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Physiological traits as indicators of seed aging and yield potential in rapeseed and mustard (*Brassica* spp.)

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Abstract
This study investigates the impact of seed aging on physiological traits and seed quality in rapeseed and mustard (Brassica spp.), focusing on plant height, siliquae per plant, and seed yield. Fresh and aged seeds from six Brassica varieties-PM-28, M-27, TS-36, TS-38, Kakching Yella, and Potsangbam Yella were cultivated under uniform field conditions at Pandit Deen Dayal Upadhyay Institute of Agricultural Sciences, Manipur, using a factorial randomized block design. Results revealed significant reductions in plant height, siliquae production, and seed yield across all aged seed varieties. For instance, fresh seeds of PM-28 attained a maximum plant height of 95.00 cm, while aged M-27 seeds recorded the shortest height (63.50 cm). Similarly, seed yield dropped sharply from 1258.75 kg/ha in fresh PM-28 seeds to 451.25 kg/ha in aged Potsangbam Yella seeds. These findings underscore the necessity of optimal seed storage to maintain physiological vigor and ensure agricultural productivity.

Keywords: Seed aging, *Brassica* spp., seed vigor, siliquae, oilseed crops

1. Introduction

Seed quality is a critical determinant of agricultural productivity, directly influencing germination, seedling vigor, and crop yield. Seed aging is an inevitable biological process that progressively diminishes quality due to physiological and biochemical degradation. This issue is particularly significant for high-value oilseed crops such as rapeseed and mustard (Brassica spp.), where aging-related quality losses can severely impact crop performance and agricultural sustainability. Factors like temperature and humidity during storage exacerbate oxidative damage, reducing seed viability and vigor [1-3].

In India, Brassica species play a vital role in the agricultural economy as major oilseed crops. With an oil content of 30-35% and a protein content of 34-39%, these crops are indispensable for dietary and industrial purposes. However, their high oil content makes them prone to rapid deterioration during storage, necessitating strategies to maintain seed quality. Prior studies [4-6] have highlighted the vulnerability of Brassica seeds to aging, which underscores the importance of understanding the physiological changes associated with this process.

Physiological changes such as reduced membrane integrity, increased electrolyte leakage, and enzymatic activity degradation have been identified as key factors in seed viability loss [7]. Research suggests that traits like plant height, siliquae per plant, and seed yield are reliable markers of seed aging effects and overall crop performance [8, 9]. Building on these findings, this study focuses on evaluating the physiological responses of six Brassica varieties-PM-28, M-27, TS-36, TS-38, Kakching Yella, and Potsangbam Yellato seed aging.

This study aims to assess the effects of seed aging on key physiological traits plant height, siliquae per plant, and seed yield in six Brassica varieties. By examining the correlation between seed aging and these traits, the study seeks to identify reliable markers for seed quality assessment and to inform optimal storage and cultivation practices for sustainable crop production.

2. Materials and Methods
2.1 Experimental Setup
The experiment was conducted during the Rabi season of 2018-2019 at the experimental fields of the PanditDeenDayalUpadhyay Institute of Agricultural Sciences, Manipur. Laboratory analyses were carried out at the ICAR Seed Technology Laboratory, Imphal. A factorial randomized block design (FRBD) was employed to assess the physiological traits of fresh and aged seeds from six Brassica varieties: PM-28, M-27, TS-36, TS-38, Kakching Yella, and Potsangbam Yella. Fresh seeds were briefly stored under controlled conditions, while aged seeds had been stored for 24 months in ambient conditions to simulate natural aging.

2.2 Physiological Traits Monitored
1. **Plant Height:** Plant height was measured from the base of the plant to the apex at full maturity using a standard measuring scale.
2. **Siliquae per Plant:** The average siliquae count was recorded from five randomly selected plants per plot to ensure representative sampling.
3. **Seed Yield:** Seed yield was calculated from net plot harvests and standardized to kilograms per hectare (kg/ha) for uniform comparison.

Field plots were prepared with a row-to-row spacing of 30 cm and plant-to-plant spacing of 15 cm. Treatments were replicated four times to enhance statistical reliability. All cultivation practices, including irrigation, fertilization, and pest management, adhered to standard agronomic protocols. Data were collected under consistent environmental conditions to minimize variability.

2.3 Standards and Data Collection
All experimental procedures followed ISTA (2019) standards to ensure accuracy and reproducibility. Environmental variables were monitored throughout the experiment to maintain uniform growing conditions across treatments.

2.4 Data Analysis
Statistical analysis was performed using analysis of variance (ANOVA) to evaluate the significance of differences among the treatments. Least Significant Difference (LSD) tests were conducted at a 5% significance level to identify statistically meaningful variations in physiological traits among Brassica varieties and seed age groups.

3. Results and Discussion
3.1 Plant Height
Seed aging significantly impacted plant height across all Brassica varieties studied. Fresh seeds exhibited superior growth vigor, with PM-28 and TS-36 achieving a maximum height of 95.00 cm. In contrast, aged M-27 seeds showed the lowest average height of 63.50 cm. These results highlight the sensitivity of plant height to seed quality and the physiological effects of aging on growth potential. Variations in plant height across seed age groups were statistically significant (Table 1), underscoring the importance of maintaining seed vigor for optimal growth. Figures 1 graphically illustrate these trends, highlighting the substantial length of siliquae difference between fresh and aged seeds.

Table 1: Effect of ageing on siliquae length of seeds in different varieties of rapeseed and mustard

Varieties	Siliquae length in cm		
	Fresh seed	**Aged seed**	**Mean**
PM 28	4.05	3.95	4.00
M 27	3.925	3.65	3.78
TS 36	4.55	4.15	4.35
Kakching yella	3.72	3.47	3.60
Potsangbam yella	3.35	3.25	3.30
TS 38	4.27	4.02	4.15
Mean	3.979	3.750	
Factor	A	B	A X B
SE(m)	0.154	0.089	0.218
C.D (0.5)	0.445	0.257	0.628

Mean of four replication in each treatment
A-Varieties, B-condition (Fresh and Aged seed)

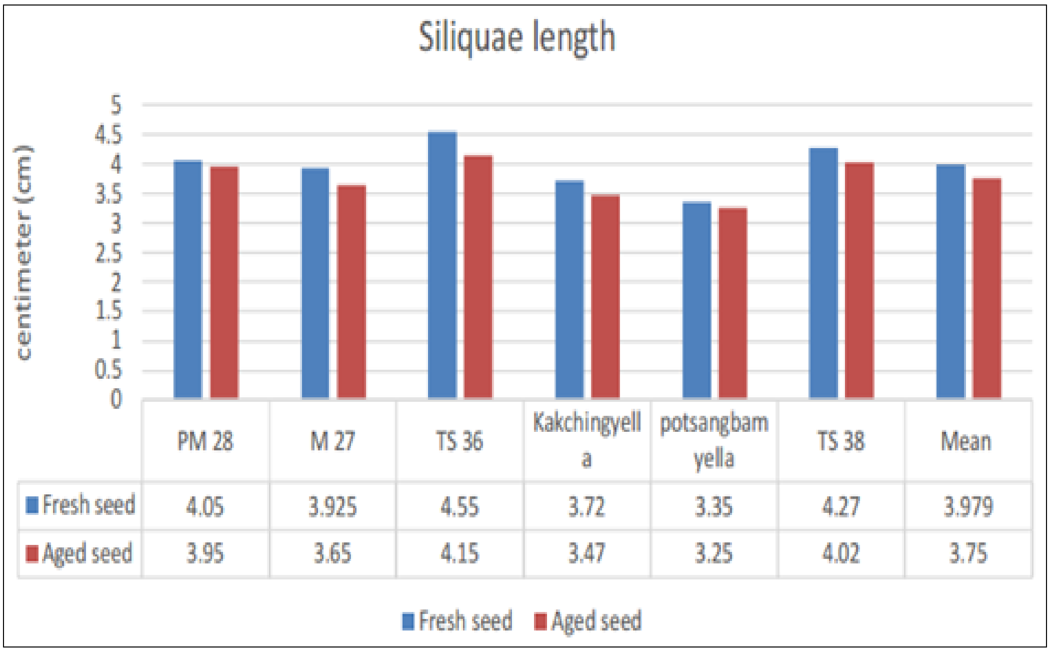

Fig 1: Effect of ageing on siliquae length of seeds in different varieties of rapeseed and mustard.

3.2 Siliquae per Plant
The number of silique per plant, an indicator of reproductive success, also showed a marked decline in aged seeds. Fresh PM-28 seeds recorded the highest silique count at 143 per plant, while aged TS-38 seeds exhibited a significant reduction in reproductive output. The decline in siliquae count demonstrates the adverse effects of seed aging on the reproductive capacity of Brassica crops (Table 2). This reduction in reproductive potential can be attributed to aging-induced physiological changes, such as reduced enzymatic activity and membrane degradation, which compromise seed vigor. Figures 2 graphically illustrate these trends, highlighting the substantial number of seed per siliquae difference between fresh and aged seeds.

Table 2: Effect of ageing on seeds per siliquae of seeds in different varieties of rapeseed and mustard.

Varieties	No of seeds per siliquae		
	Fresh seed	Aged seed	Mean
PM 28	14.50	13.25	13.87
M 27	13.25	12.50	12.87
TS 36	12.00	11.25	11.62
Kakching yella	13.00	12.25	12.62
Potsangbam yella	14.00	13.25	13.62
TS 38	11.75	11.50	11.62
Mean	13.08	12.33	
Factor	A	B	A X B
SE(m)	0.407	0.235	0.576
C.D (0.5)	1.176	0.679	1.662

Mean of four replication in each treatment
A-Varieties, B-condition (Fresh and Aged seed)

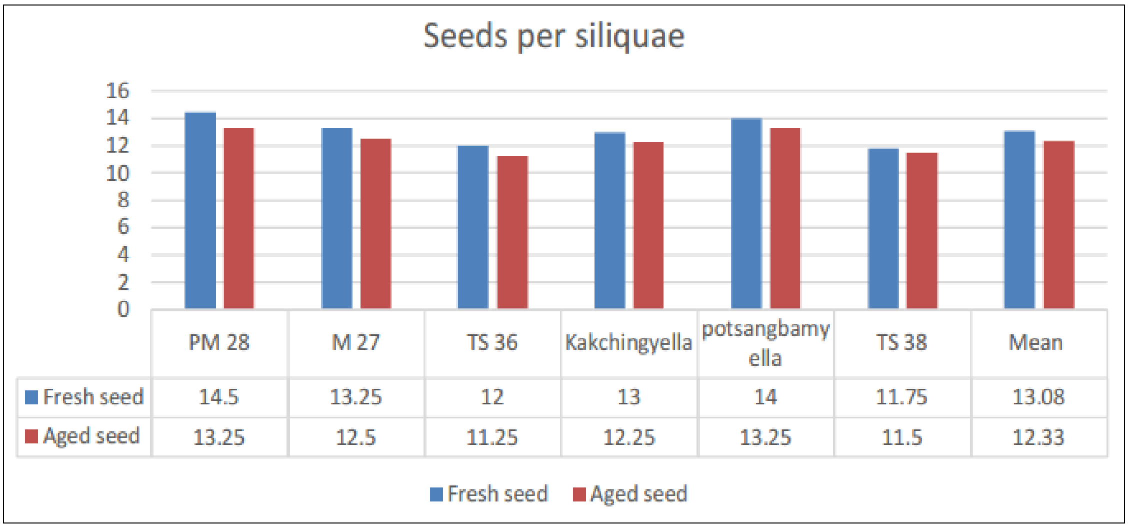

Fig 2: Effect of ageing on seeds per siliquae of seeds in different varieties of rapeseed and mustard.

3.3 Seed Yield
Seed yield, a critical measure of crop productivity, displayed the most pronounced impact of seed aging. Fresh PM-28 seeds produced the highest yield of 1258.75 kg/ha, while aged Potsangbam Yella seeds yielded the lowest at 451.25 kg/ha (Table 3). The observed yield differences correlate strongly with reductions in plant height and siliquae per plant, reinforcing the interdependence of physiological parameters in determining crop productivity. Figures 3graphically illustrate these trends, highlighting the substantial productivity gap between fresh and aged seeds.

Table 3: Effect of ageing on seed yield of seeds in different varieties of rapeseed and mustard.

Varieties	No of seeds per siliquae		
	Fresh seed	Aged seed	Mean
PM 28	1258.75	1086.50	1,172.62
M 27	984.75	876.50	930.62
TS 36	954.00	834.00	894.00
Kakching yella	623.25	502.75	563.00
Potsangbam yella	526.00	451.25	488.62
TS 38	907.00	833.00	870.25
Mean	875.70	764.00	
Factor	A	B	A X B
SE(m)	9.752	5.630	13.791
C.D (0.5)	28.182	16.271	39.855

Mean of four replication in each treatment
A-Varieties, B-condition (Fresh and Aged seed)

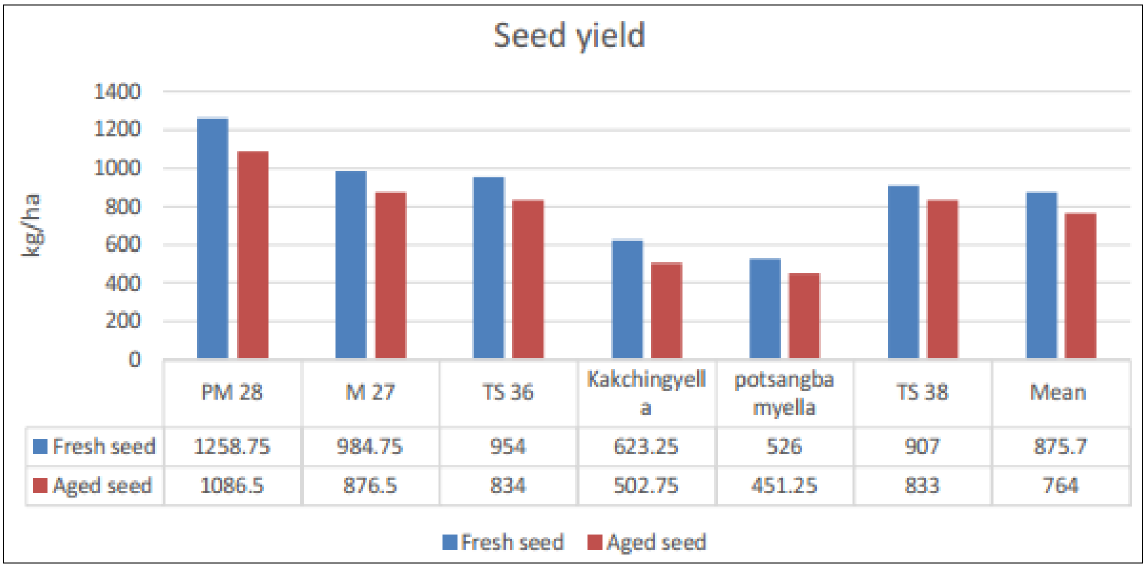

Fig 3: Effect of ageing on seed yield of seeds in different varieties of rapeseed and mustard.

3.4 Interpretation of Findings

The observed decline in plant height, siliquae per plant, and seed yield with aging aligns with established research on seed deterioration. Physiological degradation, including reduced membrane integrity and increased electrolyte leakage, has been identified as a key factor in the decline of seed performance [8-9]. High oil content in Brassica seeds further exacerbates oxidative damage during storage, accelerating the aging process [3, 6]. The results of this study emphasize the critical need for proper storage practices to mitigate seed quality loss and sustain productivity [2, 10].

4. Conclusions

This study has conclusively demonstrated that physiological traits, including plant height, siliquae per plant, and seed yield, are reliable and consistent indicators of seed aging in rapeseed and mustard. Fresh seeds consistently exhibited superior outcomes in these critical traits, highlighting the significant impact of seed age on overall plant development and productivity.

The findings suggest that seed vigor, directly influenced by the preservation of seed quality, plays a crucial role in ensuring high yields. Fresh seeds showed optimal growth and productivity, which is vital for maintaining the desired quality of crops, particularly for high-value oilseeds such as rapeseed and mustard, which are highly susceptible to oxidative aging. This oxidative process leads to a decline in seed viability, resulting in decreased productivity and economic losses.

Given these insights, it becomes evident that appropriate and optimized seed storage practices are of utmost importance in mitigating the effects of seed aging. The need for strategic seed management-ranging from timely harvesting, proper handling, and the use of advanced storage techniques-is imperative for maintaining the integrity of seed quality over time. Such practices will not only safeguard seed vigor but also enhance the overall resilience and productivity of Brassica crops.

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