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Production of Sorghum Seed and Straw Biomass for Feed as Affected by Different Harvesting Ages

Nazla Iftikhar, Panca Dewi Manu Hara Karti*, Nur Rochmah Kumalasari, Luki Abdullah, Ghina Tazkia Amalia

Department of Nutrition and Feed Technology, Faculty of Animal Science, IPB University, Bogor, 16689, Indonesia

*Corresponding author; email: pancadewi@apps.ipb.ac.id

Abstract

This study evaluated the sorghum “Samurai Two” production for feed harvested at different times after planting during the rainy season. A randomized block design was employed with five groups and five treatments representing different harvesting ages: 90, 95, 100, 105, and 110 days after planting. The variables measured included panicle length, weight, dry weight, seed dry weight per panicle, 1000-seed weight, number of seeds, dry seed production, total fresh and dry weight of panicles, moisture content, and total fresh and dry weight of straw biomass. Harvesting between 90 and 100 DAP resulted in a higher fresh and dry panicle weight, fresh and dry biomass, seed dry weight per panicle, 1000-seed weight, and dry seed production. The optimal seed production for “Samurai Two” occurred at 90 DAP during the rainy season. Conversely, harvesting at 95 DAP significantly increased straw biomass’s total fresh and dry weight, with this age being optimal for straw biomass production.

Keywords: biomass, harvest age, panicle, seed, sorghum

Introduction

Sorghum “Samurai Two” is a dual-purpose crop used for food and feed, as its stems contain sugar, and its seeds are suitable for inclusion in poultry feed rations (Malalantang et al., 2023). “Samurai Two” has several advantages, including fast growth, high yield potential, good forage quality, and high biomass production (Bajang et al., 2015). Sorghum straw’s nutrient content is comparable to corn and rice straw (Liu et al., 2016). This sorghum variety was released by the National Nuclear Energy Agency of Indonesia (BATAN) in 2013, with characteristics including a flowering age of 63 days, a harvesting age of approximately 113 days, a plant height of around 198.7 cm, broad and elongated leaves, elongated panicles, clear white seeds, relatively small seed size, lodging resistance, a total biomass yield potential of 28.6 tons/ha, and waste that can be used as feed (Dudato et al., 2020). Malalantang et al. (2023) reported that “Samurai Two” has the best panicle length and seed production compared to other varieties, such as “Suri 3”, “Kawali”, and “Suri 4”.

Sorghums are propagated by seeds. Factors influencing sorghum seed production include the availability of quality seeds, seed size, seed purity, physiological seed maturity, and genetic factors (Wahyuningrum et al., 2022). Environmental factors such as rainfall, humidity, nutrient availability, light intensity, and temperature also play a role, as genetic traits may not be fully expressed due to environmental conditions (Widianti et al., 2022). The optimal physiological maturity can enhance seed germination and root development, increasing seed and straw biomass production.

Providing quality seeds is essential for developing sorghum cultivation. However, limited knowledge regarding the optimal season and timing for harvesting sorghum seeds often results in suboptimal growth and low biomass yields. Previous research conducted during the dry season indicated that environmental conditions and harvesting age impact seed and sorghum straw biomass production, including in “Samurai Two”. Therefore, this study aims to evaluate seed and sorghum straw biomass production at different harvesting ages during the rainy season. This study is part of our long-term study on sorghum seed production for feeds.

Material and Methods

This study was conducted at the Jonggol Animal Science Teaching and Research Unit (JASTRU) and the Agrostology Laboratory, Department of Nutrition

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and Feed Technology, IPB University, from April 2022 to January 2023. The soil type at JASTRU is latosol, with a pH of 4.73-5.17 (Pramono et al., 2017).

Procedure

"Samurai Two" sorghum seeds from BATAN were used, and the land was prepared mechanically. Fourteen days after tillage, the seeds were planted individually in holes with a spacing of 30 cm and 100 cm between rows. The plots measured 3 m x 3 m, and five seeds were planted per hole. Immediately after planting, a mixture of husk and livestock manure was applied at 10 tons/ha. Once the seeds germinated and the plants grew normally, thinning was done to leave one plant per hole. Fertilization was carried out with urea at 200 $kg.ha^{-1}$, phosphorus at 100 $kg.ha^{-1}$, and potassium chloride (KCl) at 60 $kg.ha^{-1}$, applied in two stages: 1/3 at 14 days after planting (DAP) and the remaining 2/3 at 30 DAP. Weed control was done weekly by trimming, and the study relied on rain-fed agriculture for irrigation.

Sorghum was harvested at the first node above the soil surface (approximately 10 cm above ground). The panicles were trimmed using pruning shears, and the panicles, stalks, and seeds were weighed. Harvesting occurred from 27 July to 17 August 2022 at 90, 95, 100, 105, and 110 DAP. The harvested panicles, seeds, and straw were sun-dried for 2–3 days before drying in an oven at 60°C for 2 x 24 h. The seeds were threshed, cleaned by sieving, and weighed. The panicle length, weight, dry weight, seed dry weight per panicle, 1000-seed weight, number of seeds, dry seed production, total fresh and dry weight of panicle biomass, moisture content, and total fresh and dry weight of straw biomass were measured. The harvest map and plot details are presented in Figure 1.

Research Design and Data Analysis

The research used was a randomized block design consisting of five groups representing different research land positions (K1-K5) and five treatments based on different harvesting ages: 90 DAP (P1), 95 DAP (P2), 100 DAP (P3), 105 DAP (P4), and 110 DAP (P5). The research area had a heterogeneous environment and varying soil fertility. Data collected were analyzed using analysis of variance (ANOVA), and if a significant effect was found, Duncan's Multiple Range Test (DMRT) was performed. Data analysis was conducted using SPSS Statistics 26 software.

Results and Discussion

General Environment

Planting occurred on 28 April 2022, with harvesting occurring from July to August. Rainfall distribution and intensity were high from June to October, gradually decreasing in November. The precipitation, temperature, humidity, and duration of sunlight in 2022 are presented in Table 1.

Production of Sorghum Panicles and Seeds

Harvesting age significantly affected ($p<0.01$) panicle length, dry weight of panicles, total fresh biomass of panicles, total dry biomass of panicles, dry weight of seeds per panicle, and the number of seeds. In addition, harvesting age significantly affected ($p<0.05$) the fresh weight of panicles, 1000-seed weight, and dry seed production (Table 2). The best panicle length was observed at 90 and 105 DAP and decreased at 95, 100, and 110 DAP.

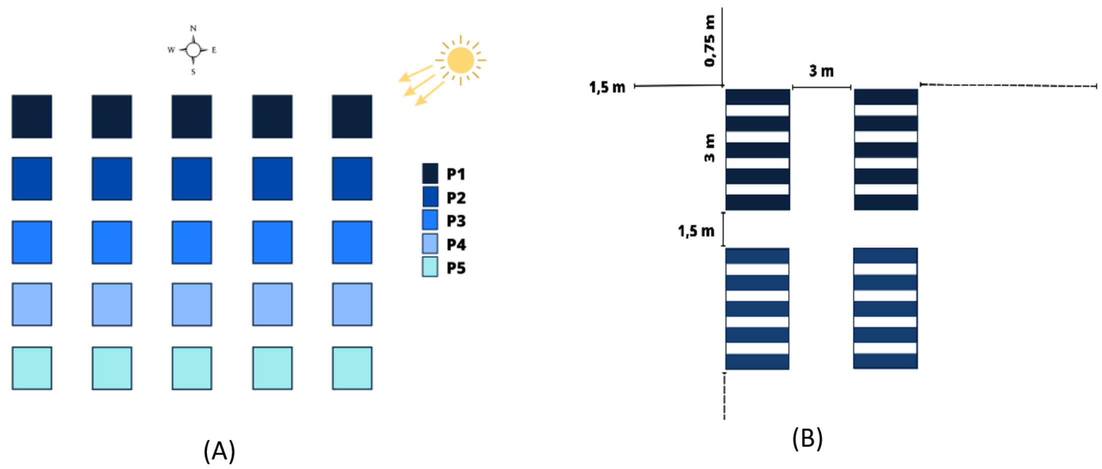

Figure 1. Harvest map (A); details of plot arrangement on the field (B)

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Table 1. The average of precipitation, temperature, humidity, and duration of sunlight in 2022

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Precipitation (mm)	107	150	111	317	217	464	359	385	344	496	321	214
Temperature (°C)	26	25.8	26.1	26.4	26.5	25.5	26.2	26.1	26	26	26	25.7
Humidity (%)	85	85	85	85	85	86	83	83	84	86	86	86
Duration of sunlight (%)	50	35	46	61	56	62	70	77	70	44	41	32

Source: Meteorological, Climatological, and Geophysical Agency (BMKG) Bogor, West Java (2022).

Table 2. Panicles and seeds production of sorghum “Samurai Two”

Variables	Harvest age (DAP)				
	90	95	100	105	110
Panicle length (cm)	33.73±2.33^{A}	31.91±1.76^{B}	32.74±1.99^{AB}	33.71±2.20^{A}	32.39±2.19^{B}
Fresh weight of panicle (g per plant)	74.81±6.60^{b}	76.01±7.29^{b}	81.46±7.61^{a}	81.22±7.55^{a}	77.46±8.08^{ab}
Dry weight of panicle (g per plant)	65.75±6.49^{B}	68.77±6.76^{AB}	73.00±6.26^{A}	72.81±7.08^{A}	69.14±6.98^{AB}
Total fresh biomass of panicle (ton.ha-1)	3.14±0,33^{BC}	3.82±1.12^{AB}	4.71±0.63^{A}	3.25±0.68^{BC}	2.72±0.63^{C}
Total dry biomass of panicle (ton.ha-1)	3.05±0.82^{BC}	3.30±0.88^{B}	4.11±0.52^{A}	3.07±0.67^{BC}	2.38±0.54^{C}
Dry weight of seed per panicle (g per plant)	47.50±1.98^{B}	47.59±2.97^{B}	52.93±4.90^{A}	52.31±5.33^{A}	47.75±6.56^{B}
1000 seeds weight (g per plant)	15.93±1.58^{b}	16.42±1.48^{ab}	17.39±1.67^{a}	17.19±1.70^{a}	16.61±1.49^{ab}
Number of seeds	3056.43±485.21^{A}	2711.24±375.43^{BC}	2959.61±373.73^{AB}	3038.13±424.03^{A}	2694.63±429.05^{C}
Dry seed production (ton.ha-1)	2.82±0.94^{b}	3.31±1.01^{ab}	3.90±0.54^{a}	2.87±0.87^{b}	2.42±0.64^{b}
Moisture content (%)	8.94±1.90^{b}	9.41±5.57^{ab}	11.22±5.07^{a}	6.87±4.97^{c}	8.75±3.68^{bc}

Notes: Values followed by different superscripts in the same row or column show highly significant differences (A.B = p<0.01) and significant differences (a, b = p<0.05) according to DMRT; DAP = Days After Planting.

Fluctuation in panicle length is influenced by environmental conditions such as rainfall; too high a rainfall can reduce panicle length. Furthermore, the fresh and dry weights of the panicles are also impacted by rainfall, causing fluctuations in their values. The panicles’ highest fresh and dry weights were observed at 100 and 105 DAP, decreasing at 90, 95, and 110 DAP. A significant reduction in fresh and dry weights occurred at 110 DAP, likely due to plant damage, which caused seeds to become damaged and fall from the panicles before harvest. Kurniasari et al. (2023) found that high rainfall reduces nutrient availability due to the faster leaching process, resulting in suboptimal conditions for the seed-filling process. This disruption causes nutrient translocation from leaves to seeds to be impaired, affecting photosynthesis and ultimately reducing panicle and seed production.

Based on harvest age, panicles’ highest total fresh and dry biomass was recorded at 100 DAP. After this peak, biomass production declined, which can be attributed to high rainfall that inhibits photosynthate production during photosynthesis. These compounds are essential for optimal plant growth, and their translocation via the phloem supports stem growth and panicle biomass. If photosynthesis is not optimal, a decline in panicle biomass will follow.

The best dry weight of seeds per panicle and 1000-seed weight were recorded at 100 and 105 DAP, with decreases at 90, 95, and 110 DAP. The size of the produced seeds influences this fluctuation. High rainfall and increased soil moisture affect carbohydrate (assimilate) formation, disrupting the seed formation process and resulting in smaller

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seeds. Additionally, weed competition around the plants may have contributed to the decrease in seed size. This aligns with Horvath et al. (2023), who state that seed size and weight are determined during seed formation, influenced by soil nutrients and competition with weeds for these essential nutrients.

The highest number of seeds per panicle was observed at 90 and 105 DAP, with a decrease at 95, 100, and 110 DAP. The size of the seeds produced influences this fluctuation. The seeds were smaller at 90 and 105 DAP than at other harvest ages, resulting in a higher seed count. This observation is consistent with Suryaningsih et al., (2018), who found that plants producing many seeds tend to have smaller seed sizes, while those producing fewer seeds tend to have larger seeds. The peak in dry seed production was recorded at 100 DAP, after which it declined. This reduction in dry seed production is also linked to the decrease in panicle biomass, influenced by high rainfall, humidity, and suboptimal nutrient absorption. Purnamasari et al., (2015) found that dry seed production is affected by genetic and environmental factors, including soil properties, and a decline in biomass is typically followed by reduced seed production in sorghum plants (Ristiani et al., 2021).

Differences in harvesting age for “Samurai Two” Two sorghum significantly affected ($p<0.05$) moisture content. Moisture content is crucial in seed viability and germination ability, with seeds typically containing 16-20% moisture at harvest (Kolo and Tefa., 2016). To maintain maximum viability, moisture content must be reduced. The lowest moisture content after drying was observed at 90, 105, and 110 DAP, with values still within the normal range for maintaining seed viability, typically between 6% and 8%. The rainfall during the harvesting period influences the moisture content, as higher rainfall increases soil moisture, raising seed moisture content. Conversely, lower rainfall results in reduced seed moisture content, as noted by Ashari et al., (2014).

Production of Sorghum Straw Biomass

The results showed that harvesting age had a highly significant effect ($p<0.01$) on total fresh straw biomass (Table 3). However, it significantly affected ($p<0.05$) total dry straw biomass and moisture content. The highest total fresh and dry weight of “Samurai Two” straw biomass was observed at 95 and 100 DAP, indicating a decrease in production with increasing plant age, with the lowest total fresh biomass recorded at 110 DAP. This aligns with the findings by Arshad et al. (2019), who observed that straw biomass production in sorghum tends to be higher at earlier harvest ages. This is due to several factors, including increased lignification, crude fiber accumulation, decreased protein content, and other nutrients. Najam et al. (2021) recorded the highest straw biomass production at 105 DAP, with a yield of 55.8 tons per hectare, which exceeds the results of this study. The difference could be attributed to variations in harvest seasons. Andriani and Isnaini (2013) found that planting during the late rainy season, followed by harvesting in the dry season, is ideal for sorghum cultivation. This is critical because sorghum seeds are prone to sprouting and pest infestation if rainfall is too high as the harvest age approaches. The high rainfall during this study may have hindered plant growth, caused damage, and increased the risk of fungal diseases, reducing straw biomass quality and production. Najam et al. (2021) also noted that differences in harvest age affect sunlight absorption, which influences sorghum metabolism, respiration, photosynthesis, and nutrient transport, ultimately impacting straw biomass production.

Conclusion

Sorghums harvested between 90 and 100 days after planting had increased fresh panicle weight, dry panicle weight, total fresh biomass, total dry biomass, dry seed weight per panicle, 1000-seed weight, and

Table 3. Straw biomass production of sorghum “Samurai Two”

Variables	Harvest age (DAP)				
	90	95	100	105	110
Total fresh weight of straw biomass (ton.ha-1)	17.96±4.67^{B}	24.78±7.05^{A}	23.81±3.92^{A}	13.59±2.57^{BC}	10.37±2.24^{C}
Total dry weight of straw biomass (ton.ha-1)	3.30±0.69^{ab}	4.19±1.17^{a}	4.02±0.74^{a}	2.72±0.40^{b}	2.54±0.57^{b}

Notes: Values followed by different superscripts in the same row or column show highly significant differences (A.B = $p<0.01$) and significant differences (a, b = $p<0.05$) according to DMRT; DAP = days after planting.

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dry seed production. The best seed production for "Samurai Two" occurs at a harvest age of 90 DAP, whereas 95 DAP resulted in the highest total fresh and dry weight for straw biomass.

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