Evaluation of the Morphological and Physiological Changes of Okra (Abelmoschus esculentus) during Seed Maturation

Arsenio Jr. D. Bulfa
College of Agriculture, Silliman University

Marjun C. Alvarado
Graduate School, University of the Philippines Los Baños

Annalissa L. Aquino
Institute of Crop Science, College of Agriculture and Food Science, University of the Philippines Los Baños (UPLB)

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Evaluation of the Morphological and Physiological Changes of Okra (*Abelmoschus esculentus*) During Seed Maturation

Arsenio Jr. D. Bulfa[1,2], Marjun C. Alvarado[2], Annalissa L. Aquino[3]
[1]College of Agriculture, Silliman University, Dumaguete City 6200, Philippines
[2]Graduate School, University of the Philippines Los Baños, Laguna, Philippines
[3] Institute of Crop Science, College of Agriculture and Food Science, University of the Philippines Los Baños (UPLB), College 4031, Laguna, Philippine
Corresponding author email: arseniodbulfa@su.edu.ph

Abstract: *This study investigated the intricacies of seed maturation of Okra (Abelmoschus esculentus) by analyzing the morphological and physiological changes, aiming to understand the trajectory of seed development and maturity. The study tracked the changes in seed dry weight, moisture content, germination, and seed size at various developmental stages. Results show that, initially, high moisture content decreases as seeds mature, paralleling an increase in dry weight, indicating nutrient accumulation. Thickening of the seed coat aids desiccation tolerance and dormancy induction. Seed size and germination follow a developmental sequence, with early stages focused on seed growth and later stages aligning with dormancy transitions for optimal germination potential. The peak germination percentage around Day 24 signifies an equilibrium point where seed size, resource allocation, dormancy, and maturity converge, maximizing offspring success. This research discussed the progression from seed development to physiological maturity, providing insights into optimizing seed quality and germination potential.*

Keywords: Seed maturation, physiological maturity, okra, okra seeds, dormancy, maturity.

1. INTRODUCTION

Seed maturation involves a series of crucial changes both in structure and function that influence the development from a fertilized ovule to a dormant seed and ultimately impact the quality and viability of seed [1]. Physiological maturity, a pivotal stage in seed development, underscores the intricate relationship between these changes and their implications for seed quality, storage, and successful germination [2], [3].

Morphologically, seeds gradually transform into their characteristic forms, often becoming smoother, plumper, and acquiring a more defined seed coat. This transformation is driven by cell expansion and the accumulation of storage reserves [3], [4]. In some seeds, like okra, achieving a nearly spherical shape signifies the culmination of this morphological transformation, indicating physiological maturity [5].

Physiologically, the seed undergoes a dramatic shift in its metabolic machinery. The once highly active embryo transitions into a quiescent state, dramatically reducing its metabolic activity and respiration [3]. This shift is accompanied by a decline in water content, paving the way for desiccation tolerance. This crucial adaptation allows the seed to withstand harsh environments and survive for extended periods, waiting for the opportune moment to germinate.

The accumulation of storage reserves is another key feature of seed maturation. Sugars, starches, proteins, and oils are meticulously synthesized and deposited within the embryo, providing the energy and nutrients required for the seedling's initial growth [3]. This process is tightly regulated by a complex interplay of hormonal and environmental signals. Morphological alterations during seed maturation are visible signs of the intricate processes occurring within. The embryo matures as the seed coat thickens, enhancing impermeability and resistance to external stressors. The rigid seed coat of okra restricts water absorption, creating a major physiological obstacle to uniform stand establishment and optimal performance [6]. Additionally, storage tissues like endosperm or cotyledons undergo significant changes, accumulating essential reserves of carbohydrates, proteins, and lipids. These reserves fuel the embryo during germination [7], underscoring the connection between morphological changes and successful seedling establishment.

Concurrent with morphological shifts, physiological changes play a crucial role in reaching physiological maturity, the stage where seeds attain their maximum potential for successful germination. Hormonal dynamics, particularly the balance between abscisic acid and gibberellins, dictate dormancy and germination potential. As seeds mature, hormonal changes induce dormancy, ensuring seeds remain dormant until conditions are optimal for germination. Understanding these physiological changes allows interventions to regulate dormancy, effectively managing germination across different crop species.

The concept of physiological maturity deeply influences seed quality, vital for sustainable agriculture. Physiologically mature seeds exhibit optimal vigor and storability, displaying resilience to environmental stresses, storage, handling, and field conditions. Harvesting seeds before physiological maturity may reduce germination potential and compromise vigor. Conversely, harvesting after physiological maturity may decrease storability and pose challenges in breaking dormancy [2].

Understanding these morphological and physiological changes is crucial for optimizing seed quality and agricultural practices. By identifying the markers of physiological maturity, such as maximum dry matter accumulation or specific changes in seed shape [5], we can harvest seeds at the optimal time, ensuring their viability and vigor. Hence, this activity aimed: 1) to determine the changes associated with the physiological maturity of seeds and 2) monitor the developmental processes of the embryo of various seeds.

2.MATERIALS AND METHODS

2.1. Plant Selection and Flower Tagging

A mature Okra plants already at productive flowers and fruits grown at ICropS Field Demonstration Area were selected to be tagged for morphological and physiological changes during seed maturation study.

At the onset of flowering take note of the time of anthesis (the period during which the flower is fully open and ready for pollination) the flowers were tagged to indicate the date of anthesis. Three days after anthesis, and at three days intervals thereafter, parameters such as dry weight, seed size, moisture content, and the germination capacity of the developing seeds were determined. Flower tags were labelled Day 3-33 (11 observations) with five replications randomly assigned to all okra buds to have sufficient seed samples for fresh weights, ODW, and germination tests.

2.2. Seed Observation and Characterization

Every 3 days interval, development of the seed was observed under the microscope. A digital caliper was used to measure the seed every after extraction. The data were recorded and plotted on a graph to determine the point of physiological maturity.

2.3. Seed germination test

Every 3 days interval the seed were extracted from the pods, weighed, and germinated in petri dishes with filter paper under ambient temperature. The germination was observed for 7 days and considered successful germination when there was at least 2 mm protrusion of the radicle [8]. Germination was then computed as follows:

$$\text{Germination (\%)} = \frac{\text{\# seeds germinated}}{\text{\# total seeds sown}} \text{ x } 100 \quad \text{Eq. 1}$$

2.4. Seed moisture content (MC) and oven-dried weight (ODW)

The initial fresh weight of the extracted seeds replicated 3 thrice with 10 seeds per replication was recorded and the weighed using the analytical balance. The seeds were then oven-dried at 103°C for 17 hours. After drying, the samples were placed inside the desiccator to cool down without absorbing moisture before recording the oven-dried weight using an analytical balance. The seed moisture content, on a wet basis, was computed using Eq. 2, while seed dry weight was computed using Eq. 3.

$$\text{MC (\%)} = \frac{\text{Initial weight}-\text{ODW}}{\text{Initial Weight}} \text{ x } 100 \quad \text{Eq. 2}$$

$$\text{DW (mg)} = \frac{\text{ODW}}{\text{Total \# seeds}} \quad \text{Eq. 3}$$

2.5. Data Analysis

Data gathered in the study were qualitatively compared and analyzed using standards in published literature.

3. RESULTS AND DISCUSSIONS

3.1. Seed dry weight and Moisture content

Figure 1 shows the fluctuations in seed dry weight and moisture content throughout various stages of development in Abelmoschus esculentus. At the initial stages, the moisture content might be high, indicating a period of water uptake or imbibition by the seeds and slowly decreased until it stabilized at Day 30 onward.

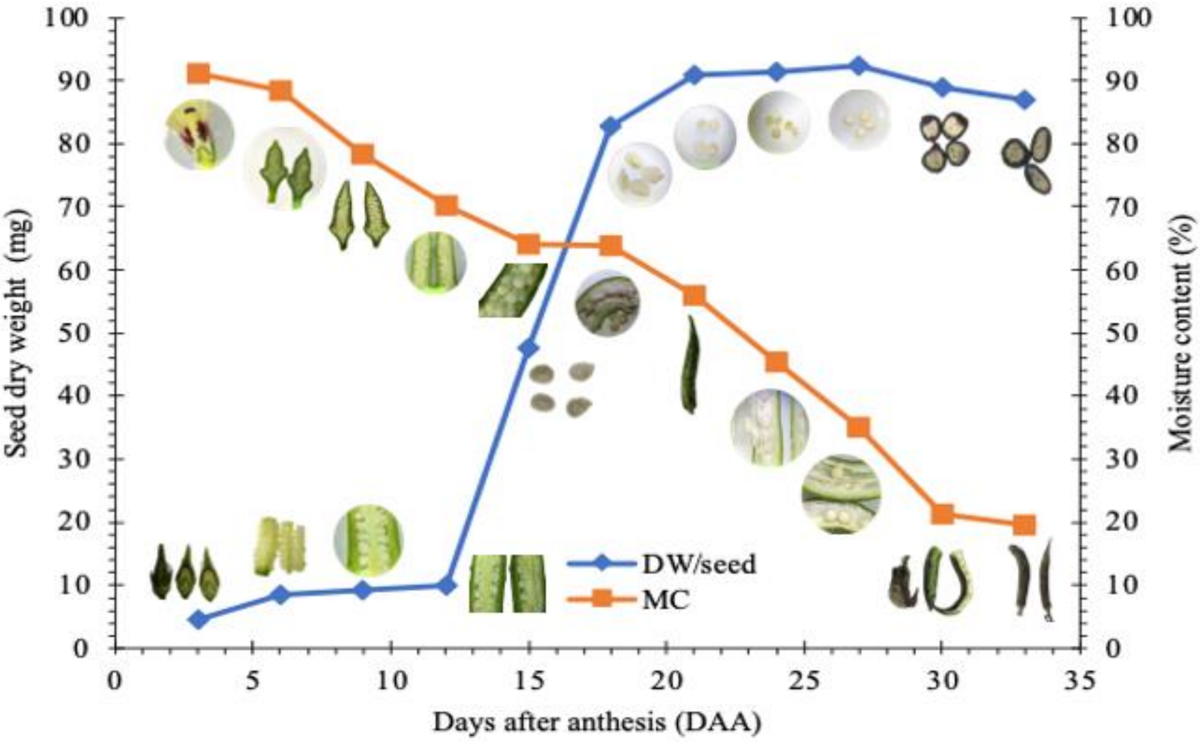

Fig. 1. Changes in seed dry weight and moisture content at different times of development of Okra seeds.

This phase was accompanied by dry weight increase. This increase in DW is due to nutrient accumulation. The developing seed actively imports nutrients and

assimilates them into carbohydrates, proteins, and oils, contributing to its dry weight [9].
Also, water translocation from the seed coat and pericarp to the embryo concentrates stored nutrients, further increasing dry weight [2]. Moreover, the rapid cell division and enlargement in the embryo, particularly in the cotyledons, increases the embryo's mass and dry weight [10].
The moisture content decrease might be due to the thickening and waxing of the seed coat that reduced water loss through transpiration, leading to decreased moisture content [2]. The seed development of desiccation tolerance, including the accumulation of protective molecules, enhances the seed's ability to survive drying [2]. While this phase is happening, dormancy induction occurs, the desiccation and decreased moisture content are associated with the induction of seed dormancy, ensuring germination under suitable conditions [2].
The stabilization of dry weight reaching a maximum at Day 21 and moisture content stabilizing around Day 30, respectively, suggest completion of active nutrient accumulation and water movement [2]. Once sufficient reserves are stored, further growth and water translocation slow down, leading to seed maturation [10].

3.2. Germination and seed size

The germination percentage is a function between dormancy and activation. The early in development (before Day 15), the seed still was developing to be physiologically capable for germination. As the seed matures and accumulates sufficient reserves, the balance shifts towards increasing the potential for successful germination [2]. The optimal seed size for germination often contains more stored energy and resources, providing the seedling with a greater advantage during the initial stages of establishment [11]. This explains the initial increase in germination percentage with increasing seed size in okra.
However, there can be a trade-off between seed size and number. Producing larger seeds requires more resources, potentially limiting the total number of seeds produced [12]. This could explain the eventual decrease in germination percentage after Day 24, as the plant may prioritize resource allocation towards fewer, larger seeds for optimal offspring survival.

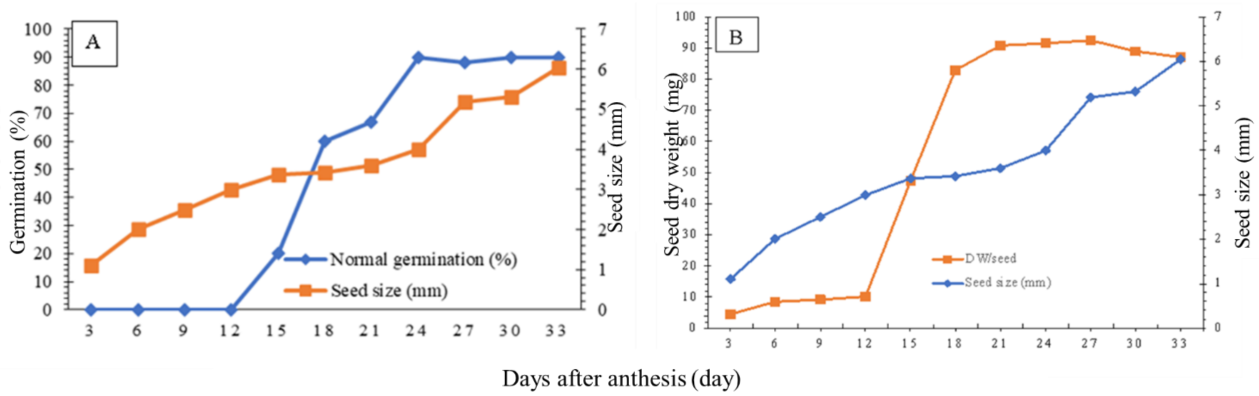

Fig. 2. Changes in seed size (mm) and germination percentage (%) (A); and a comparative analysis of seed dry weight (mg) and seed size (mm) at different developmental stages of okra seeds.

The peak germination percentage on Day 24 likely represents the point where the balance between seed size, resource allocation, and dormancy is most optimized for successful germination in Abelmoschus esculentus or its physiological maturity. At this stage, the seeds have accumulated sufficient reserves, overcome dormancy requirements, and maintain a balance with resource availability to maximize offspring success.

The growth and developmental sequence delineate the evolution of seeds from three days after anthesis (DAA) to 33 DAA. Initially, at 3 DAA, the seeds were undifferentiated, signifying the initial phase of their formation. By 6 DAA, recognizable pods and distinct seeds marked the onset of visible seed growth. Progressing to 9 DAA, both pods and seeds exhibited visible growth, with the seeds displaying a sticky nature when cut open. At 12 DAA, increased growth was noticeable in both pods and seeds, accompanied by a reduction in the seeds' stickiness upon slicing. Advancing to 15 DAA, seeds became easily detachable from the pods, displaying a whitish appearance and an empty center, indicating incipient maturity. Subsequent stages witnessed a progression towards maturity: at 18 DAA, despite a drying appearance, seeds remained filled with water; by 21 DAA, pod edges became distinct, marking maturity onset, while the seeds' flesh thickened. Evolving further, at 24 DAA, pod color changed to light green, and seeds showed a greener center. As maturity continued at 27 DAA, pods started drying, and seedcoats thickened, followed by a progression to brownish hues by 30 DAA as pods and seed flesh began drying up. Ultimately, at 33 DAA, pods attained complete dryness and brown coloration, while seedcoats turned brown, signifying the peak of seed maturation. The changes in appearance, texture, and moisture content elucidates the seed development and maturity ok okra (Table 1).

Table 1. Observations of pod and seed changes at different times of development of Okra seeds.

Days after anthesis (DAA)	Description	Pods	Seeds
3	Seeds were undifferentiated		
6	Pods were recognizable; seeds were distinct		
9	Growth of pods and seeds were visible; seeds were sticky when cut open		
12	Increased growth of pods and seeds were observed; seeds were less sticky when sliced		
15	Seeds can easily be detached from the pods; seeds were whitish and empty in the middle		
18	Pods and seeds looked drier compared to earlier stages; seeds were filled with water		
21	Pod edges were distinct as sign of maturity; flesh of seeds thickened		
24	Pod color changed to light green, seeds turned more green at the center		
27	Pods started to dry-up, seedcoats turned thick		
30	Pods turned brownish and flesh started to dry-up, seedcoats turned brown		
33	Pods were completely dry and brown; seedcoats turned brown and lighter		

4. CONCLUSIONS

This study aimed to determine the changes associated with the physiological maturity of seeds and monitor the developmental processes of the embryo of various seeds. Results show that the changes in seed dry weight and moisture content of Abelmoschus esculentus indicated a clear trajectory of seed growth and maturation. Initially, active water uptake resulted in high moisture content and gradually decreased as seed matures. This decline coincides with increased dry weight, signifying nutrient accumulation and water movement within the seeds. The seed coat's thickening reduces water loss, supporting desiccation tolerance and seed dormancy. In terms of germination and seed size, the developmental sequence reveals a progression from seeds development towards germination to fully matured ones. Seed development aligned with dormancy phases, transitioning to a germination-suitable state as reserves accumulate. The peak germination percentage around Day 24 signified the optimal stage balancing seed size, resource allocation, dormancy, and maturity, enhancing offspring success.

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