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Improving Seed Quality of Four Genotypes of Sweet Corn (*Zea mays* saccharata) Based on Harvest Time and Initial Water Content

Astryani Rosyad[1,*], Arya Widura Ritonga[1], Erik Mulyana[1], Punjung Medaraji Suwarno[1], Mertya Anugrah[2]

Abstract

Quality seeds are crucial for successful sweet corn production. Various factors influence seed quality, including harvest time and initial water content. Therefore, understanding the interaction between harvest time and initial water content is essential for optimizing the quality of sweet corn seeds. This study aims to determine the optimal harvest time and initial water content for assessing the seed quality of four sweet corn genotypes: T13.1.8, SB13.1.3, T8.3.6, and T8.3.2. The experiment employed a factorial Randomized Complete Block Design (RCBD) with two factors. The first factor, harvest time, consisted of five levels (73, 76, 79, 82, and 85 days after planting [DAP]). In contrast, the second factor was the initial water content for seed testing, categorized as harvest water content and 10-12% moisture content. Each treatment was replicated three times, resulting in a total of 30 experimental units. The findings indicated that the sweet corn genotypes T13.1.8 and SB13.1, which were harvested at 76 to 82 hours after sowing (DAP) and had an initial water content of 10 to 12%, represented the optimal treatment combination. These genotypes exhibited germination rate and vigor index variables ranging from 92.7 - 100% and 70.67 - 96.67%. Sweet corn genotypes T8.3.6 and T8.3.2 can be harvested between 79 - 85 DAP with an initial water content of 10-12% to obtain seeds with a germination rate ranging from 86.00 - 98.67% and a vigor index of 58.00 - 86.67%. The study results can be used as a recommendation for seed producers to apply the harvest time and water content according to the genotype used, to ensure that the seeds produced have high viability and vigor.

Keywords: Drying, Dry Weight, Germination Rate, Physiological Maturity, Seed Producer, Vigor Index

1. Introduction

Sweet corn (*Zea mays* saccharata) is a horticultural commodity widely cultivated and consumed worldwide. It contains more sugar than regular corn, attributed to the shrunken-2 gene (sh2). This gene enables sweet corn to accumulate two to three times more sucrose at harvest, enhancing its flavor and consumer appeal (Jompuk et al., 2020). In addition to its appealing taste, sweet corn is a source of vitamin A, minerals, and antioxidants (Chhabra et al., 2022; Singh et al., 2023). In Indonesia, sweet corn productivity can reach 6 to 10 tons per hectare, depending on agronomic conditions, hybrid varieties, and cultivation practices. Applying fertilizers in the correct dosage and frequency has effectively increased crop yields (Sembiring et al., 2020). Research by Rambe et al. (2024) indicates that the simultaneous application of organic and inorganic fertilizers can boost crop yields by up to 25%.

Seed viability is a critical factor in the development of sweet corn varieties. The decline in viability of sweet corn seeds occurs more rapidly than that of other types of corn. Various factors, including genetic traits, often influence this decline. Research conducted by Ruanjaichon et al. (2021) indicates that sweet corn seeds with mutations for supersweet traits possess higher sugar content; however, their viability levels may be lower than those of regular corn seeds. Using high-quality seeds in sweet corn production is essential to ensure optimal seed viability and vigor, which affects overall production and yield. Several factors influence seed quality, including harvest timing and initial moisture content.

*Correspondence: astryanirosyad@apps.ipb.ac.id
1) Institut Pertanian Bogor - Jl. Meranti, Babakan, Kec. Dramaga, Kabupaten Bogor, Jawa Barat 16680, Indonesia
2) Politeknik Negeri Lampung - Jl. Soekarno Hatta No.10, Rajabasa Raya, Kec. Rajabasa, Kota Bandar Lampung, Lampung 35141, Indonesia

The right harvest time contributes to optimal seed maturation. Determining the ideal harvest time is crucial in ensuring seed development reaches physiological maturity. Marinho et al. (2019)stated that delaying harvest, especially if followed by suboptimal weather conditions, can worsen seed viability and shorten its shelf life. Research Harakotr et al. (2022) stated that sweet corn seeds harvested at the right time showed significant changes in sugar and starch content during seed development, directly affecting seed quality. Sweet corn seed maturity can be determined through plant age evaluation. However, the challenge in this case is the absence of clear morphological indications, such as a black layer in other types of corn. Maximiano et al. (2023) stated that physiological seed maturity relates to plant age and physiological development during growth. Therefore, plant age can be used to determine the right harvest time.

Another condition often found in sweet corn seed production is that the seeds can germinate on parent plants under high water content conditions. This shows that germination depends on physiological maturation and environmental conditions, especially the available humidity. Optimal humidity conditions when the seeds are on the parent plant can stimulate a faster germination rate, even though the seeds are not fully physiologically mature (Maximiano et al., 2023).

Several mechanisms can explain this phenomenon, including hormonal conditions. Hormone content, such as abscisic acid (ABA) and Gibberellin, is key in regulating germination under high humidity conditions. Wang et al. (2022) noted that high levels of ABA can inhibit germination, while the right conditions increase seed vigor. If seeds are in a high-humidity environment while on the mother plant, the germination process can be scheduled earlier, allowing seeds to utilize available resources before environmental conditions change. Harakotr et al. (2022) indicated that sweet corn seeds can start germinating at an early maturity stage and in a high-humidity environment. This also aligns with the finding that seeds with higher water content allow for more active metabolic processes, contributing to accelerated germination even though they have not reached physiological maturity.

Therefore, it is essential to understand the interaction between harvest time and initial water content to optimize the quality of sweet corn seeds. By considering this aspect, producers need to align the two factors to ensure that the seeds produced have high quality. (Stanisavljević et al., 2013).The alignment between environmental conditions at harvest and post-harvest handling can also increase seed resistance to pests and pathogens, and ensure that the seeds produced have the best quality for planting in the following season (Fitriati et al., 2021). This study aims to determine the right harvest time and initial water content for testing the seed quality of four sweet corn genotypes.

2. Material and Methods

The experiment was conducted in the experimental garden of the Center for Tropical Horticulture Studies (PKHT) IPB (6° 36′ 13″ S 106° 46′ 50″ E), Pasirkuda, Bogor City with an altitude of 259 meters above sea level and the Seed Testing Laboratory, seed science and technology study program, IPB Vocational School (6°33'33.4"S 106°43'49.0"E) with an altitude of 240 meters above sea level. The study was conducted in October-November 2024. The materials used were sweet corn genotypes T13.1.8, SB13.1.3, T8.3.6, and T8.3.2, genotypes of the IPB sweet corn collection originating from selfing polycross results with pedigree selection. Other materials used were stencil paper, plastic, and envelopes. The tools used were an oven, IPB 72-1 type germinator, desiccator, porcelain cup, scales, Ms.Excel 365, and SAS V.9.0.

The experiment was conducted on four sweet corn genotypes, namely T13.1.8, SB13.1.3, T8.3.6, and T8.3.2. The experiment used a factorial Randomized Complete Block Design (RCBD) with two factors. The first factor was harvest time, consisting of five levels (73, 76, 79, 82, 85 DAP), and the second factor was the initial water content of the seed test (harvest water content and KA 10-12%). Each treatment was repeated three times to produce 30 experimental units. One experimental unit consisted of one corn cob without husk. The experimental procedure began by harvesting corn cobs for each genotype for each level of harvest time treatment, then shelling for the harvest water content treatment, and then conducting seed quality testing. For the water content treatment level of 10-12%, after the corn cobs are harvested, they are then dried under the sun for four days, starting at 08.00 - 11.00 until they reach a water content of 10-12%, then the corn is shelled and seed quality testing is carried out. Seed quality testing is done on dry seed weight, water content, germination percentage (%), and vigor index (%). The flow diagram of the experiment is presented in Figure 1.

The dry weight of the seeds was determined by drying 25 seeds three times using an oven at a temperature of 80 °C for 24 hours. The water content of the seeds was determined by drying 25 seeds three times using an oven at a temperature of 103 ±5 °C for 17 hours. The water content of the seeds was calculated using the following equation:

$$\textbf{Water content}(\%) = \frac{\textbf{M2} - \textbf{M3}}{\textbf{M2} - \textbf{M1}} \textbf{x 100}\%$$

where M1 = weight of porcelain crucible, M2 = weight of porcelain crucible + seeds before oven, M3 = weight of porcelain crucible + seeds after oven.

Testing of seed viability and vigor with germination rate variables and vigor index was conducted by germinating 25 seeds for each replication. The germination method used the Paper Established in Plastic Test (UKDdp). Seeds were germinated in the *Eco-germinator*

Type IPB 72-1. Germination rate and vigor index were calculated using the following equation:

$$\textbf{Germination Rate}\ (\%) = \frac{\Sigma\,\textbf{NS I} + \Sigma\,\textbf{NS II}}{\Sigma\,\boldsymbol{planted\ seeds}}\ \textbf{x 100}\%$$

$$\textbf{Vigor Index}\ (\%) = \frac{\Sigma\,\textbf{NS I}}{\Sigma\,\textbf{planted seeds}}\ \textbf{x 100}\%$$

NS I = normal seedling on the first day (day 3), and NS II = normal seedling on the first day (day 5).

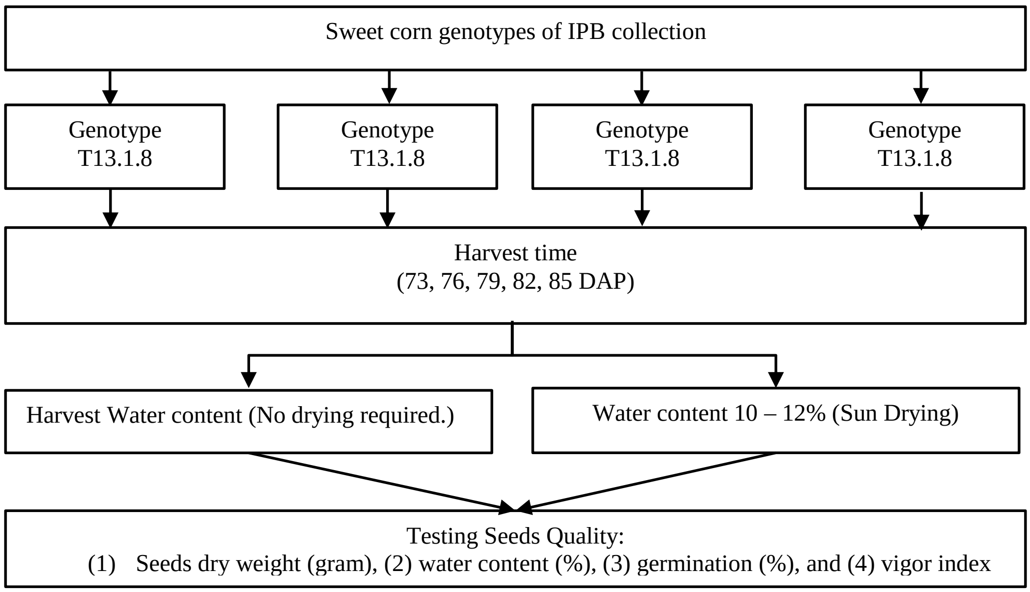


Figure 1. Research Flow Diagram

Data were analyzed using ANOVA, and Duncan's Multiple Range Test (DMRT) was conducted if the treatment significantly affected the response at a 5% significance level. The analysis will be performed using SAS V.9.0 software. Dry weight and water content are presented in graphical form using Microsoft Excel 365.

3. Results and Discussion

Environmental conditions recorded at the West Java Climatology Station from October to November 2024 indicated an average temperature of 26.9 °C, a humidity level of 81.47%, monthly rainfall of 350.5 mm, and an irradiation duration of 6.4 hours. The analysis of variance for each genotype revealed a highly significant interaction between the two treatment factors for each observed variable. The results of the variance analysis are presented in Table 1.

3.1. Water content and dry weight of seeds

Seeds reach physiological maturity indicated by a decrease in water content and an increase in dry weight. Decreasing water content is essential because it suggests that the seeds have developed the physiological stability to survive extreme environmental conditions. (Da Silva et al., 2019). This also means that the seeds have reached a stage where the reserves stored in the endosperm function optimally to provide energy to the embryo when starting the germination process. (De Souza Vidigal et al., 2011). The increase in dry weight indicates that in the physiological maturity phase, seeds not only accumulate the reserves needed for embryo development, but also show increased germination ability and vigor (Da Silva et al., 2019). Changes in water content and dry weight in each genotype at each treatment of harvest time and initial water content are presented in Figure 2.

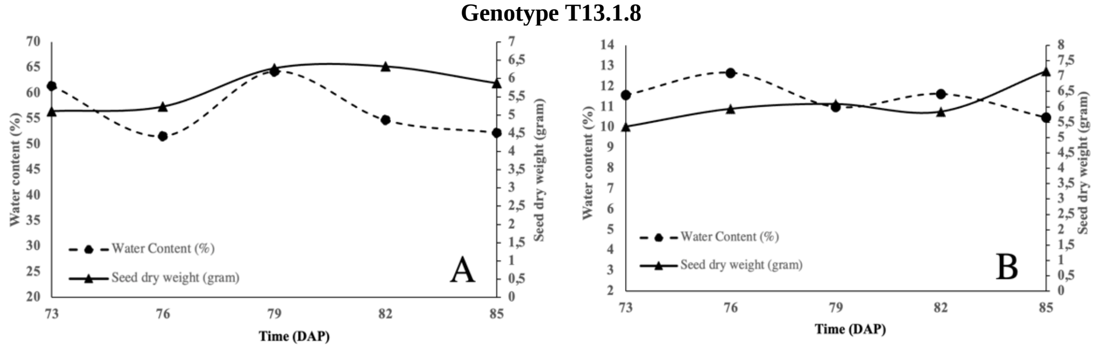
The results showed that genotype T13.1.8 in the treatment of harvest water content (A) and water content of 10-12% (B), the water content variable decreased, and the dry weight of seeds increased with increasing plant age. In the treatment of harvest water content, the maximum dry weight was achieved at 82 DAP, while in the treatment of water content, 10-12%, it was 85 DAP. A similar thing happened to Genotype SB13.1.3, in the treatment of harvest water content, the maximum dry weight was achieved at 82 DAP, while in the treatment of water content, 10-12% was achieved at 85 DAP. At the same age, genotype SB13.13 tended to have a higher water content. Genotype T8.3.6 in the treatment of harvest water content, the water content variable decreased, and the dry weight reached a maximum point at 82 DAP. At 85 DAP, there was an anomaly where the dry weight tended to decline again. This is thought to be due to unrepresentative cob sampling. In the 10-12% water content treatment, the maximum dry weight of seeds was achieved at 79 DAP. Genotype T8.3.2 in the harvest water content treatment had a significant decrease in water content from 73 DAP to 8 DAP of around 25.76%, and dry weight increased in line with the increase in harvest time. In the 10-12% water content treatment, the dry weight of seeds increased along with harvest time, with maximum dry weight achieved at 82 DAP. The performance of cobs when harvested at 72 - 85 DAP for each genotype is presented in Figure 3.

Table 1. Results of the analysis of treatment variance for each genotype

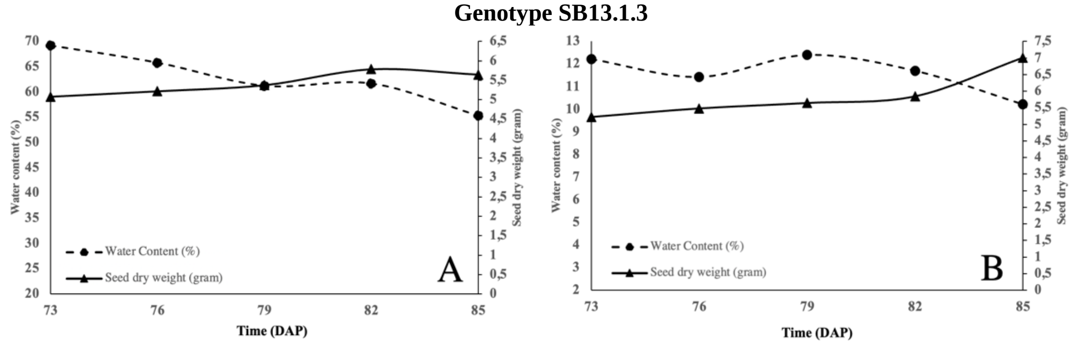
Variable	Harvest time (Pr>F)	Initial water content of the test (Pr>F)	Drying* Harvest time (Pr>F)
Genotype T13.1.8			
Water content (%)	**	**	**
Dry weight of seeds (g)	**	**	**
Germination rate (%)	**	**	**
Vigor index (%)	**	**	**
Genotype SB13.1.3			
Water content (%)	**	**	**
Dry weight of seeds (g)	**	**	**
Germination rate (%)	**	**	**
Vigor index (%)	**	**	**
Genotype T8.3.6			
Water content (%)	**	**	**
Dry weight of seeds (g)	**	**	**
Germination rate (%)	**	**	**
Vigor index (%)	**	**	**
Genotype T8.3.2			
Water content (%)	**	**	**
Dry weight of seeds (g)	**	**	**
Germination rate (%)	**	**	**
Vigor index (%)	**	**	**

Description: **very significant with three test repetitions

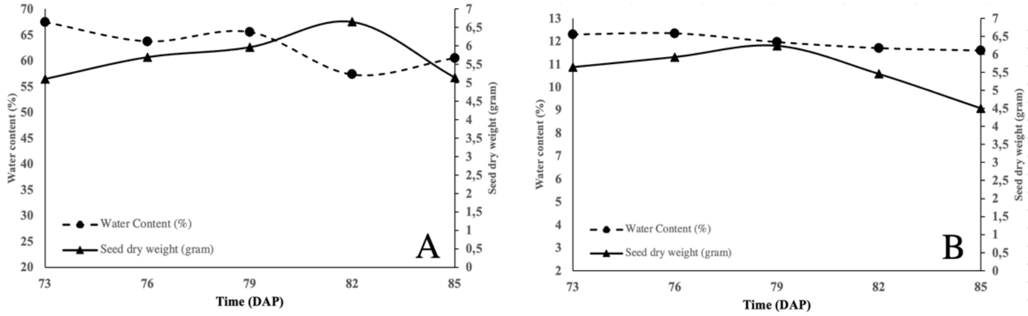
Genotype T13.1.8



Genotype SB13.1.3



Genotype T8.3.6



Genotype T8.3.2

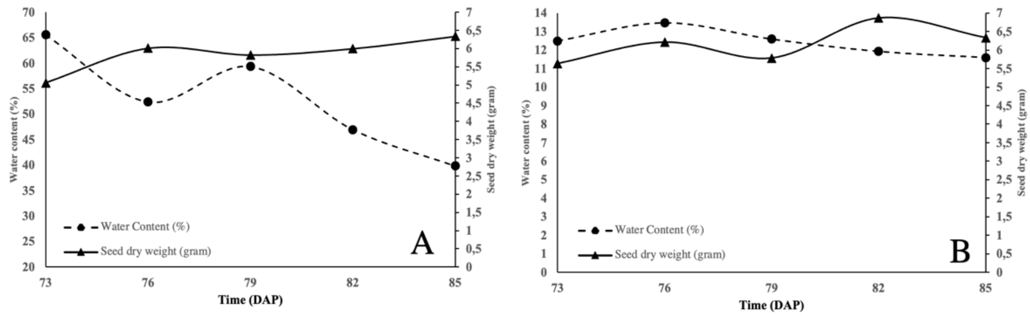
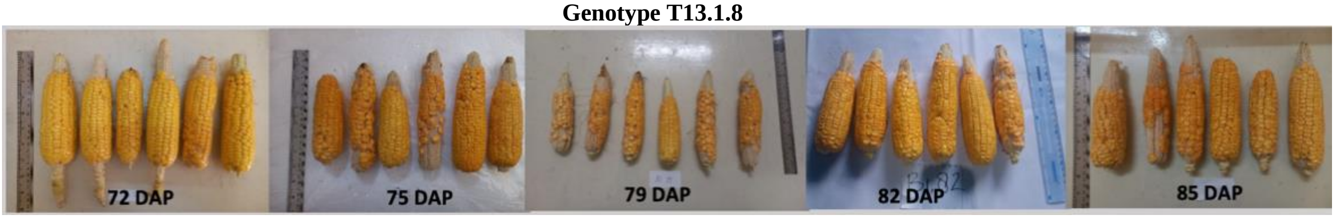
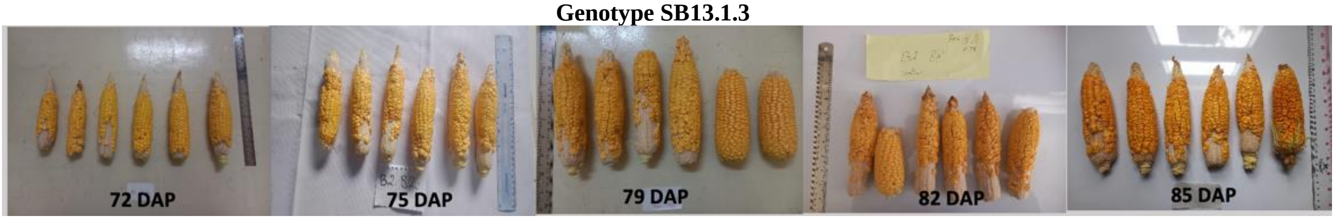


Figure 2. Seed water content, dry weight of seeds in four genotypes, and initial water content of the test, where A: harvest water content, and B: water content of 10-12%

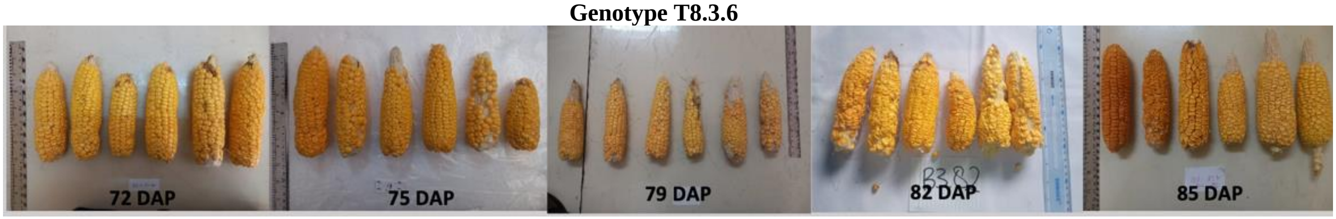
Genotype T13.1.8



Genotype SB13.1.3



Genotype T8.3.6



Genotype T8.3.2

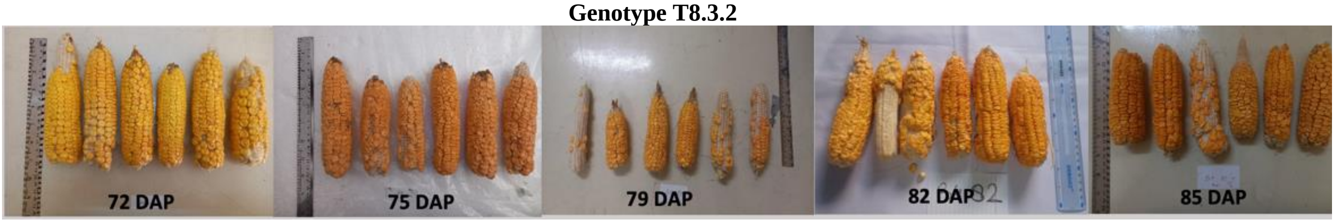


Figure 3. Performance of cobs at each harvest age for each genotype.

The seed water content variable decreased, and the dry weight increased in line with the increase in harvest time in all four genotypes. The maximum dry weight was achieved in the 79 - 85 DAP range, indicating that the seeds reached physiological maturity. This result aligns several previous research results where the dry weight of sweet corn seeds generally reached a peak around 70 to 90 days after planting (DAP), depending on the fertilization treatment and other environmental factors ((Sari et al., 2018); (Nurhayati & Sebayang, 2022); (Amir et al., 2022). Marcos-Filho et al. (1994) confirmed that the peak point of dry weight accumulation of seeds is directly proportional to the achievement of physiological maturity. After reaching physiological maturity, the seeds must be harvested immediately to prevent a decrease in seed quality due to degradation of food reserve accumulation due to metabolic processes (Ferreira et al., 2017)

3.2. Seed viability and vigor

Seeds harvested at physiological maturity are significantly related to seed viability and vigor. The effect of harvest time and initial seed water content on germination rate and vigor index variables is presented in Table 2.

Table 2. Effect of harvest time and initial water content on each genotype on germination rate and vigor index variables

Variable	The initial water content of the test	Harvest time (DAP)				
		73	76	79	8 2	85
		Genotype T13.1.8				
Germination rate	Harvest water content	22.0 ±4.0 i	28.7 ±5.7 h	49.3 ±2.5 e	42.0 ±3.7 f	29.3 ±4.6 g
	Water content 10 -12%	92.7 ±2.6 d	96.7 ±1.3c	92.7 ±2.4 d	100.0 ±0.0 a	98.7 ±0.7 b
Vigor index	Harvest water content	1.33 ±0.7 h	20.00 ±5.0 h	11.00 ±2.5 i	20.33 ±3.8 g	29.33 ±4.7 f
	Water content 10 -12%	86.67 ±3.7 c	82.67 ±4.1 d	87.00 ±1.5 b	91.33 ±1.3 a	71.33 ±3.3 e
		Genotype SB13.1.3				
Germination rate	Harvest water content	76.7 ±6.3 f	30.7 ±3.5 h	34.7 ±0.7 i	42.0 ±3.5 g	41.3 ±2.1 h
	Water content 10 -12%	98.7 ±0.7 b	100.0 ±0.0 a	93.3 ±5.7 e	97.3 ±0.7 c	94.7 ±3.5 d
Vigor index	Harvest water content	19.33 ±3.3 h	20.67 ±5.2 g	34.67 ±0.7 f	10.67 ±2.7 i	20.67 ±1.0g
	Water content 10 -12%	95.33 ±2.4 b	96.67 ±0.7 a	83.67 ±1.3 c	70.67 ±2.4 e	74.67 ±3.7 d
		Genotype T8.3.6				
Germination rate	Harvest water content	24.67 ±4.7 h	4.67 ±0.7 h	12.00 ±2.0 i	30.67 ±1.5 g	49.33 ±2.5 f
	Water content 10 -12%	56.00 ±4.6 e	98.00 ±2.0 b	94.67 ±2.4 c	91.33 ±2.9 d	98.67 ±0.7 a
Vigor index	Harvest water content	0.00 ±0.00 f	1.33 ±0.7 e	0.00 ±0.0 f	0.00 ±0.0 f	0.00 ±0.0 f
	Water content 10 -12%	48.67 ±4.4 d	94.67 ±2.4 a	86.67 ±1.8 b	78.67 ±1.8 c	86.67 ±3.3 b
		Genotype T8.3.2				
Germination rate	Harvest water content	12.00 ±0.7 h	5.00 ±0.6 h	11.00 ±0.6 i	19.00 ±2.0 g	26.67 ±4.4 f
	Water content 10 -12%	51.33 ±2.6 e	93.33 ±1.3 c	96.00 ±1.2 b	86.00 ±1.2 d	98.67 ±0.7 a
Vigor index	Harvest water content	1.33 ±0.7 g	0.00 ±0.0 h	0.00 ±0.0 h	0.00 ±0.0 h	26.67 ±4.4 f
	Water content 10 -12%	44.67 ±2.2 e	74.00 ±3.7 c	86.00 ±2.0 b	58.00 ±2.3 d	86.67 ±3.3 a

Description: Numbers followed by the same letter in the same row and column indicate that they are not significantly different in the DMRT test with a significance level of 5 % in three replications.

The results showed that the maximum germination rate (100%) and vigor index (91.33%) in genotype T13.1.8 were achieved in seeds harvested at 82 DAP with an initial 10-12% water content treatment. The highest germination rate and vigor index in genotype SB13.1.3 were obtained from the harvest time 76 DAP treatment and initial water content of 10-12%. However, in this genotype, the seeds tested at the earliest harvest time (73 DAP) with harvest water content achieved a germination rate of 76.7%. Genotype T8.3.6 obtained the highest percentage of germination rate from the treatment of harvest time 85 DAP and water content of 10-12%, while the vigor index was at 76 DAP with the same water content treatment. Genotype T8.3.2 had the highest germination rate and vigor index from time 85 DAP treatment and initial water content of 10-12%.

Corn seeds in all four genotypes achieved maximum viability and vigor at an initial 10-12% water content and harvest time between 76 - 85 DAP. Corn seeds are included in the orthodox seed group, which requires a "maturation drying" process. This process is fundamental because it functions to prepare the seeds physiologically so that they can survive in a state of dormancy and are ready to activate the germination process when environmental conditions are favorable (Angelovici et al., 2010; Groot, 2022)According to Groot (2022), maturation drying plays a role in improving seed viability by lowering water content to an optimal level. This helps reduce the risk of physiological damage from excessively high water content.

The four corn genotypes used in the study can germinate at high water content conditions (harvest water content) with a water content range of 39.80 - 69.12%. (Liu et al., 2017)stated that the water content of sweet corn seeds during germination varies between 53.51% and 74.33%. In sequence, the genotypes SB13.1.3, T13.1.8, T8.3.6, and T8.3.2 occupy a potential position to germinate under high seed water content conditions. Therefore, proper harvest time and seed handling are needed to avoid the possibility of seeds germinating while still in the parent plant and during the seed processing process.

The sweet corn seeds of genotypes T13.1.8, SB13.1.3, T8.3.6, and T8.3.2 all reached physiological maturity at different times, with T13.1.8 reaching maturity at 85 DAP, SB13.1.3 and T8.3.6 at 82 DAP, and T8.3.2 at 79 DAP. However, the results of viability and vigor tests did not always align with the seeds' physiological maturity status. The sweet corn seeds with genotype T13.1.8 and SB 13.1 can be harvested earlier, between 76 DAP and 82 DAP. Genotypes T8.3.6 and T8.3.2 can be harvested between 79 and 85 hours after sowing (DAP). In contrast, the harvest time for sweet corn intended for consumption typically ranges from 65 to 74 DAP (Haitami & Wahyudi, 2019). This result indicates a difference in harvest time for consumption of approximately 11 to 14 days. This study recommends earlier harvest times compared to the findings of Soon et al. (2004), which indicate that the optimal harvest times for sweet corn seed production of the Xtrasweet 82 and Fortune varieties are 42 DAP and 49 DAP, respectively. For supersweet corn, the optimal harvest time is between 92 and 99 DAP, considering factors such as the level of emergence, dry weight of plumules in cold soil tests, sugar and electrolyte leakage from seeds, and α-amylase activity.

4. Conclusion

Understanding the interaction between harvest time and initial water content is essential for seed producers aiming to optimize the quality of sweet corn seeds. The sweet corn genotypes T13.1.8 and SB13.1, harvested between 76 and 82 hours after sowing (DAP) with an initial 10-12% water content, represent the most effective treatment combinations. These genotypes exhibit germination rates and vigor indices ranging from 92.7% to 100% and 70.67 to 96.67, respectively. Additionally, sweet corn genotypes T8.3.6 and T8.3.2 can be harvested between 79 and 85 DAP, also with an initial water content of 10-12%, yielding germination rates between 86.00% and 98.67% and vigor indices from 58.00 to 86.67. The findings of this study can serve as valuable recommendations for seed producers, guiding them in selecting appropriate harvest times and water content based on the specific genotype used. This approach is crucial for ensuring that the seeds produced possess high viability and vigor, ultimately enhancing the efficiency of seed production and supporting the availability of superior seeds for farmers.

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