82.33	3.24	M1H2	72.65	3.11
S.Em+	0.74	0.55	M1H3	74.82	3.18
C.D at 5 %	3.12	2.33	M1H4	77.46	3.25
H1	77.83	3.10	M2H1	85.24	3.14
H2	78.16	3.16	M2H2	83.66	3.20
H3	77.62	3.23	M2H3	80.41	3.28
H4	78.73	3.30	M2H4	80.00	3.34
S.Em+	1.05	0.78	S.Em+	0.49	0.37
C.D at 5 %	4.42	3.30	C.D at 5 %	2.08	1.55

Factor I: Mulching (M) *viz*., M1: Control, M2: Mulching with polythene cover, **Factor II**: Harvesting stages (H) *viz*., H1: Harvesting at 150 days after sowing, H2: Harvesting at 160 days after sowing, H3: Harvesting at 170 days after sowing, H4: Harvesting at 180 days after sowing.

In mulching physical purity (%) was significantly maximum in M2 (82.33) and minimum in M1(73.84), among harvesting stages it was high in H4 (78.73) and low in H3 (77.62). Among interaction it was maximum in M2H1 (85.24) and minimum in M1H1 (70.41). In mulching test weight (g) was significantly maximum in M2 (3.24) and minimum in M1 (3.15), among harvesting stages it was high in H4 (3.30) and low in H1 (3.10). Among interaction it was maximum in M2H4 (3.34) and minimum in M1H1 (3.05).

Discussion

S. hamata exhibited significant responses to both mulching and various stages of harvesting, indicating the importance of careful management practices. Physiological maturity represents the stage where the plant's qualities are optimized for seed production. Mulching not only enhanced plant growth but also contributed to improved soil health and ecosystem resilience, promoting sustainable agricultural practices (Xue et al., 2016). Moreover, mulches play a vital role in soil moisture conservation, nutrient enrichment, erosion control, weed suppression, and mitigation of environmental pollution, highlighting their multifaceted benefits in modern farming systems (Iqbal et al., 2020).

In mulched plants, the delayed onset of flowering and increased branching suggest a positive impact of mulching on reproductive processes and overall plant vigor. Additionally, by reducing evaporation losses and creating a protective barrier against disease transmission, mulches contribute to improved plant health and yield stability. This integrated approach to pest and disease management underscores the importance of ecological principles in agricultural sustainability (Chalker-Scott, 2007).

Mulches offer a range of indirect benefits that contribute to disease prevention and overall plant health. By enhancing plant nutrition, promoting better drainage, moderating soil temperature, improving soil structure, and conserving soil moisture, mulch materials create an optimal environment for crop plants (Turchetti et al., 2003). This favorable atmosphere facilitates vigorous plant growth and development while minimizing the presence of pathogenic organisms.

Furthermore, the presence of mulch on the soil surface affects weed management strategies. Reduced light penetration due to mulch barriers inhibits the germination of small-seeded weed species, leading to decreased weed establishment and proliferation (Stinson et al., 1990; Mohtisham et al., 2013; Kader et al., 2019). Additionally, mulches physically obstruct weed emergence, acting as barriers that impede the growth and spread of weeds in agricultural fields (Ahmad et al., 2015, 2020).

Seed quality parameters, such as germination, root and shoot length, and seedling vigor index, exhibited superior performance in mulched plants compared to those without mulch, particularly when harvested at 170 days after sowing. Mulch materials mitigate evaporation losses, enhancing soil water retention and reducing weed species. Additionally, mulches promote root establishment, growth, and development, allowing crop plants to expand their root systems extensively, resulting in increased biomass and height (Fausett and Rom, 2001; Wood, 1994; Burgess et al., 1997; Watson, 1988).

The percentage of seeds remaining on the plant was notably higher in plots with Mulching with polythene cover (M2) and Harvesting at 180 days after sowing (H4), while it was lower in plots without mulch (M1). Conversely, the percentage of seeds fallen on the ground was lower in M2 and H4 compared to M1, attributed to the indirect benefits of mulching. These benefits include improved plant nutrition, enhanced drainage, moderated soil temperature, better soil aggregation, and increased soil moisture retention. Consequently, mulch materials create a favorable environment for crop plants, facilitating robust growth and development while reducing susceptibility to pathogenic organisms. This conducive environment promotes the retention of intact seeds at physiological maturity (Turchetti et al., 2003).

Determining the optimal timing for harvesting is crucial whether using machinery or hand-cutting methods for seed head collection. Opting for a single harvest at the ideal time proves efficient, requiring less labor and time, particularly advantageous in extensive fields where completing harvesting before seed shedding is imperative (Phaikaew and Pholsen, 1993). Harvesting seed heads 15 days after 50% emergence yielded higher seed quantities compared to harvesting at either 10 or 20 days, with satisfactory seed quality. This approach demands careful monitoring during flowering and seed setting, alongside experienced judgment to identify when 50% of seed heads have emerged. Harvesting prematurely resulted in adequate seed yield but poor seed quality as the seeds were not fully matured. Conversely, delayed harvesting led to significantly reduced seed yield due to seed shedding prior to harvest, a common phenomenon in ripe tropical grass seeds (Humphreys and Riveros, 1986), posing challenges in seed recovery.

Mulching and harvesting at 170-180 days after sowing (DAS) significantly enhanced the physical purity and test weight of seeds compared to the control group (no mulching), suggesting that 180 DAS marks the physiological maturity stage in S. hamata. Additionally, plastic mulch elevates soil temperature in the root zone, creating favorable conditions for water and mineral nutrient uptake. This fosters improved foliage, growth, and fruit set in plants, resulting in maximum seed filling, as well as increased physical purity and test weight (Verma et al., 2016).

Our research findings affirm the efficacy of mulching as a beneficial practice for enhancing both the quantity and quality of seed yield in *S. hamata*. Specifically, our study suggests that implementing mulching techniques can significantly contribute to achieving higher seed yields and improving seed quality attributes. Furthermore, our observations indicate that the period between 170 to 180 days after sowing appears to represent the physiological maturity stage for S. hamata. This critical insight provides valuable guidance for farmers and agronomists, indicating the optimal timing for seed harvesting to maximize crop productivity and ensure optimal seed quality. Overall, our study underscores the importance of employing mulching practices and precise timing in crop management strategies to optimize the performance of *S. hamata* cultivation.

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