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GROWTH STAGES AND PHENOLOGICAL ANALYSIS OF SORGHUM (*Sorghum bicolor* L.) IN EAST SUMBA

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Abstract
Sorghum (Sorghum bicolor L.) is a cereal crop with strong potential as an alternative food source, animal feed, and bioenergy material due to its adaptability to marginal, dry, and nutrient-poor soils. In Indonesia, however, local sorghum utilization remains limited because of the lack of improved varieties and insufficient knowledge of growth and phenology. This study analyzed the growth phases and phenological traits of two East Sumba genotypes, Watar Hammu Miting Walla and Watar Hammu Rara Kadita. The research was conducted at the Experimental Farm of the Faculty of Agriculture, UKSW (June–December 2024), using morphological observations and growth-phase documentation until flowering. Variables measured included leaf traits, chlorophyll content, plant height, stem diameter, sugar content, seed weight and size, and panicle form. Both genotypes exhibited similar growth patterns, but Miting Walla progressed through early phases more rapidly. Morphologically, Miting Walla had narrower leaves, sturdier stems, higher sugar levels, and compact panicles, while Rara Kadita had wider leaves, taller stems, lighter seeds, and looser panicles. These contrasts indicate distinct adaptive strategies and underline the potential of local sorghum as a dual-purpose crop for food and bioenergy.

INTRODUCTION

Sorghum (Sorghum bicolor (L.) Moench) is a cereal crop with high adaptability that has potential as a source of carbohydrates, alternative food, bioethanol, and animal feed. Its advantage lies in its ability to grow on marginal land with dry, hot conditions and poor soil, which are common in Indonesia. (Siregar et al., 2016). As a food source, sorghum has a relatively high nutritional content. Sorghum contains 83% carbohydrates, 3.5% fat, and 10% protein. (D et al., 2015).

In Indonesia, sorghum development remains limited due to a lack of superior varieties and insufficient knowledge of its cultivation. (Purba et al., 2022). One of the main obstacles to increasing sorghum production is the use of low-quality seeds. Efforts to maintain viability and provide high-quality seeds are significant because they can increase productivity and influence plant phenotypes and yield components. (Edi et al., 2022). Other obstacles to sorghum development include limited availability of certified seeds, suboptimal seed management, and a weak market, which discourages farmers from switching to sorghum cultivation. (Kusumawati et al., 2013)

These conditions provide an essential basis for research on sorghum plant growth phases and phenological analysis to understand their growth patterns and adaptability to various environmental conditions in Indonesia. A deep understanding of the growth phases and phenology of sorghum is expected to improve cultivation strategies, thereby optimizing sorghum productivity and promoting more effective use of marginal land.

This study aims to identify the phenological characteristics of sorghum plants, particularly in two local genotypes from East Sumba, namely Watar Hammu Miting Walla and Watar Hammu Rara Kadita.

This study focuses on plant growth phases and phenology as a basis for developing superior varieties, selecting suitable planting locations, and planning sorghum cultivation strategies. The research results are expected not only to contribute to scientific improvements in the genetic quality of sorghum but also to provide practical benefits for the development of cultivation technology in Indonesia. Additionally, the information obtained can serve as a reference for researchers and plant breeders in formulating more effective and sustainable cultivation management strategies.

MATERIAL AND METHODS

This research was conducted at the garden Fakultas Pertanian dan Bisnis (Science Techno Park), Wates Village, Getasan District, Semarang Regency, at an altitude of 1,118 meters above sea level, located in a highland area. The research was conducted from June to December 2024.

The tools used include a black background board, a ruler, a tape measure, a refractometer, an RHS color chart, a caliper, and a high-quality cell phone camera. The research materials consist of local sorghum seeds from East Sumba, namely the genotypes Watar Hammu Miting Walla (Sorghum A) and Watar Hammu Rara Kadita (Sorghum B).

This type of research is descriptive qualitative, employing descriptive and narrative analysis methods. The observation variables consist of plant growth stages and phenology. Growth stage observations were conducted using the growth stage scale proposed by the Sorghum Checkoff, from the vegetative phase through the generative phase (flowering or physiological ripening). Meanwhile, phenological observations were conducted by describing the morphological characteristics of sorghum plants using literature references and field observations, as presented in Table 1.

Table 1. Variables and observation methods

No	Observation Variable	Observation Method
1.	Leaf margin	The leaf margin is observed with a magnifying glass, and its shape is identified.
2.	Leaf surface	The leaf surface is observed with a magnifying glass to identify its type.
3.	Leaf color	Leaf color is identified during the flowering phase by matching it with the RHS color chart.
4.	Leaf chlorophyll	Leaf chlorophyll is measured during the flowering phase using SPAD on the third leaf after the flag leaf.
5.	Leaf length (cm)	Leaf length is measured by selecting the longest leaf, then measuring from the base to the tip of the leaf.
6.	Leaf width (cm)	Leaf width is measured at the widest part of the middle using a ruler or measuring tape.
7.	Leaf angle (°)	Leaf angle is measured during the flowering stage using a protractor at the point between the node and the axillary bud.
8.	Stem diameter (mm)	Stem diameter is measured during the flowering stage using a digital caliper at the point near the stem node.
9.	Sugar content (% Brix)	Brix content is measured during the flowering phase using a portable Brix refractometer by squeezing the sap from the lower, middle, and upper parts of the stem..
10.	Weight of 1000 seeds (g)	The weight of 1000 seeds is determined by weighing 1000 sorghum seeds on a digital scale, then averaging three measurements of 100 seeds.

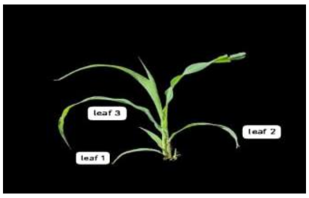
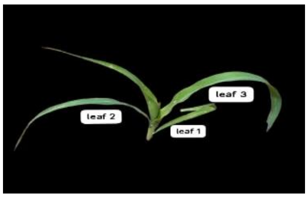
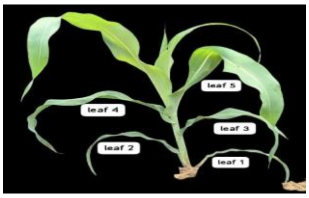
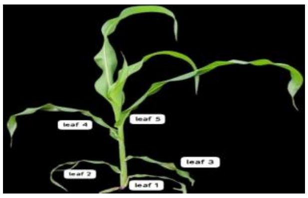
11.	Seed size (mm)	Seed size observations, including length and width, were measured using a vernier caliper.
12.	Panicle characteristics	Observations were conducted during the maximum vegetative phase and documented.
13.	Seed shape and color	Observations were conducted during the maximum vegetative phase and documented.

RESULTS OF THE DISCUSSION

Growth Phase of Sorghum Miting Walla and Rara Kadita

The growth phase is a series of stages that plants go through from germination to producing seeds or fruit. Each phase has different characteristics. Sorghum plants go through various growth stages during their lifetime, with varying periods of time between each stage. The growth of sorghum plants can be divided into three parts: the vegetative phase, the generative phase, and the stage of seed formation and physiological maturity. The growth phases of sorghum plants can be observed to determine agronomic characteristics, such as plant height, number of leaves, leaf angle, stem diameter, and dry weight of the plant. (Utami et al., 2022). In the study (Zilfida et al., 2024) It is said that there are significant differences in plant height, sugar content (brix), and dry weight. The physiological ripening phase produces the highest plant height, followed by the flowering phase, and the lowest is the flag leaf phase. Information on plant growth phases can serve as a basis for developing plant cultivation technologies, including planting patterns, land preparation, appropriate fertilization times, and other cultivation activities.

Table 2. Growth Phases of Sorghum Miting Walla and Rara Kadita

Growth Phase	WH Miting Walla	WH Rara Kadita
Phase 0: characterized by the emergence of buds and no leaves yet	 (4-5 DAP)	 (4-5 DAP)
Phase 1: characterized by the emergence of 3 fully opened leaves	 (14-17 DAG)	 (18-20 DAG)
Phase 2: characterized by the emergence of 5 fully opened leaves	 (28-30 DAG)	 (35-39 DAG)

Phase 3: The plant enters a period of rapid growth.

(41-47 DAG)

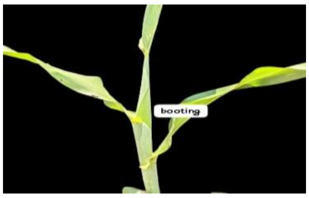
(43-52 DAG)

Phase 4: characterized by the emergence of the flag leaf

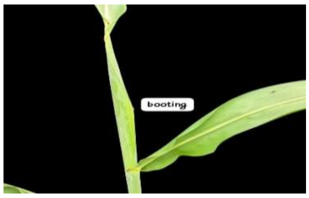
(54-62 DAG)

(60-67 DAG)

Phase 5: Characterized by the flag leaf sheath, which can be seen as a protrusion or swelling



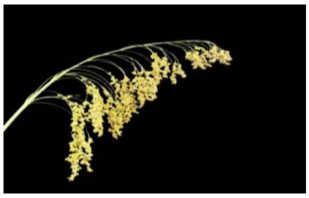
(62-67 DAG)



(64-71 DAG)

Phase 6: marked by. The plant begins to flower from the top of the panicle and develops downward.

(71-78 DAG)



(71-78 DAG)

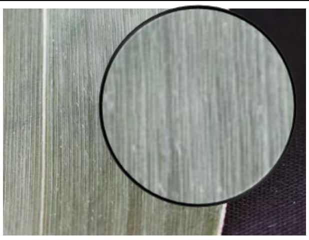
Description: WH (Watar Hammu), DAP (day after planting), DAG (the day after germination).

Phenology of Sorghum Watar Hammu Miting Walla and Watar Hammu Rara Kadita

a. Leaf Description

The differences in the length and width of sorghum leaves between the Watar Hammu Miting Walla and Watar Hammu Rara Kadita genotypes are evident in morphological observations, which show significant variation. The Watar Hammu Miting Walla genotype has shorter leaves (±52 cm) and narrower leaves (±8.5 cm) compared to the Watar Hammu Rara Kadita genotype, which has longer leaves (±62 cm) and wider leaves (±9 cm). The larger leaf size in Rara Kadita is thought to provide better photosynthetic capacity.

A



B

Figure 1. Surface of sorghum leaf A: WH Miting Walla, B: WH Rara Kadita

The Watar Hammu Miting Walla genotype has smoother and shinier leaves. In comparison, the Watar Hammu Rara Kadita genotype has rougher leaves with more fine hairs, which can affect photosynthesis and light absorption. These differences affect the physical appearance and growth efficiency of the genotypes, and it is suspected that leaf surface texture influences the plant's water use efficiency. Genotypes with smooth leaf surfaces, such as Watar Hammu Miting Walla, exhibit higher transpiration rates, resulting in increased water loss. Conversely, the Watar Hammu Rara Kadita genotype with rough leaf surfaces is more efficient at maintaining soil moisture and reducing water stress. (Hill et al., 2022) States that leaf surface plays a vital role in water absorption and plant adaptation to the environment. Large leaves with trichomes help absorb dew during drought, while surface structure affects water use efficiency (WUE) and chlorophyll content. Watar Hammu Miting Walla, with a smooth surface, is more efficient at absorbing light, thereby supporting chlorophyll synthesis and optimal photosynthesis. Conversely, Watar Hammu Rara Kadita with a rough surface tends to hinder light absorption, thereby reducing chlorophyll, photosynthesis, and plant growth.

A B

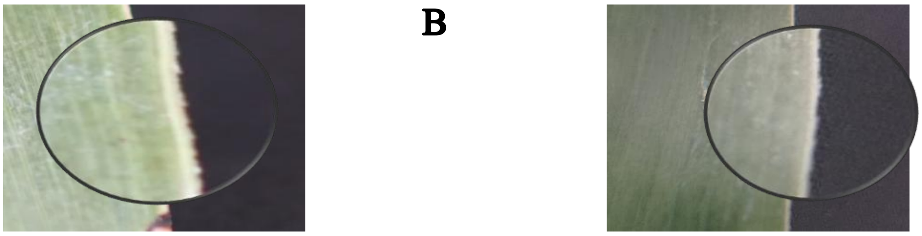


Figure 2. The edge of a sorghum leaf A: WH Miting Walla, B: WH Rara Kadita

Both sorghum genotypes have serrated leaf margins, but they differ in size and depth. Watar Hammu Miting Walla has fine, regular serrations, while Watar Hammu Rara Kadita has sharp, deep serrations that potentially serve as a defense against herbivores. These differences in serrations affect photosynthesis, transpiration, and gas exchange. Deep serrations can increase CO_2 absorption but carry a greater risk of water loss. According to (Wang et al., 2024) The serrated edges of the leaves increase light absorption, regulate temperature and water runoff, and are more tolerant to heat and cold.

A B

Figure 3. Color of sorghum leaves A: WH Miting Walla, B: WH Rara Kadita

According to Huo et al. (2024), the green color of the leaves reflects the chlorophyll content, which plays a vital role in photosynthesis. Watar Hammu Miting Walla has an average chlorophyll content of 56.25 mg/g and a grayish-green color (NN137 grayish olive green A), indicating lower photosynthesis. In contrast, Watar Hammu Rara Kadita has a higher chlorophyll content (60.28 mg/g) and a brighter green color (137 Moderate olive green B), suggesting it may be more efficient in photosynthesis.

According to (Huo et al., 2024) Chlorophyll is the primary pigment in photosynthesis and an indicator of plant health. Measuring chlorophyll content can reflect a plant's physiological and nutritional status and help detect stress and pest attacks in precision agriculture. This is in line with (Murti Indriatama et al., 2023) This states that chlorophyll content is related to the aging process and the mobilization of nutrients from old tissues to young and reproductive tissues to support seed maturation. Sorghum has a stay-green trait that delays senescence during grain filling, keeping the leaves green from the reproductive phase through harvest.

A

B

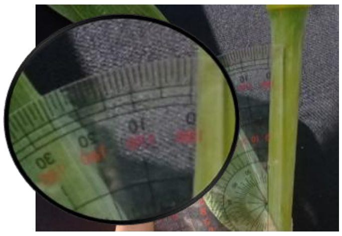


Figure 4. The angle of sorghum leaves A: WH Miting Walla, B: WH Rara Kadita

Sorghum genotypes exhibit different leaf angles: 27° in Watar Hammu Miting Walla and 25° in Watar Hammu Rara Kadita, which affect light absorption and photosynthesis. The smaller angle in Rara Kadita makes the leaves more upright, enabling more efficient light capture. In comparison, the larger angle in Miting Walla helps reduce shading and allows light to reach lower leaves, though it may increase temperature and transpiration. Additionally, variations in leaf angle can affect pest accessibility, with larger angles potentially creating more favorable conditions for pests.

Leaves with larger angles tend to cast more shade, creating a humid environment under the canopy that can attract pests and pathogens. In the study (Isti et al., 2025) Saying that leaves with upright angles capture sunlight more efficiently, enabling more efficient energy absorption, increased photosynthesis, and higher crop yields.

b. Description of the Stem

The Miting Walla genotype has a sturdier and shorter stem, while Rara Kadita tends to be taller and slimmer. According to (Zilfida et al., 2024) During the flowering phase, the sorghum stem tends to be larger, but as harvest approaches, it shrinks due to a decrease in water content. Observations show significant differences between genotypes: the stem diameter of Watar Hammu Miting Walla is 18.44 mm, and that of Watar Hammu Rara Kadita is 13.20 mm. (Isti et al., 2025) Also said that plants with larger stem diameters tend to be sturdier and stronger, so the diameter of sorghum plants can be an indicator of stem strength. This is in line with research. (Setiyagama et al., 2017) This says that plants with large diameters are sturdier and less prone to falling over.

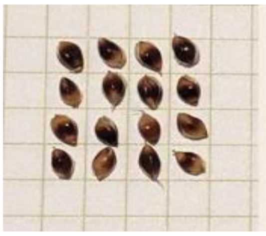
According to Zilfida et al. (2024), the Brix level is used to measure dissolved solids, especially sucrose, fructose, and glucose, reflecting the sweetness level of sorghum sap in the stalk. (Ratna Anugrahwati et al., 2024) In general, the highest Brix level is reached during the flowering phase, followed by the flag leaf phase, and the lowest during the physiological ripening phase. The Watar Hammu Miting Walla genotype has the highest brix level (10%), while Watar Hammu Rara Kadita has 9%. (Zilfida et al., 2024) said that the physiological ripening phase produced the tallest plants, followed by the flowering phase and the lowest in the flag leaf phase. The highest Brix content was obtained in the flowering phase, not significantly different from the flag leaf phase, while the lowest content was found in the physiological ripening phase. Research (Isti et al., 2025). The increase in Brix level in the stem correlates with the level of sweetness. In this study, Brix measurements were taken from the upper stem.

c. Description Seed

The weight of 1000 seeds is used to assess seed quality, where the greater the food reserves, the heavier the seeds. The weight of 1000 seeds is the ratio of the weight of 1000 seeds produced by a variety. The weight of 1000 sorghum seeds will affect the yield per hectare. According to (Ibrahim & Naim, 2018), varieties with a higher thousand-seed weight will also produce a higher yield per hectare compared to other varieties. A high 1000-seed weight indicates the plant's ability to perform photosynthesis better and efficiently store the results of assimilation in the sorghum plant's zinc, which is the seed. The 1,000-seed weight is required to determine the seed requirement per hectare. Seeds with a high weight can grow into strong seedlings and accelerate the germination period of the three rice varieties tested. Seeds with high and medium weights have better vegetative growth than seeds with low weights. (Kusumawardana et al., 2025). The weight of 1000 sorghum grains differed significantly between the two genotypes, namely 17.89 g in Watar Hammu Miting Walla and 12.4 g in Watar Hammu Rara Kadita. This difference affects crop yield because the weight of 1,000 grains is closely related to the number of grains per ear and the weight of grains per plant, making it an important parameter in breeding to increase sorghum productivity.

Tao et al., (2017) Stating that seed size and seed weight are the primary quality attributes and key determinants of crop yield, which have been rigorously selected during plant adaptation. Large-seeded varieties facilitate harvesting, processing, and planting, resulting in larger seed size. Seed size and weight are closely related to carbon supply and transport between carbon sources and seeds. Sorghum seed size differs between the two genotypes, with Watar Hammu Miting Walla having wider seeds (±4.77 mm) but shorter (±3.27 mm), while Watar Hammu Rara Kadita has narrower seeds (±2.77 mm) but longer (±5.05 mm). According to (Aryani et al., 2022) Sorghum seeds measure approximately 4x2.5x3.5 mm, and 100 seeds weigh between 8 mg and 50 mg, with an average weight of 28 mg.

A



B

Figure 5. Sorghum seeds A: WH Miting Walla, B: WH Rara Kadita

The Watar Hammu Miting Walla genotype has an oval shape with a slightly pointed top and a curved bottom. The seeds of this genotype are black with red tips and white bases. Meanwhile, the seeds of the Watar Hammu Rara Kadita genotype also have an oval shape with slightly pointed upper and lower ends. The seeds of this genotype are dark red or black. According to Slamet et al. (2020), Red and black sorghum contain ten times more tannins and anthocyanins than white sorghum. But, According to (, et al., 2018) states that seed color does not affect the quality of sorghum seeds but can be economically valuable because it determines consumer acceptance of a sorghum variety. The color of sorghum seeds is determined by the color of the husk, which is the outer layer of the seed. In addition, according to (Aryani et al., 2022) It states that sorghum seeds are round in shape with three main layers: outer skin (8%), germ (10%), and endosperm (82%). They measure approximately 4.0 × 2.5 × 3.5 mm, with weights ranging from small (8–10 mg), medium (12–24 mg), to large (25–35 mg). The seed coat can be white, red, or light brown. According to (Kusumawati et al., 2013) There are four types of husks in sorghum plants: very short (covering 25% of the grain), short (covering 50% of the grain), moderately long (covering 75% of the grain), and very long (covering 100% of the grain). The watar hammu miting walla genotype has a moderately long husk (covering 75% of the seed). Meanwhile, the watar hammu rara kadita genotype has a very long husk (covering 100% of the seed).

d. Description Malai

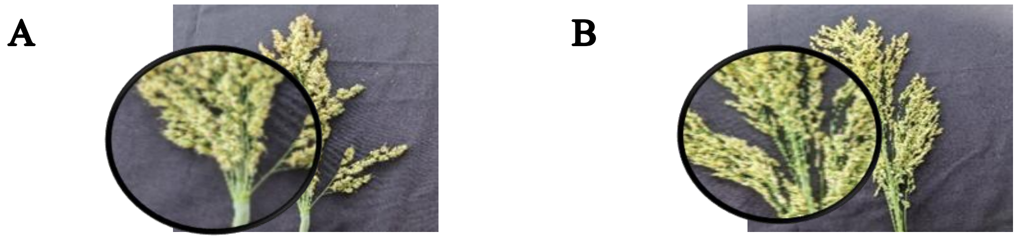


Figure 6. Sorghum plan pollen A: WH Miting Walla, B: WH Rara Kadita

Sorghum has male and female flowers. Pollination occurs almost without the help of insects. Approximately 95% of the female flowers that bear fruit are the result of self-pollination (Aryani et al., 2022). According to (Kusumawati et al., 2013) Sorghum panicles have five shapes: inverted pyramid, broad top, symmetrical, broad bottom, and pyramid. Panicle density distinguishes genotypes, for example, the watar hammu miting walla genotype (pyramid, compact) and the watar hammu rara kadita genotype (symmetrical, loose). Panicle shape is the main distinguishing characteristic of sorghum genotypes (, et al., 2018). The Watar Hammu Miting Walla genotype has short, dense panicles that are wind-resistant and have the potential to increase seed yield. Meanwhile, Watar Hammu Rara Kadita has long, sparse panicles that allow room for seed development, but are more susceptible to damage from wind or rain (Sulistyawati et al., 2019) explains that long panicles are not always accompanied by a large number of leaves and heavy seeds; this is related to panicle density. The Watar Hammu Miting Walla genotype with dense and compact panicles has greater sink capacity due to a higher number of seeds, but has the potential to cause competition between seeds when photosynthetic supply is limited. Conversely, the Watar Hammu Rara Kadita genotype with sparse panicles has a lower sink capacity, but its seeds are more evenly filled, resulting in relatively larger seed size. These differences indicate that panicle density affects the balance between seed quantity and quality in sorghum (TIAN et al., 2023). This relationship is also seen in the weight of 1000 seeds, where Watar Hammu Miting Walla has a higher weight than genotype Watar Hammu Rara Kadita . This shows that the shape of the panicle affects the storage capacity of the seeds. Watar Hammu Miting Walla and Watar Hammu Rara Kadita have different panicle colors: The watar hammu miting walla genotype exhibits denser, more compact panicles with a darker greenish-yellow color, while the watar hammu rara kadita genotype exhibits looser panicles with a greenish-yellow color. These differences indicate morphological variation and different levels of maturity between genotypes.

CONCLUSION

The growth phases of Watar Hammu Miting Walla and Watar Hammu Rara Kadita are similar, but Miting Walla is faster in the early phase. Both flower at 71–78 HSBand morphological differences are observed in the leaves, stems, seeds, and panicles. In general, they differ in leaf size and shape, stem structure, seed size, color, and shape, as well as panicle shape and density, indicating morphological diversity among genotypes.

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